ATOMIC ENERGY REGULATORY BOARD
25 YEARS OF SAFETY REGULATION

Editors:

A.R. Sundararajan
K.S. Parthasarathy
S. Sinha

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FOREWORD

A unique feature of the nuclear industry right from its early days has been that the scientists and engineers engaged in its development have been conscious of the hazard potential associated with use of nuclear energy and ionizing radiations. Accordingly several safety elements like defence-in-depth in the form of multiple safety layers, redundancy, diversity and physical separation of components, guarding against single failures and common cause failures were introduced in the design of nuclear reactors right from the beginning. For operation of the facilities, strict rules and operating procedures including procedures for upset conditions and for handling of emergencies were put in place. This all slowly led to the development of a strong safety culture in all activities related with use of nuclear energy. When the Indian Atomic Energy programme came into being with the formation of the Atomic Energy Establishment, Trombay in 1954 and the commissioning of Apsara research reactor in 1956, the safety of this plant was ensured essentially through self regulation. It is relevant and important to point out here that Dr. H.J. Bhabha, the founder and the main architect of the Indian atomic energy programme, laid a strong foundation for a good safety culture which one sees today prevailing in all the activities related to Atomic Energy in India. The following directive which Bhabha issued on February 27, 1960 reads like a safety mission statement of an ideal nuclear industry: "Radioactive material and sources of radiation should be handled in Atomic Energy Establishment, in a manner, which not only ensures that no harm can come to workers in the Establishment or any one else, but also in an exemplary manner so as to set a standard which other organizations in the country be asked to emulate."

As the nuclear energy activities started expanding in India, a need was felt to have specialists to monitor their safety. Thus started the practice of assigning a health physicist to each of the nuclear facility whose mandate was to provide safety surveillance to its operations.

While the Health Physics Division of Bhabha Atomic Research Centre (BARC) provided safety surveillance of DAE facilities, the Directorate of Radiation Protection as the Competent Authority under Radiation Protection Rules 1971, focused on the regulation of radiological safety in non-DAE facilities. In 1972 when the first unit of Rajasthan Power Station was getting commissioned, DAE appointed an apex Committee called DAE Safety Review Committee (DAE-SRC) to review all safety aspects of RAPS-1 unit. Later, DAE-SRC continued to deal with major safety aspects and issues of all the nuclear and industrial units of DAE. In 1979 a senior level committee chaired initially by M.D. Karkhanawala and later by V.N. Meckoni reviewed the specific functions and responsibilities of DAE-SRC in order to enable DAE to discharge its obligations under the Atomic Energy Act, in particular the regulatory and safety functions envisaged under Sections 16, 17 and 23 of the Act. The Report of the Committee titled "Reorganization of Regulatory and Safety Functions" (February 1981) recommended the creation of Atomic Energy Regulatory Board by the Atomic Energy Commission with powers to lay down safety standards and assist DAE in framing rules and regulations for enforcing regulatory and safety requirements envisaged under the Atomic Energy Act 1962. The Committee also recommended that AERB should be a statutory body under the Act (if necessary by suitable amendment of the Act) to give AERB a legal basis as this would be not only in line with international practice but also enhance the public confidence on the safety of the nuclear power plants in the country.

Thus it was on November 15, 1983 that AERB was constituted under the Atomic Energy Act, 1962. Rules promulgated under this Act and the Environment Protection Act of 1986 provide the authority to AERB to ensure that the use of ionizing radiation and atomic energy in the country does not cause undue harm to the health of the workers and the public and to the environment. In the last twenty-five years the Board has grown from a handful of scientists and engineers to a vibrant institution of more than 200. Its professional strength and quality management system are vindicated by the fact that it secured

in 2006 the ISO 9001:2000 certification from the Bureau of Indian Standards. The Board uses such an accredited system for formulating and enforcing its rigