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AERB Newsletter

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ATOMIC ENERGY REGULATORY BOARD

Mission: The mission of Atomic Energy Regulatory Board is to ensure that the use of ionizing radiation and nuclear energy in India does not cause unacceptable impact on the health of workers and the members of the public and on the environment.

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From the Chairman's Desk

Greetings to all,

The successful attainment of criticality and subsequent steps towards commissioning of Kudankulam Nuclear Power Plant (KKNPP), this year, is indeed a landmark achievement for the Indian Nuclear Power programme. AERB has recently granted KKNPP, further permission to operate up to 50% of full power. This is a result of the sustained efforts by the utility and the regulatory body to establish safety and assumptions with acceptance criteria at every stage of reactor operation. The permissions granted to KKNPP are after a multi-tier review by expert committees along with compliance review of their stipulations by a team of AERB observers, onsite at KKNPP.

Another milestone this year is the launching of the of e-governance portal for automation of regulatory processes involved with radiation facilities. This system, e-Licensing of Radiation Applications (e-LORA), is initially launched for radiotherapy facilities and provides for online submission of licensing applications. The e-LORA system has far-reaching benefits to the stakeholders using radiation sources all over the country. More about the developments in the use of this portal will be published in the forthcoming newsletters, with constant updates on AERB (new look!) website. This edition of newsletter includes a brief write up on the process of registration of radiation protection professionals through e-LORA.

As a safety and regulatory body regulating a spectrum of nuclear and radiation facilities, AERB is continually redefining "Safety". By involving in safety research and joint initiatives nationally and internationally, AERB strives to extend its knowledge base and suitably use it to reframe safety requirements. Thus, AERB routinely funds relevant safety research projects and has recently signed a MoU with Anna University for collaborative research in various areas of regulatory interest. Also, AERB under a joint collaboration with IRSN (France) is presently carrying out severe accident analysis for VVER type reactors.

Post-Fukushima, severe accident analysis of Nuclear Power Plants (NPP) is one area of "Safety" that has acquired a renewed topicality, worldwide. AERB supports R&D studies towards an in-depth understanding of severe accident phenomenology, to be able to envisage regulatory mechanisms towards severe accident prevention, mitigation, development of effective severe accident management guidelines (SAMG) and emergency operation planning (EOPs), for NPPs in India.

"Safety" in the context of essentially low hazard potential medical X-ray diagnostic equipment is being addressed through information dissemination and decentralisation of regulation. Thus, AERB has put out advertisements calling for accreditation of agencies involved in providing QA services and licensing of x-ray equipment manufacturer and supplier. Towards decentralisation, AERB has signed a MoU for the formation of Directorate of Radiation Safety (DRS) in the state of Odisha. The advertisements form part of this newsletter edition.

AERB promotes and duly acknowledges units of Department of Atomic Energy (DAE) diligently practicing industrial safety, by way of instituting the "Industrial and Fire Safety Awards for Excellence". It is indeed heartening to note that industrial safety performance, based on incidence rates, of DAE Units is far better as compared to other similar industries in the country and even comparable with international levels. The Fire Safety week, this year, was commemorated with an "Office fire safety", demonstration at AERB by the Fire Services Section, Bhabha Atomic Research Centre.

This edition of the newsletter includes research articles on severe accident analysis and an article on "Periodic Safety Review by AERB"

(S.S. Bajaj)

Safety Review and Regulation

AERB Board Meeting

In the 108th Board meeting held on February 26, 2013, the Board reviewed the safety status of operating Nuclear Power Plants (NPPs), NPP projects, fuel-cycle facilities/projects and radiation facilities. The Board was apprised on the audit of RAPS-3&4 by the Operation Safety Review Team (OSART) of IAEA during October 29 to November 14, 2012. In addition, a briefing was made on the Convention on Nuclear Safety (CNS) report of India. The Board was also briefed on the second extra-ordinary meeting of CNS which held in August 2012 with reference to the actions taken by Member States after the Fukushima accident.

The Board approved the proposal made on the consenting stages to be followed for Fast Reactor Fuel Cycle Facilities (FRFCF) Project and Demonstration Fast Reactor Reprocessing Plant (DFRP) being set up by Indira Gandhi Centre for Atomic Research (IGCAR) at Kalpakkam.

The Board was apprised of the actions being taken for updating inventory of radiation sources and strengthening inspections of completed and on-going radiation facilities. The Board was informed about the circulars sent to Universities (462 nos.) for obtaining information on possession of radiation sources and several awareness programmes conducted. The Board was also briefed on the status of development of web-based system for licensing of radiation facilities, viz, e-Licensing of Radiation Application (eLORA).

The 109th Board meeting was held on May 27, 2013 wherein the latest safety status on facilities regulated by AERB was reviewed. The Board was informed of status of safety review report on First Approach to Criticality and Phase-B procedures for KKNPP-1 and compliance to the judgment of the Honorable Supreme Court on KKNPP on May 6, 2013.

Consents Issued by AERB

1) Concurrence for conduct of Hydro Test, Heat up of RCS and Associated Test for KK Unit-1 (January 24, 2013)
2) Concurrence for In-Situ Testing of Double Check Valve (DCV) of KK Unit-1, (April 20 and 29, 2013).
3) Clearance for First Approach to Criticality (FAC) and Phase-B Low Power Physics Experiments of KK Unit-1, (July 04, 2013)
4) Permission for First Approach to Criticality (FAC) of KK Unit-1, (July 11, 2013)
5) Concurrence for Phase-B Low Power Physics Experiments of KK Unit-1, (July 14, 2013)
6) Clearance for Phase –C1 commissioning of KK Unit-1. (August 14, 2013)
7) Permission for 21st Irradiation campaign at FBTR
8) Operation license upto June 2018 to FBTR after review of PSR
9) License for operation of mineral separation plants of M/s Industrial Mineral Company at Vijayapathy and Kalikumarapuram, Tirunelveli (February 8, 2013).
10) License for operation of Tummalapalle mine (March 01, 2013).
11) Consent for Siting & Construction of the proposed 2000 amp sodium test cell at HWP (Baroda) (March 05, 2013).
12) Clearance for Commissioning and Operation of New Oxide Chlorination Facility at NFC, Hyderabad (April 23, 2013).
13) Clearance for operation to Thermal Battery Division-ECIL (May 15, 2013).
14) Registration certificate for plant operation was issued to M/s Metallurgical Products (India) Pvt. Ltd. Taloja (April 22, 2013).
15) Consent for Commissioning and Operation of the proposed 2000 ampere sodium test cell at HWP (Baroda) (June 11, 2013).
16) Extension of licence for operation of MAPS 1&2 upto June 2014
17) Extension of licence for operation of TAPS 1&2 upto December 2014
18) Extension of licence for operation of NAPS 1&2 upto September 2014
19) Extension of licence for operation of KGS 3&4 upto April 2018
20) Extension of authorization for construction of 10000 TPA Monazite Processing Plant (MoPP) at IREL-OSCOM upto September 2013.
21) Extension of authorisation for Operation of INDUS-1, RRCAT upto August 31, 2013.

AERB Board meeting in progress

Human Resource Development and Safety Research Programme

AERB Training Activities

AERB Orientation Course for Regulatory Process (OCRP-2012) was organised for forty newly joined scientific officers/scientific assistants in various divisions of AERB during the last one year. On January 11, 2013, a valedictory function for OCRP was conducted and certificates were distributed to the successful course participants.

Shri M.M. Kulkarni receiving certificate from Shri S. Duraisamy, Vice Chairman, AERB during OCRP valedictory function.

Amongst eight stipendiary trainees (Cat-I), five have successfully completed and absorbed as Scientific Assistants in AERB on July 2, 2013 and the other three trainees are currently undergoing training.

A refresher course on "Reactor Physics Aspects of Indian NPPs (PHWRs, LWRs and FBRs)" was organized in AERB Auditorium on March 26, 2013. Lectures were delivered by senior officers of AERB. In this refresher course, speakers addressed topics related to basic operational reactor physics (four factor formula, reactivity, Xenon, initial core loading, criticality aspects, etc.,), reactor physics aspects in heavy water reactors, light water reactors and fast breeder reactors, reactivity anomalies, salient reactivity related incidents etc.

Dr. A. Ramakrishna, Head, TS and RPS and Training Coordinator briefing about OCRP during valedictory function.

Four technical talks related to regulatory functions of AERB were organized in AERB. The topics such as Commissioning Programme of Kudankulam-NPP-1 & Current Safety Review Status of Commissioning, Information Security -The end-users perspective, Regulation of Nuclear Fuel Cycle Facilities, role of AERB/NF/SG/G-2 and AERB/NF/SM/G-2, Developments in IAEA - INES, IRS and International Regulatory Review Service (IRRS) of IAEA were covered.

Two AERB colloquia were organized on "Caveats of Programmable Systems (Software & Hardware) - Are we doing enough verification?" by Shri R. K. Patil, Associate Director, E&IG, BARC and Dr. A.K. Bhattacharjee, SO (H), RCnD, BARC in AERB and on 'Life Style Management' by Dr. K. P. Misra, Senior Consultant Cardiologist, Apollo Hospitals, Chennai and Honorary Consultant to Hindu Mission Hospital, Chennai.

Safety Research Programme (SRP)

Two meetings of Committee for Safety Research Programmes (CSRP) were held at AERB to review the progress of on-going projects, and to consider funding of new project proposals, The Committee agreed for funding of following 7 new project proposals and renewed 7 on-going projects.

Approved New CSRP Projects during the period

S. No.	Project Title	Principal Investigator (PI)
1.	Survey of Effective Dose Received by Pediatric Patients from Digital Radiography at Various Hospitals in South India.	Dr. C.S. Surekha, Bharathiar University, Coimbatore, Tamil Nadu
2.	Fabrication of Nano oxide based Sensor on Stabilized Zirconia for Nano Detection of Hydrogen Sulfide	Dr. T. M. Sridhar, Rajalakshmi Engineering College, Chennai
3.	Markov Approach for Reliability Assessment of Safety Critical Software	Dr. R. Sujatha, SSN College of Engg, Kalavakkam
4.	Image Quality/Patient - Staff Dose Studies & Development of Dose Audit Procedures in Interventional Cardiology	Dr. K.N. Govindarajan, PSG College of Technology, Coimbatore
5.	Reliability assessment of the passive systems and its integration in to PSA	Dr. Suneet Singh, IIT Bombay
6.	Thermo luminescence Characterization of Phosphors used in Display Devices for Possible use in Accident Dosimetry	Dr. A. S. Sai Prasad, Vaisnavi college of Engg, Hyderabad
7.	Radiation Doses and its Impact from Radiological and Cardio logical interventions	Dr. Roshan S. Livingstone, Christian Medical College, Vellore

Renewal of on-going projects

1. Non-contact Strain Measurement of Zircalloy using Digital Image Correlation (DIC) under high Temperature ambience (PI: Dr. M. Ramji, IIT Hyderabad)
2. Evaluation and Intercomparison of QA Measurements in Radiation Oncology (PI: Shri P. Krishna Reddy, MNJ, Hyderabad)
3. A study on Radioactivity in Phosphogypsum based Building and Construction Materials and Indoor Radon Inhalation Dose Estimate in Tamil Nadu, (PI: Dr. P. Shahul Hameed, J.J College of Engineering & Technology, Thirchy)
4. Numerical Simulation of the Response of Nuclear Containment subjected to Aircraft Crash (PI: Dr. Pradeep Bhargava, Professsor, IIT, Roorkee
5. Studies of the transport of Hydrogen-Air Steam mixture within a Confinement (PI: Dr. Sarit Kumar Das IIT Madras)
6. Thermomechanical Failure in CT Tubes under severe Accident Conditions (PI: Sri Krishna N. Jonnalagadda, IIT Bombay)
7. Lysimeter based Sub-surface Investigations to Assess the Transport Behaviour of Contaminants in the Vadoze Zone Surrounding Near Surface Disposal Facility at Kalpakkam, (PI: Dr. Sudhakar Rao, IISc, Bangalore)

Directorate of Radiation Safety

AERB Signs MoU with the Governments of Maharashtra and Odisha for Setting up Directorate of Radiation Safety

Diagnostic radiology facilities utilizing X-ray units are widely available in the country and a large number of persons undergo diagnostic X-ray procedures every year. These X-ray units, if not designed or operated properly, may lead to unwanted radiation exposure to the patients as well as the operators. AERB has stipulated various regulatory requirements for X-ray facilities such as Design Certification, i.e. Type Approval / No Objection Certificate, Licensing of X-ray Equipment for operation, Certification of Radiological Safety Officers (RSOs) and Certification of Service Engineers.

In view of the tremendous increase in the medical diagnostic installations using medical X-ray units in the country, AERB has taken proactive steps to exercise regulatory control over all such installations by decentralizing the regulation of these units by having an Memorandum of Understanding (MoU) with State Government and Union Territories to set up Directorate of Radiation Safety (DRS) in various States/Union Territories. Towards this, AERB has entered into an agreement during this period with two State authorities of Maharashtra and Odisha. The MoU to this effect was signed by Secretary, AERB, with the Additional Chief Secretary, Public Health Department, Government of Maharashtra on January 18, 2013 and the second one with Principal Secretary, Health and Family Welfare Department, Govt. of Odisha on January 24, 2013.

With these, AERB has signed MoUs with a total of ten States (Kerala, Mizoram, Madhya Pradesh, Tamil Nadu, Punjab, Chhattisgarh, Himachal Pradesh, Gujarat, Maharashtra and Odisha) of which DRS in Kerala and Mizoram are already functioning. AERB is also following up with other States for establishment of DRS.

Shri R. Bhattacharya, Secretary (right), AERB greeting
Shri Thomas Benjamin, Addl. Chief Secretary, Public Health Department, Govt. of Maharashtra at the MoU signing ceremony

Shri R. Bhattacharya, Secretary (left), AERB exchanging the MoU with Principal Secretary, Health & Family Welfare, Govt. of Odisha

NOTICE FOR AGENCIES PROVIDING SERVICES FOR MEDICAL DIAGNOSTIC X-RAY EQUIPMENT

Government of India

Atomic Energy Regulatory Board

Niyamak Bhavan, Anushaktinagar, Mumbai-400094

REQUIREMENT FOR OBTAINING AUTHORISATION FROM AERB

As per the provisions of Atomic Energy (Radiation Protection) Rules, 2004 and AERB Safety Code[AERB/SC/MED-2 (Rev.1)]; it is mandatory that all Service Agencies of medical diagnostic x-ray equipment shall obtain Authorisation from Atomic Energy Regulatory Board (AERB) for installation/servicing-maintenance including quality assurance/supply of pre-owned medical diagnostic x-ray equipment in India.

Major regulatory requirements for obtaining Authorisation are:

- Availability of appropriate Quality Assurance (QA) and radiation monitoring equipment
- Employment of qualified and trained personnel
- Availability of personnel monitoring services for radiation workers

The guidelines and relevant application form(s) for obtaining Authorisation may be downloaded from AERB website http://www.aerb.gov.in

The duly filled-in application form for obtaining Authorisation along with necessary documents shall be submitted to The Head, Radiological Safety Division, AERB, Niyamak Bhavan-B, Anushaktinagar, Mumbai-400094 within forty five days from the date of issue of this Notice.

Issued by: **Atomic Energy Regulatory Board,**
Niyamak Bhavan, Anushaktinagar,
Mumbai- 400094

Industrial and Fire Safety

AERB Presents the Industrial and Fire Safety Awards for Excellence

The annual Industrial Safety Awards and Fire Safety Awards presentation function for the year 2012 was held on April 16, 2013 at AERB, Mumbai.

The Industrial Safety Awards are given for achieving high levels of performances in industrial safety activities. Industrial Safety Award in Production Units Group comprising Nuclear Power Plants and Heavy Water Plants was jointly bagged by Tarapur Atomic Power Station 3&4 and Heavy Water Plant, Thal (Maharashtra). Kakrapar Atomic Power Project 3&4 (Gujarat) received the Industrial Safety Award in the Construction Group.

Fire Safety Awards are given for achieving high levels of performance in fire safety aspects. Fire Safety Award in the category of high fire risk unit was given jointly to Heavy Water Plant, Kota (Rajasthan) and Kakrapar Atomic Power Station 1&2 (Gujarat). Indira Gandhi Centre for Atomic Research, Kalpakkam (Tamil Nadu) was winner of the Fire Safety Award in Category of low fire risk units group.

The Chief Guest of the function, Shri R.G. Rajan, Chairman and Managing Director, Rashtriya Chemicals and Fertilizers Ltd. presented the Awards to the winner units of the DAE for the year 2012. On this occasion, Shri S. S. Bajaj, Chairman, AERB released a compilation for DAE units titled "Occupational Injury & Fire Statistics 2012". This compilation provides the information on number of accidents, injuries and man-days lost due to such injuries and their analysis. Analysis of fire incidents based on severity is also covered in this document. The industrial safety related data is also compared with similar units outside DAE. It is seen that industrial safety performance based on incidence rates of DAE Units is significantly better as compared to other similar industries in the country and comparable with international levels. Shri S. Duraisamy, Vice-Chairman, AERB and Shri R. Bhattacharya, Director, Industrial Plants Safety Division and Secretary, AERB also addressed the august gathering on aspects related to industrial and fire safety.

Award winners along with Chief Guest and AERB Senior officials during the Industrial and Fire Safety award function

Demonstration on Rescue and Fire Fighting Operation held at AERB premises

In view of the observance of Fire Service Week during April 14-20, 2013, Fire Services Section of BARC in coordination with AERB organized a demonstration programme on April 18, 2013 at AERB, Mumbai with special emphasis on "Office Fire Safety". High elevation rescue operation and use of first-aid firefighting equipment were demonstrated. The programme was also attended by BARC employees of adjoining CTCRS building located in the same AERB premises. The programme proved to be fruitful in increasing awareness amongst officials about fire safety and instilling confidence in them to handle fire incidents in Office premises.

Demonstration of the rescue operation in progress

Industrial and Fire Safety

Publication of Safety guidelines on uranium tailings management

Uranium ore is excavated from uranium mines and processed in uranium mill. The process involves crushing, grinding, leaching, and filtration to obtain the required uranium concentrate or intermediate product. This process results in generation of tailings containing uranium, its daughter products, chemicals, which are neutralised and then transported in form of slurry through pipelines to tailings pond. Recovered water from tailings pond is generally collected in decant water pond where the remaining solid particle gets settled. The supernatant water is treated in effluent treatment plant (ETP). Treated water is then collected in a monitoring pond, where the quality of water is checked for ensuring that the quality of water is within the permissible limits before discharge into public domain.

The tailings pond contains a large quantity of tailings and slurry, breaching of which may lead to flooding and contamination in the surrounding area. The design and operation of the tailing pond depends upon the characteristics of the tailings and site. Siting, design, construction and operation of tailings pond and its components needs to be engineered to ensure environmental and radiological safety. The typical environmental problems from mill tailings are radon emanation, dust dispersal, acid formation and leaching of contaminants. Various causes for failure in uranium tailings dam may be earthquake-induced instability, liquefaction, physical weakness of the embankment, erosion from rain, spillway collapse and cracking induced by settlement and foundation instability. It is important that necessary monitoring and control techniques and safety systems are adopted.

The document on 'Siting, design, construction, commissioning, operation, closure and monitoring of tailings management facilities' outlines the various safety aspects related to tailings dam, tailings pond and other tailings management systems such as decantation pond, effluent treatment plant, monitoring pond, excess water pond etc. These aspects are reviewed by AERB prior to grant of consent for related activities/ facilities.

Quality Management System (QMS) in AERB

Awareness Programme on ISO 9001:2008 Quality Management System (QMS)

AERB official participants during the awareness programme on ISO 9001:2008

A program on promotion of awareness on ISO 9001:2008 Quality Management System (QMS) was organized on April 29, 2013 by the QMS Monitoring Committee (QMS-MC) of AERB. The program was an essential requirement to enhance awareness level on QMS requirements and improve the documentation.

Conducting awareness program on ISO 9001:2008 QMS once in six months is a requirement as per Quality Manual of AERB. Talks on 'Guidelines for Auditors', 'Competency of Regulators' and 'Regulations for Safe Transport of Radioactive Material in India' were arranged during this period.

Safety Research Institute

AERB Signs MoU with Anna University for Research Collaboration

To promote and develop cooperation and synergy in mutually beneficial areas of research related to regulatory aspects of nuclear facilities and to enhance collaborative research with academic institutions, Atomic Energy Regulatory Board (AERB) signed a Memorandum of Understanding (MoU) with Anna University (AU), Chennai. The MoU was signed by Secretary, AERB and Registrar, AU on May 21, 2013 in Chennai in the presence of Chairman, AERB and Vice-Chancellor, AU.

Shri S.S. Bajaj, Chairman, AERB (second from left) along with Vice-Chancellor, Anna University (third from left) at the MoU signing ceremony.

The aim of this MoU is to accelerate the pace of research in advanced and challenging areas of nuclear science and technology. Mutual benefits that accrue from the interactions include time bound applied research, enhanced professional skills, and opportunities for scholars to work in advanced areas of science and technology. In addition, sharing of infrastructure resources; promotion of scholarly activities; promotion of joint programs, opportunity for researchers/ doctoral students of AU and regular availability of research fellows of Safety Research Institute (SRI) are few additional areas proposed for collaboration. Taking into account the high level of scientific skill and technical expertise available in the SRI, Kalpakkam and AU, Chennai, several important areas of research areas are identified. The generic areas of collaborative research include, but are not limited to, Reliability Engineering, Physics, Environmental and Geographical Information Sciences, Remote Sensing, Thermal hydraulics, Structural Mechanics, Disaster Mitigation and Management etc. The MoU will further strengthen the research collaboration and will provide a platform for enhanced academic interaction and bring academics and research a step closer.

Radiological Safety

Interactive session with delegates of FICCI

A Meeting of delegates of Medical Electronics Forum of FICCI (Federation of Indian Chambers of Commerce and Industry) was held with AERB and BARC officials in April 2013. The delegation requested for revision of certain regulatory procedures involved in procurement and installation of radiotherapy equipment. After deliberations, AERB has agreed to consider issuance of No Objection Certificates (NOCs) to more than one user, subject to suitable justification, till the Type Approval is granted. Earlier, only one NOC was granted for obtaining Type Approval. This modification was issued so as to not delay patient treatment.

AERB officials interacting with the delegates of FICCI

For medical diagnostic x-ray equipment, the delegation put forth the need for effective checks in place to stop the availability of third party equipments/imports in markets that may not conform to the quality and safety standards. AERB has expressed that policy decisions on issues related to third party equipments/imports will soon be in place.

AERB has welcomed the proposal for joint workshops to create awareness towards application submissions for import authorizations, acceptance testing protocols and similar subjects.

Interactive Session and Training Program with Underwriters Laboratories (UL)

An interactive session with UL was held on March 14, 2013, in AERB. The interaction was mainly to discuss the BIS 13450 (Bureau of Indian Standards) which covers Diagnostic radiology/Radiotherapy Simulation and an overview about the electrical safety, Mechanical safety, essential performance criteria and Radiation safety linked to Essential performance.

The interactive session also covered NEMA (National Electrical Manufacturers Association) standards with relevance to X ray/ Nuclear Medicine and Global regulations for X-ray devices with respect to European Union (EU), Food and Drugs Administration (FDA) etc; vis-à-vis Indian regulations.

e-Licensing of Radiation Applications

Registration of Radiation Professionals through "eLORA"

As a part of e-Governance initiative of AERB for delivering regulatory services, exchange of information, communication transactions, integration of various stand-alone system and services between AERB and licensed radiation facilities, AERB is implementing web-based system, named eLORA (e-Licensing of Radiation Applications), for complete automation of regulatory processes associated with the use of ionizing radiation in India. On May 3, 2013, eLORA system was made operational for registration of Radiation Professional (RP). The term 'Radiation Professional' referred in eLORA pertains to Radiation Worker whose role is defined in relevant AERB safety codes. This eLORA module permits Radiation Professionals to submit on-line application for registering themselves as Radiation Professional. Initially registration has been opened for professionals of Radiotherapy practice (viz. Radiation Oncologist, Medical Physicist and Radiotherapy Technologist).

AERB is responsible for enforcing the rules and regulations under relevant acts for all Radiation Facilities in India from radiological safety point of view. Safety is to be ensured in siting, design, construction, commissioning, operation and decommissioning of different types of radiation facilities. 'Operation' is the one of the most important stage in the life cycle of a radiation facility. Safety during operation is heavily dependent on the competency of professionals working in the facility. AERB, in its safety codes for various practices, specifies professional's role and responsibilities, relevant eligibility criteria and minimum number required at a facility for safe operation.

AERB verifies the competency of professionals as per safety code before issuing any regulatory consent to the facility. With the existing paper based system, an applicant has to submit documentary proof for eligibility of employed professionals in every application. With advent of eLORA and RP registration facility, the above verification process has been greatly simplified.

The main advantages of RP registration through eLORA are:

- On-line one-time registration, no paper submissions
- Only RP registration number needs to be given in all future submissions to AERB
- Access given to RP for updating details and interaction with AERB

RP registration module is currently operational for Radiotherapy and will be extended soon for registration of radiation professionals in other radiation facilities such as Nuclear Medicine, Research and Industrial arena. The regulatory practice module for Radiotherapy has been released in August 2013 for Mumbai based Institutes and will be rolled-out in a phased manner for other Radiotherapy centers in India.

[Reference: The article on eLORA system (earlier named AERB-RSD Information System) were published earlier in Vol. 24, No.1 (Jan-Jun 2011) and Vol. 25, No.2 (Jul-Dec 2012) of AERB newsletter.]

AERB's new website launched

The new website of Atomic Energy Regulatory Board (AERB) (www.aerb.gov.in) was launched by Shri S.S. Bajaj, Chairman, AERB on August 15, 2013. The website has been developed with the state of the art technology. Apart from having an elegant professional look, it is also associated with various useful features for public like advanced search mechanism, availability of feedback form for suggestions, links to external agencies and details about various functions carried out by AERB.

Chairman AERB llaunches AERB's new Website.

NOTICE FOR AGENCIES PROVIDING QUALITY ASSURANCE SERVICES TO MEDICAL DIAGNOSTIC X-RAY EQUIPMENT

Government of India

Atomic Energy Regulatory Board

Niyamak Bhavan, Anushaktinagar, Mumbai-400094

CAUTION X-RAY

REQUIREMENT FOR OBTAINING ACCREDITATION FROM AERB

As per the provisions of Atomic Energy (Radiation Protection) Rules, 2004; it is mandatory that all Agencies interested in providing quality assurance (QA) services to medical diagnostic x-ray equipment in India shall obtain Accreditation from Atomic Energy Regulatory Board (AERB).

- Major regulatory requirements for obtaining Accreditation are:
- Availability of appropriate Quality Assurance (QA) and radiation monitoring equipment
- Employment of qualified and trained personnel
- Availability of personnel monitoring services for radiation workers

The guidelines and relevant application form(s) for obtaining Accreditation may be downloaded from AERB website http://www.aerb.gov.in

The duly filled-in application form for obtaining Accreditation along with necessary documents shall be submitted to The Head, Radiological Safety Division, AERB, Niyamak Bhavan-B, Anushaktinagar, Mumbai-400094 within forty five days from the date of issue of this Notice.

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Awareness Programme by Southern Regional Regulatory Centre (SRRC)

An Awareness Program was organised by SRRC on January 09, 2013 at the Massa Maritime Academy, inside Seafarers Club, Chennai. The programme was arranged by a company called "SB Teknik" located at the Port Trust, Chennai. The company carries out CO_2 level measurement using ^{60}Co gamma gauge in the fire extinguishers installed in the ships. The programme was meant to impart radiation awareness among the staff of the company as well as to some seafarers who come across with many radioactive consignments in their ships.

Demonstration using the Co^{60} gamma gauge for CO_2 level measurement

There were thirty-two participants with various academic backgrounds including few defence personnel. The awareness program contained four modules namely 1) Basic Radiation Theory, Radiation Protection and Dose Concepts etc., 2) History of Regulatory framework, role and responsibilities of AERB, 3) Radiation Safety and Regulatory Aspects of Nucleonic Gauges, and 4) Environmental monitoring.

This was followed by a demonstration for correct use of level gauge used for CO_2 with appropriate radiation safety precautions to be followed. The program was well received by the participants.

Nuclear Safety

ConvEx-2b exercise under the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency

The Convention on Early Notification of a Nuclear Accident

The Convention on Early Notification of a Nuclear Accident was adopted in 1986 following the accident at Chernobyl Nuclear Power Plant. This convention establishes a notification system for nuclear accidents which have the potential for international transboundary release that could be of radiological safety significance for another State. It requires States to report the accident's time, location, radiation releases, and other data essential for assessing the situation. Notification is to be made to affected States directly or through the IAEA, and to the IAEA itself. India ratified this convention in the year 1988.

Under this convention IAEA receives notifications of emergencies or incidents and then alerts its Member States and relevant international organizations.

The Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency

The Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency was also adopted in 1986 following the Chernobyl nuclear plant accident. It sets out an international framework for co-operation among States and IAEA to facilitate prompt assistance and support in the event of nuclear accidents or radiological emergencies. It requires States to notify the IAEA of their available experts, equipment, and other materials for providing assistance. In case of a request, each State decides whether it can render the requested assistance as well as its scope and terms. The IAEA serves as the focal point for such cooperation by channelling information, supporting efforts, and providing its available services. India ratified this convention in the year 1988.

IAEA coordinates exercises under these conventions to test the response to a simulated accident. These exercises are referred to as Convention Exercise (ConvEx) and comprises of three types of exercises:

i. **ConvEx-1:** to test that National Warning Points are continuously available, whether fax contacts and Unified System for Information Exchange in Incidents & Emergencies (USIE) alert channels are accurate and that Contact Points can access USIE properly.

   a. **ConvEx-1a:** to test that National Warning Points for receiving notifications are available continuously.

   b. **ConvEx-1b:** to test that National Warning Points are available continuously and that National Competent Authorities can promptly respond to received notifications.

   c. **ConvEx-1c:** to validate the USIE Administrators' access to USIE

   d. **ConvEx-1d:** to test the IAEA's emergency communication channels

ii. **ConvEx-2:** to test whether National Competent Authorities can appropriately fill out reporting forms and to drill the appropriate procedures for information exchange and requesting and providing assistance.

   a. **ConvEx-2a:** to test the ability of National Competent Authorities to complete the appropriate reporting forms

   b. **ConvEx-2b:** to test the arrangements for a request and the provision of assistance

   c. **ConvEx-2c:** to test arrangements for a transnational radiological emergency

   d. **ConvEx-2d:** to test arrangements for a transnational nuclear emergency

iii. **ConvEx-3:** to test the full operation of the information exchange mechanisms and requesting and providing assistance

On June 11-12, 2013 a ConvEx-2b exercise was conducted. In this exercise, India was registered as assistance state for providing assistance to the state of Slovenia. India participated in the exercise through the Crisis Management Group (CMG-DAE) - National Contact Point (ECR, DAE).

Assistance request was received from Slovenia through IAEA´s Incident and Emergency Centre (IEC) for Environmental Radiological Survey and Medical Support. India offered assistance to both assistance requests.

India was asked to give assistance for medical support and provide details of the medical team. The details of three expert doctors and medical equipments, prophylactics, antidotes, antibiotics, external decontamination agents, dressing/ bandages, surgical items and personal luggage were communicated to IEC.

Kudankulam Nuclear Power Project

Quality Checks of KK Unit-1

Kudankulam Nuclear Power Project (KK NPP Unit-1&2) each of 1000 MWe capacity are VVER type (i.e. water-cooled water-moderated energy reactor) Russian reactors, and these are located at the Kudankulam, near Kanyakumari in Tamilnadu. Even though the plant had a proven design which was licensable in the Russian Federation, AERB advocated to carry out detailed safety review as part of consenting process for construction, commissioning and operation. The Preliminary Safety Analysis Reports (PSARs) of KKNPP, Topical Reports and QA documents were submitted to AERB, which formed the primary basis for review and assessment by AERB. In addition, applicable quality assurance (QA) programmes were addressed during safety review for consenting process in all stages of the plant.

Consequent to the media reports regarding doubts on quality of items supplied to Kudankulam NPP from a particular supplier, AERB issued a press release highlighting the safety review w.r.t. various quality checks and implementation of quality standards during different stages of nuclear power plants (NPPs) and safety review prior to issuance of consents.

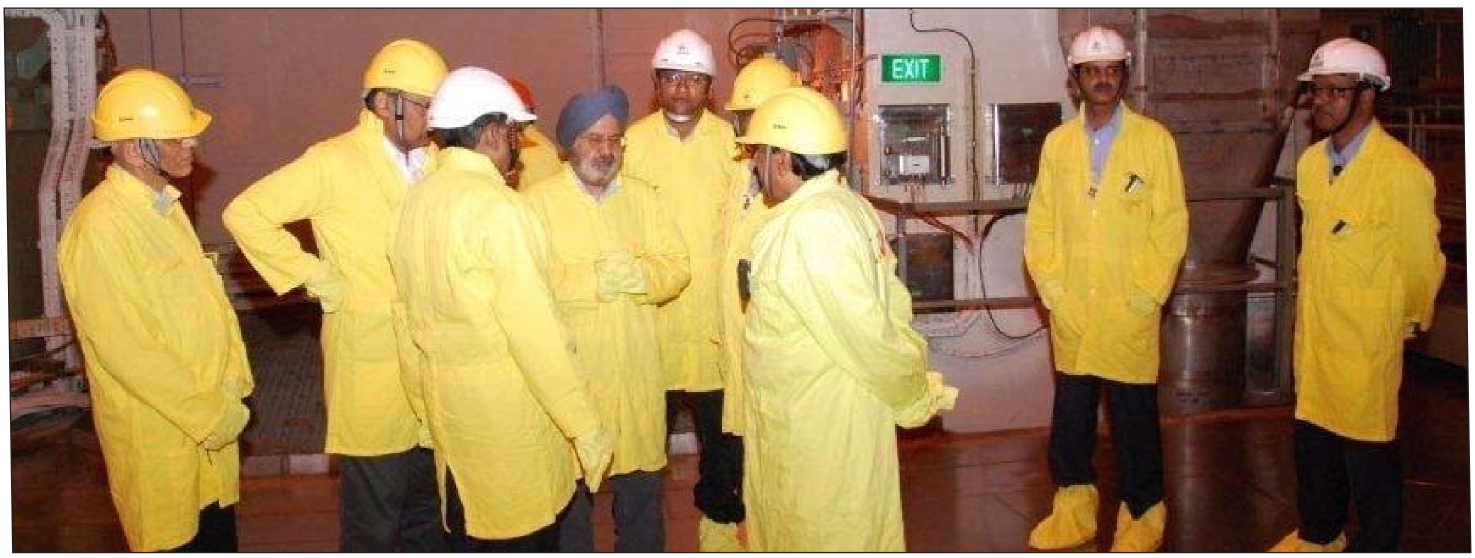
AERB emphasized that multi-level checks for ensuring conformance with the quality requirements have been developed and implemented during the course of the safety review of the plant. Based on the established regulations and AERB guidelines, the QA Programme for the NPPs require formulation of detailed quality assurance plans specifying the sequence of activities and identifying the quality control points at which inspection/ verifications were performed by the Quality Assurance Groups of contractors/ manufacturers as well as by the utility (NPCIL) independently. In addition to the audit conducted by plant management for verifying the effectiveness of the quality assurance program, periodic regulatory inspections were also carried out by AERB at various stages of the NPPs on sample basis for verification of QA programme compliance.

During commissioning, thorough performance testing of components/ systems were carried out to ensure satisfactory performance of the overall plant. The commissioning tests results/ reports were subjected to review by Designers followed by multi-tier safety review at AERB. Satisfactory demonstration of functional capability is a pre-requisite for grant of consent for subsequent phase of NPPs.

Further, during commissioning of KK Unit-1, the test results at each stage of commissioning for various systems were noted to be within the acceptable limits.

First Approach to Criticality (FAC) of KK Unit-1

Following the grant of permission by AERB for 'Initial Fuel Loading' (IFL) in Unit-1 of KK-NPP in September, 2012, NPCIL submitted application for 'First Approach to Criticality' (FAC) of KKNPP Unit # 1. Specialist Groups and the Advisory Committee for Project Safety Review (ACPSR) of AERB reviewed the application along with relevant documents. Based on the in-depth review of commissioning results, corrective measures of the identified non-conformances and all associated safety aspects regarding fulfilment of various regulatory requirements, AERB granted clearance for FAC and Low power physics experiments of KKNPP Unit # 1. It was ensured that the directives of the Honourable Supreme Court vide its judgement of May 6, 2013 were fully complied with. AERB also released a press note after grant of clearance for FAC of first pressurized water reactor (first of the two units of VVER reactors at Kudankulam) of the country. KKNPP Unit-1 achieved the first criticality on July 13, 2013. Further based on satisfactory review of commissioning results related to FAC and low power physics experiments of KKNPP Unit # 1, clearance for Phase –C1 was given on August 14, 2013.



Chairman, AERB along with site officials at Kudankulam Nuclear Power Projects-1 during his special visit after criticality of unit1.

Feature Article

Periodic Safety Review by AERB

P. Bansal & A.P.Garg,
Operating Plant Safety Division,
Atomic Energy regulatory Board, Mumbai-94

Atomic Energy regulatory Board (AERB) is the national regulator for nuclear and radiation safety in the country. In order to fulfil the trust placed on AERB, it regulates a number of different types of facilities, Nuclear power plants being one of them. This is achieved by a robust "Consenting Process" whereby AERB divides the life cycle of a nuclear power plant into various stages (namely, siting, construction, commissioning, operation and de-commissioning) grants licenses/consents for various stages and sub-stages.

Unlike many other countries, in India, AERB, does not grant an operational license for design life of an NPP (which is typically 40 years) but grants it for a limited period of not more than 5 years. By doing so it also satisfies the requirement given under Clause 9.0 of Radiation Protection Rules 2004. Over a period, this practice of AERB has become one of the cornerstones in the regulation of operating NPPs in India and has proved to be a very powerful tool in assessing and enhancing safety of NPPs.

The five years cycle is divided into two types, namely Renewal of License (ARA) and Periodic Safety Review (PSR). In a ten year cycle, utility seek two license renewals for operation, first after five years based on ARA and the second after ten year based on PSR. In case of NPP of new design, the first PSR is carried out after five years of operation and the subsequent PSRs of these NPPs are carried out at ten year intervals.

The renewal of license of an NPP involves a detailed safety review of safe operation of NPP as per its design intent, safety systems performances, and improvements in safety etc.

PSR, which comes once in 10 years, is a much more detailed review and includes additional factors like advancement in technology, feedback of operating experience from within India as well as from other countries, comparison with current safety standards, cumulative effects of plant ageing, probabilistic safety assessments etc.

AERB has published a guide on "Renewal of Authorisation for Operation of Nuclear Power Plants", AERB/SG/-12 which outlines the requirements with respect to periodic safety reviews on NPPs.

As is the set practice of AERB all these reviews are carried out in a multi-tier structure comprising of committees with experts from AERB, Technical Support Organisation (BARC) and the utility.

Till date AERB has processed 26 applications for renewal of license and the first round of PSR for all operating NPPs has been completed except KGS 3&4 and RAPS 5&6 (as these are latest additions to nuclear power sectors).

But as is commonly phrased in Latin "Continuus Lenimentus" which means "continuous improvement", AERB aspires to further improve upon PSR methodology and content based on the feed-backs from utility as well as in-house. In this regard, AERB organised a discussion meet on " Periodic Safety Review of NPPs, Research Reactors and Fuel Cycle Facilities" on 4th March 2013 at Niyamak Bhavan "A" auditorium.

The discussion meet was attended by more than 100 delegates from AERB and other facilities of DAE, namely NPCIL, BARC, BHAVINI, HWB, IGCAR and NFC.

The programme comprised of Presidential address by Chairman AERB in which he outlined the objective of the meet along with his suggestion for further improvements. This was followed with inaugural address from Director Operations, NPCIL in which he brought out safety improvements achieved in NPPs due to the exercise of PSR.

Eight Technical sessions were conducted, participated by AERB, NPCIL, FBTR and NFC. These technical sessions were mainly focussed on regulatory feedback, challenges in carrying out PSR, areas of strengths & scope of improvements, experience of license renewal for other facilities.

These sessions were concluded with an expert panel discussion in order to discuss and summarise the valuable suggestions made during the meet for further action and follow-up. It was decided that all the valuable suggestions would be incorporated in the AERB guide on "Renewal of Authorisation for Operation of Nuclear Power Plants", AERB/SG/O-12 which is, at present, under revision.

International Collaboration

Severe Accident Analysis Activities under AERB-IRSN Collaboration

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Nuclear Safety Analysis Division,
Atomic Energy Regulatory Board, Mumbai-94

Stringent accident prevention, mitigation and management measures are adopted in nuclear power plants, still a very low probability remains that few accident scenarios may develop into a severe accident. This necessitates a thorough study of all involved events, sequences and their consequences. These needs have been intensified especially after the Fukushima Daichii accident. Several joint initiatives at international level have been taken up in this regard to continuously upgrade the knowledge base on severe accidents, preserving the research data and disseminating relevant important knowledge widely. On similar lines an activity was taken up between AERB and IRSN (France). Under this collaboration, Accident Source Term Evaluation Code (ASTEC) was provided by IRSN and in turn AERB provides the in-kind contribution to the code assessment. The ASTEC code has been jointly developed by the French-IRSN and the German-GRS, with aim to simulate entire set of severe accident sequences in a nuclear water-cooled reactor from the initiating event, up to the release of radioactive elements out of the containment. Therefore, main applications of ASTEC are source term determination studies, Level-2 Probabilistic Safety Assessment studies including the determination of uncertainties, accident management studies and physical analyses of experiments to improve the understanding of the phenomenology.

At AERB, as part of the in-kind contribution, the following severe accidents were analyzed using latest version of code ASTEC-r2:

Simultaneous rupture of all four steamlines
Simultaneous occurrence of LOCA and SBO
Station blackout

The accidents sequences were selected in such a way that it covers low/high pressure and slow/fast core damage progression events. Events in item (a) and item (c) are slow progression events with high pressure and whereas the item (b) is fast accident progression with low primary pressure. In addition to the above in-vessel scenario analyses, ex-vessel scenario for the item (b) was also identified as part of the agreement.

The containment thermal-hydraulics and hydrogen distribution analysis was carried out in an integrated manner.

The developed model includes all major components such as reactor vessel, down-comer, lower plenum, core, core bypass and upper plenum. The structural components like baffle, barrel, spacer grids, fuel rods, control rods, guide tubes etc. were simulated. The primary loops consisting of one hot leg, hot collector, one steam generator, cold collector, pump suction leg and cold leg are simulated. The reactor coolant pumps, accumulators, high pressure and low pressure injection systems, main feed-water, auxiliary feed-water are simulated. The high pressure and low pressure injection systems are simulated using boundary conditions. The pulse safety devices (PSDs) Atmospheric discharge valves (BRUAs) are also simulated. Containment is modelled in seventeen zones. Twenty six connection structures are used to connect various zones. Fifty five heat structures are used to simulate inner and external walls. Figure shows the schematic of the primary, secondary circuits and containment.

The simulations were completed up to the desired time and it was found that in revised version of ASTEC, predictions have improved significantly and are more realistic compared to the predictions made with the earlier version of the code viz; ASTEC-V1.3. The ASTEC results were also compared with the severe accident computer code SCDAP/RELAP5 predictions for some of the key parameters, which provided a means to undertake benchmarking of two elaborate integral codes against each other.

The analysis has brought out that higher amount of hydrogen generation is predicted in case of slow transients (SBO & MSLB ALL) compared to the fast transients (LOCA + SBO) due to slow core heat-up and steam availability. In case of fast transients, higher amount of molten material slumped to lower plenum, compared to slow transients. PORV opening on high core exit temperature leads to reduced primary pressure which averts the risk of high pressure melt ejection in case of SBO. Time step sensitivity analysis shows some effect on predictions such as core maximum surface temperature, molten material and hydrogen generation. Some of the passive systems designed and incorporated in VVER-1000 for mitigation of severe accidents are not credited in this analysis which would otherwise cool down the core and prevent severe accidents.

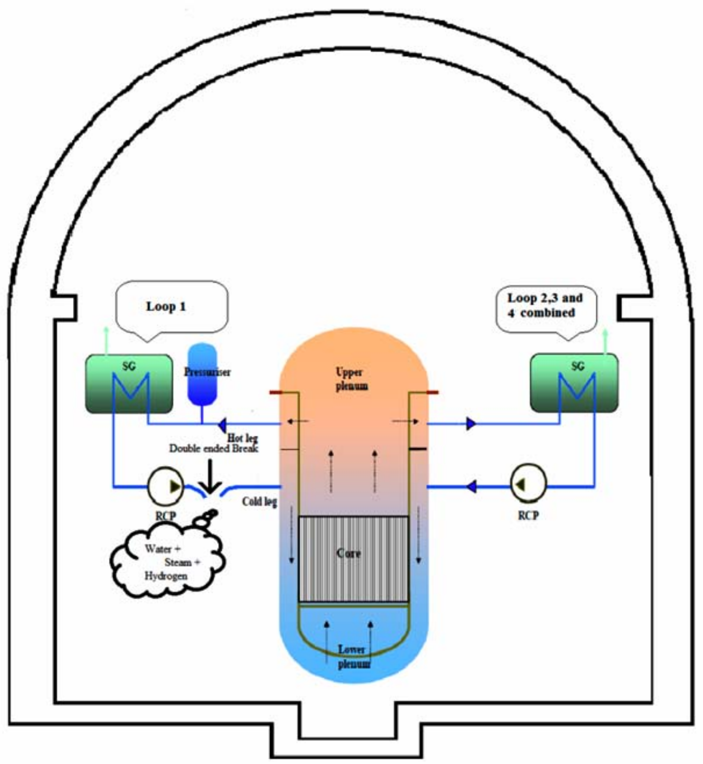

Figure: Schematic of VVER-1000 modelled in ASTEC

R & D Report

Development of Sump Model for Containment Hydrogen Distribution Analysis using CFD Codes

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The containment hydrogen distribution studies gained importance especially after Fukushima accident in Japan. To predict the local behavior accurately, Computation Fluid Dynamics (CFD) codes are essential. However, commercial CFD codes do not have all necessary models for containment hydrogen distribution analysis.

Suppression pools/sump is a containment feature whereby large amount of water is present in the containment suppression pool or sump. Additional Water gets collected in the sump due to condensation on walls of containment and spray system activation during the accident conditions. Evaporation/boiling of sump water that takes place during the accident conditions which affect the gas concentration in the containment. Hence, evaporation of the sump is required to be modelled for containment hydrogen distribution calculations. Sump models have generally been developed for the lumped parameter codes. However, with the increasing use of CFD codes for containment hydrogen distribution calculations, development of sump model for multi-dimensional calculations is also required. The sump model is implemented through user defined functions with three different approaches. These models are validated against the sump behavior experiment conducted in TOSQAN facility (IRSN, France). This experiment also includes the wall condensation phenomena.

2-D axi-symmetric computational domain is used for the simulation of TOAQN facility due to its symmetry. Full mesh is used for the condensation phase and the truncated mesh is used for the sump evaporation phase. Figure 1 shows the pressure variation during the evaporation phase and Figure 2 shows the condensation and evaporation flow rate during the evaporation phase. Figure 3 shows the steam mole fraction contours during the evaporation phase. The predictions are found to be in good agreement with the experimental data.

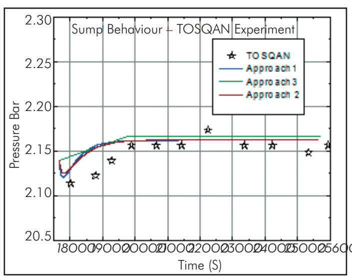

Figure 1: Pressure variation (Evaporation phase)

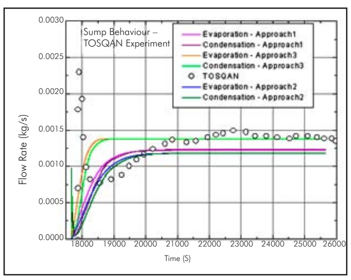

Figure 2: Evaporation and condensation flow

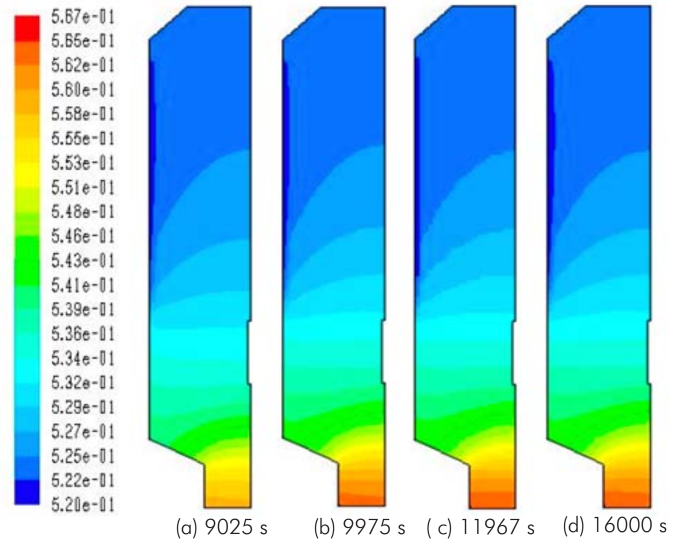

Figure 3: Steam mole fraction contours during the evaporation phase

Containment hydrogen distribution studies are being carried out using these validated models for accurate predictions.

Hybrid approach for estimation of Software Reliability in Nuclear Safety Systems

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The increasing use of computer based systems for safety critical operations in nuclear applications demands a systematic way of estimating software reliability. The high reliability requirements of safety critical software systems make this task imperative as well. Compared to general purpose systems, software designed for safety critical applications are smaller and focussed, robust and have in-built fault tolerant features, designed with defense in depth, meant to fail in fail-safe mode and are expected to have low failure rates. Software systems in nuclear reactors are classified into three categories based on their importance to safety, viz., safety critical, safety related and non-nuclear safety systems. For each category, AERB issues guidelines on best practices in software requirement analysis, defense in depth design, safe programming practices, verification and validation processes etc. in line with international practices.

The best way to ensure that the software used in a safety critical system meets a required reliability is through formal verification, a process of proving certain properties in the designed algorithm, with respect to its requirement specification written in mathematical language/notation. Unfortunately, exhaustive formal verification is not always feasible due to the difficulties

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involved such as state space explosion and difficulties involved in practical application of formal methods. Also, a major assumption in formal verification is that the requirements specification captures all the desired properties correctly. If this assumption is violated, the formal verification becomes invalid. Moreover, software failures are mainly caused due to design faults and not due to wear off. Such design faults are often difficult to visualize, classify, detect and debug. Unlike hardware reliability, the software reliability is not a pure function of time and hence the definition of software reliability with respect to time is arguable. In addition, the probabilistic nature of software reliability is due to its operational profile and the difficulty in detecting infeasible paths in the software. Typical characteristics of software demand an approach different than in hardware systems. For a reliability estimation of the safety critical software, software testing seems to be the most suitable method. However, in this approach, the amount of time required in testing or demonstrating ultra-high reliability is in-feasible. Software testing with large number of test cases without analyzing the quality/effectiveness of test cases, cannot give confidence on the reliability estimate.

Additionally, most of the models and tools for the estimation of reliability are general-purpose and are not specifically oriented for safety-critical systems.The two broad categories of methods for estimation of the reliability of software systems are white-box and black-box models. The group of white-box models consists of models that work based on the knowledge of their internal structure and processes going within them. This knowledge may be expressed by different means, such as architecture models, test case models, etc. On the other hand, the group of black-box models encompasses much larger number of methods that treat the software as a monolithic whole, i.e. as a black-box. Although considerable research has been performed in these models, standard methods for software reliability estimation are not reported. Most of the problems appear mainly due to uncertainty involved in reliability parameters such as time to failure, time between failures, number of faults identified, etc. and in identifying the factors such as software complexity, difficulty in identifying suitable metrics, difficulty in exhaustive testing and difficulty in quantifying effectiveness of test cases, that contribute to software reliability estimation. The widely used black box models (also called reliability growth models) are influenced by hardware reliability modelling techniques and have assumptions that are not suitable for safety and mission critical systems. For example,

1. There are fixed number of faults in the software being tested.
2. No additional faults are introduced when a bug found is eliminated.
3. Each fault has the same contribution to the unreliability of the software; and software with fewer faults is more reliable than one with more faults.
4. The probability of two or more software failures occurring simultaneously is negligible.
5. Enough and accurate software failure data is available for analysis.

In the present study, a theoretical approach that combines results of software verification and testing to quantify the software reliability in nuclear safety systems is proposed.In this approach, a method for generating efficient test cases, ensuring adequacy of software testing using appropriate software metrics such as Modified Condition Decision Coverage (MC/DC) and Linear Code Sequence and Jump (LCSAJ) coverage and mutation testing are suggested.

The test cases are generated through techniques such as model based testing, controlled random number generation, equivalence partitioning and boundary value analysis. The generated test cases are verified by checking against functional specification, invariants and safety properties. The test cases which satisfy these conditions are termed as verified test cases. Redundant test cases which follow the same path of executions are removed. Test coverage is calculated as a weighted average, to provide importance to large, complex, and frequently called functions:

$$\text{Test Coverage} = \frac{\Sigma_i w_i t_i}{\Sigma_i w_i}$$

Where $\mathbf{t_i}$, the conservative test coverage achieved for each function during system testing =minimum (LCSAJ, MC/DC. Statement coverage)

And $\mathbf{w_i}$, the weight assigned to each function = No. of statements x cyclomatic complexity x frequency of function call

Mutation testing is a fault injection technique, where realistic faults are induced intentionally into the source code. The fault induced program is known as a mutant. The proposed approach requires a set of single fault (first order) mutants. The result of mutation testing is the mutation score, defined as the ratio of number of mutants killed by the test cases to the total number of mutants generated.In this process, a simplified method for automatic detection and elimination of equivalent mutants is proposed. Test adequacy is measured as the product of mutation score and test coverage.

By generating large number of mutants, and ignoring all the unkilled mutants, the reliability is estimated as:

$$\text{Reliability} = \text{Test adequacy x} \frac{\text{No.of times at least one of the verified test cases failed}}{\text{Total no. of mutant killed}}$$

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The advantage of this approach is its simplicity, but its results could be biased when estimating reliability for a highly verified software, i.e.: If the mutation testing is not effective enough, then large number of verified test cases may incorrectly lead to a higher reliability estimate. Also, it is difficult to integrate operational profile into the approach. This approach is more suitable for non-safety applications, but may also be used for systems important to safety to get an initial/quick approximate estimate of the reliability.

Another similar approach based on the principle that, if in a given program, reliability of an execution path p is known, then other paths in the program sharing code with the path p also share the reliability of path p. For example: in Fig. 1, a program has four paths p1, p2, p3 and p4; and the paths p3,p4 share reliability of p2. If the reliability of path p2 (i.e.: R2) is known, then the reliability of any path pi (i.e.: Ri) can be estimated by:

Ri = R2 x (fraction of code shared between pi and p2)

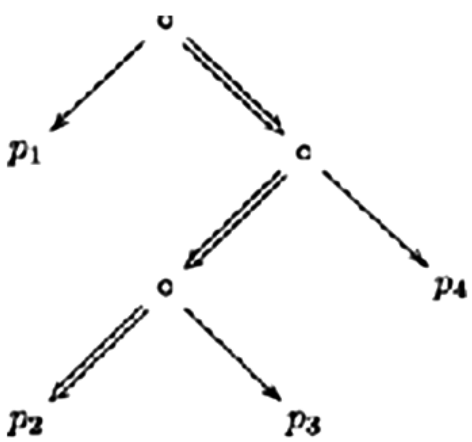

Fig.1: Paths in a program (⇒ indicates a path whose reliability is known).

The fraction of code shared between paths is estimated statistically through mutation testing, by injecting faults in paths for which reliability is unknown (e.g.: path p3). For example: in (Fig. 2) the first injected fault causes the test cases running through paths p^2, p^3, and p4 to fail; whereas the second injected fault fails test case running through path p^3. If several such single fault (first order) mutants are generated, and are tested against the test cases, then the fraction of code shared between paths pi and p^2 may be estimated by:

$$\text{Fraction of code shared between } p_i \text{ and } p_2 = \frac{F_{i2}}{F_{22}}$$

where F_{i2} is number of times test cases running through path p_i has failed, given that a fault was induced in path p_2; and F_{22} is number of times test cases running through path p_2 has failed, given that a fault was induced in path p_2.

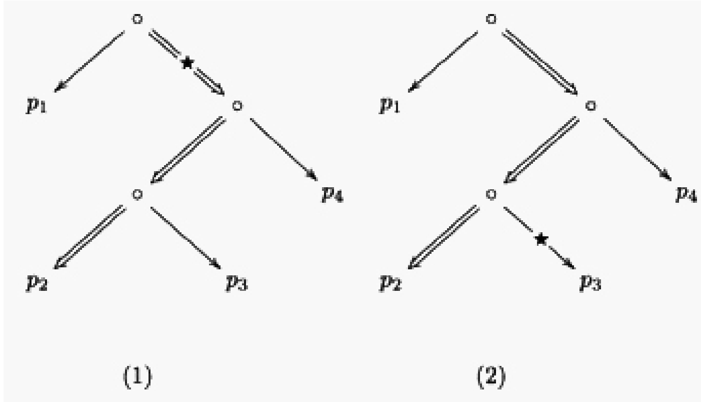

Fig. 2: Faults induced in path p_3 (★ indicates a induced fault)

In real life applications though, an un-verified path may share code with several other verified paths, and may even form cycles. To address such issues, a systematic way to estimate the fraction of code shared among paths and the software reliability is established through an indigenous tool. Unlike the first approach, here integration of the operational profile in the reliability estimate is possible and it ensures that un-verified test cases fail during mutation testing; thus eliminating any bias present due to large number of verified test cases. This property makes the reliability estimate realistic and more suitable for systems important to safety.

Traditional reliability models assume availability of accurate and adequate software failure data, which is often difficult to collect. Also, for a newly built plant with no failure history, the software reliability estimation methods do not apply and in such situations, the proposed approach can be adopted for an initial estimation of software reliability which is represented as a function of three variables: test adequacy, the amount of software verification carried out and the reusability of verified code in the software. The proposed framework has shown how software verification can be combined with software testing to assess a realistic estimate of the software reliability and is expected to aid in the quantitative risk assessment and in the licensing process. Considering the fact that all safety–critical software undergo rigorous testing and verification to ensure correctness; the proposed approach is expected to aid regulators in licensing computer based safety systems in nuclear applications.

Chairman's Address: Severe Accident Issues in Nuclear Power Plants

Complied by: **Dr. Obaidurrahman K.,**
Nuclear Safety Analysis Division,
Based on Chairman's Key Note Address at Severe Accident Analysis and Management Symposium (SAAM-2013), IIT Kanpur, on February 01, 2013

It gives me great pleasure to be present here at this important gathering of outstanding individuals across the country, working in the area of severe accident analysis. This is a timely conducted event after Fukushima accident and will surely provide an important platform to take fresh stock of all available information and expertise in the relevant areas, bringing out the knowledge gaps and providing directions for effective future work.

Nuclear industry goes to great lengths to ensure that safety takes overriding priority in design and operation of nuclear power plants (NPPs). There are well established safety principles, criteria and practices for design, operation and management of nuclear power plant. Safety in design incorporates defence-in-depth philosophy, safety design principles of multiple barriers, redundancy, diversity, testability, guarding against common cause failure etc. In operation, safety is ensured through sound operating practices based on "Technical Specifications for Operation", qualification of operators, in service inspections and management of safety through routine safety reviews, periodic safety reviews, experience feedback, inculcation of strong safety culture etc. Despite of all these multilayer safety measures, a very low probability still remains that few accident scenarios may develop into situations called 'severe accident'. Here comes the role of severe accident analysis which evaluates the ability of the design to withstand severe accidents, assesses the equipment and instrumentation that could monitor and manage the course of the accident and provide guidelines for severe accident management (SAMG). In India, considering the presence of wide variety of nuclear reactors like BWRs, PHWRs, VVERs, FBRs etc., it is important to thoroughly understand severe accident phenomenology and its mitigation measures in all these reactors. Due to differences in physics and engineering design, severe accident (SA) progression has important differences in these reactors, e.g., due to channel type reactor core design, SA progression in PHWRs is different from LWRs till the corium debris bed is formed at the bottom of the calandria vessel. Thereafter, it is similar to LWRs. Also, the presence of huge moderator inventory slows down the core disassembly in PHWRs during SA progression.

During otherwise successful operation of hundreds of power reactor over more than four decades, nuclear industry has witnessed three major accidents via; Three Mile Island (March 28, 1979), Chernobyl (April 26, 1986) and Fukushima (March 11, 2011). First of these three accidents occurred in unit-2 of Three Mile Island NPP in USA, which was a PWR. The accident was initiated by failure of feed water flow to steam generator, escalating into an unmitigated loss of coolant accident. About two third of the reactor core got exposed leading to a partial core meltdown. However, since the reactor building and the structures remained intact, most of the radioactive iodine and cesium remained safely contained within the reactor building,

Chairman AERB Inaugurating the Severe Accident Analysis and Management Symposium at IIT-Kanpur

Chairman's Address: Severe Accident Issues in Nuclear Power Plants

with minimal radiological impact in the public domain.

Chernobyl accident was a reactivity initiated accident (RIA) which occurred when a reactivity driven uncontrolled power surge led to explosions and fire in the Unit-4 (RBMK type) reactor at the Chernobyl NPP in Ukraine (then part of the Soviet Union). Accident began with a test; Tapping energy from spinning turbine to power reactor main pumps in transients following loss of main electric supply, which was being conducted to improve safety. Test requirements led the operator a series of unsafe maneuvers culminating in a situation in which positive void coefficient of RBMK design led positive reactivity addition leading to power excursion with no protection available. Within 4 seconds power rose to 100 times full power, destroying the reactor core and building. Pressure and energy from explosion released high pressure plume of radioactive products, which was carried away by winds to large distances. Accident resulted in thirty one direct fatalities and tens of subsequent fatalities, contamination of large areas and other enormous economic, social, psychological, political impacts.

The Fukushima Nuclear Accident initiated with an earthquake of magnitude 9.0 on Richter scale (plant design basis was 8.2) followed by a Tsunami of 14 meter height (Design Basis was 5.7 m) hit the BWR based NPP, leading to loss of offsite power supply as well as onsite backup power supply from diesel generator, creating a condition of extended station blackout (SBO). Function of core cooling for extracting decay heat and availability of ultimate heat sink was disrupted for varying period in three units of power plant. This led fuel heat up and consequent fuel failure, melting and hydrogen generation. Containment drywell pressurization became double the design pressure which was not quenched by timely venting. This ultimately led to hydrogen explosions and release of fission products. Accident led to large water contamination, airborne radioactive release and ground contamination, evacuation of large population for extended period. Though, neither a single casualty nor any excess exposure to public has been reported yet, accident resulted in significant social and psychological distress. Detailed analysis and investigations of these accidents brought out lacunas and errors in design, instrumentation, operation and regulation, which were used to improve safety of NPPs to the next level.

Indian nuclear community has positively responded to all these severe accidents and comprehensively reviewed safety of Indian NPPs in the light of detailed investigations and lessons learnt. Post Fukushima also, a detailed analysis of Indian power plants under the Fukushima type accident have been taken up and possible safety upgradation as a result of outcome of this analysis are being implemented at different nuclear power plant. As part of independent verification of safety analysis reports, AERB has also actively taken up severe accident analysis as one of its important activity. Several relevant activities like SBO-LOCA analysis in PHWRs and VVERs, hydrogen safety analysis, source term analysis, PHWR core disassembly studies etc. have been taken up. These studies have provided important review input for regulatory process. Details of these studies will be covered by Mr. Avinash Gaikwad during his presentation.

Presently, severe accident needs to be addressed in design more rigorously with prevention of severe accident under all circumstances as the prime focus. This may be achieved by preventing escalation of accident to severe accident with high degree of reliability, practically eliminating early containment failure, avoiding hydrogen detonation and steam explosion by appropriate engineering measures, minimizing core damage, preventing delayed containment failure to minimize release, increasing monitorability of critical parameters and rendering extended time scales for operator interventions. These challenges can be addressed in a phased manner by quality safety research, both at experimental and analytical front supported by timely industrial feedback. In regards to severe accident mitigation, appropriate combination of several engineering measures like back-up power and water supplies, quick poison injection system, primary circuit de-pressurization system, core catcher, hydrogen mitigation options like inerting and passive autocatalytic recombiners (PARs), hard venting of containment etc. can be effectively employed. Several hookup schemes e.g., firewater injection into the calendria vessel (in PHWRs) can also help in preventing severe accident progression.

To conclude, severe accident issues have received renewed topicality after Fukushima though it has been on the radar of nuclear community with varying emphasis over time. In-depth understanding of severe accident phenomenology through rigorous R&D and employment of right SA mitigation mechanisms in design can help in SA prevention, mitigation and development of effective severe accident management guidelines (SAMG) and emergency operation planning (EOPs). Before closing, I would like to emphasize the need for strengthening the mechanisms for enhancing safety in design and operation of NPPs through improved synergy among designers, R&D institutions and academia. I wish this important symposium all the success ahead.

Official Language Implementation

AERB has taken step for accomplishment of the assurances given to the Parliamentary Committee on Hindi and make up for the shortfalls mentioned in their report. The major task on hand is the translation of all the codes, guides, manuals and standards of AERB in Hindi. In first phase, twenty-seven of these documents have been translated in Hindi and printed. In second phase, thirty-five documents have been taken up for translation in Hindi out of which twenty-three documents are sent for printing. In addition, the Hindi cell has carried out the following activities.

- World Hindi Day was celebrated on January 8, 2013 organized by the Joint Official Language Co-ordination committee of the four units of DAE situated in Anushaktinagar. Secretary, AERB inaugurated the function.
- To promote use of Hindi in official work and enhance awareness about official language, Hindi Competitions were held in AERB during March 14-26, 2013. There were ten competitions in three different categories - A, B & C (based on the mother tongue).
- Two Hindi workshops were conducted in ATI on behalf of Joint Official language implementation committee between January-June, 2013. For the first quarter, it was held during February 19-21, 2013. Seven employees of AERB were trained in these workshops.
- DAE Incentive Scheme for working in Hindi was introduced in AERB almost an year ago. Starting with few employees from Administration division, the Hindi Incentive Scheme in AERB is showing a trend of slow but steady rise in AERB.
- Six employees of AERB (05 for Praveen and 01 for Pragya) have completed their training in January-May, 2013 session and appeared for the examination.
- Apart from the Annual report and the Newsletter in Hindi, AERB bulletin has been the new entrant on the publications block this year. Along with publishing it in Hindi, initiatives were taken up to bring it out in Marathi and Tamil also.
- Senior Hindi translator, Dr. K. Madhavi underwent a three months Translation Training Programme at Central Translation Bureau, (Western Region), Mumbai in which she won the Silver Medal in the examination conducted at the end of the Training programme.

Dignitaries on the dais at the World Hindi Day celebration

Participation of AERB in international fora

Chairman AERB participated in the seventh meeting of the Multinational Design Evaluation Programme (MDEP) Policy Group held at Rockville, USA on 15 March 2013. In this meeting various policy issues along with the formation of VVER working group was discussed. AERB is a member of VVER regulators forum and the formation of VVER working group under MDEP will enhance the sharing of information and co-operation on design evaluation and construction of VVER type reactors.

AERB participated in the Commission on Safety Standards (CSS) meeting held at Vienna during 19 - 21 March 2013. The CSS is a standing body of senior government officials holding national responsibilities for establishing standards and other regulatory documents relevant to nuclear, radiation, transport and waste safety. AERB took part in fourth meeting of the Technical Working Group on Nuclear Power Infrastructure (TWG-NPI) held at IAEA headquarters, Vienna during 7 – 10 May 2013. This meeting was organized by IAEA and the purpose of the meeting was to support the developments and implementation of the national nuclear power programme.

AERB participated in the consultancy meeting on the evaluation of the International Nuclear and Radiological Event Scale (INES) training material and annual meeting of the INES advisory committee at IAEA headquarters, Vienna during 10 – 14 June 2013. The topics discussed in the consultancy meeting included the draft material on E-learning INES and the possible quality improvements of the modules. The Advisory Committee meeting discussed about the follow up on the development of INES system, developments of documents related to INES user's manual, reviews of the events since last INES annual meeting, new training courses structure for trainer etc.

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Personnel Joined (January – June, 2013)

Sl. No.	Name	Designation	Date of Appointment
1.	Smt. Smita M. Ghag	Asstt. Accountant	01/02/2013
2.	Smt. Deepa R. Nair	Upper Divn. Clerk	01/03/2013
3.	Smt. Anju V. Jaiswal	Upper Divn. Clerk	28/03/2013
4.	Kum. Saptaparna Sarkar	SO(C)	03/06/2013
5.	Shri Kota Sampath Bharadwaj	SO(C)	03/06/2013
6.	Shri Neeraj Mohan V.P	SO(C)	03/06/2013
7.	Shri Nakul Sashidharan	SO(C)	03/06/2013
8.	Smt. Arundhati Padmanabhan	Accounts Officer	06/06/2013

AERB Cash Awards for Health Physics Stipendiary Training Enhanced

AERB Cash Awards are being given to the top two rank holders of the one year Health Physics Stipendiary Training Course and one year Diploma in Radiological Physics Training Course (since 1995) conducted by Radiological Physics & Advisory Division (RPAD), Bhabha Atomic Research Centre. The revised Cash Award amount is Rs.50,000 /- and Rs. 30,000 /- for first and second rank holders respectively for both the courses.

Personnel Transferred (January – June, 2013)

Sl. No.	Name	Designation	Date of Transfer/ Retirement
1.	Smt. Vasanthakumari Sasi	Sr.Accounts Officer	Transferred to BARC on 18/03/2013
2.	Shri Hukum Singh	TO(C)	Transferred to B RIT, Delhi on 10/04/2013

International Women's Day Celebration

A cultural programme was organized by women employees of AERB on International Women's Day on March 8, 2013. The programme was attended by the women employees of AERB and spouses of senior AERB officials. A special talk on "Investment Management" by Mrs .Nidhi Bhargav, Consultant Investment Management was arranged during the programme. Outdoor games were organized as part of the celebration and all ladies actively participated in the competitions. Prizes were distributed to the winners. AERB ladies worked as a team for the grand success of the programme.

Women's Day Celebrations - 2013

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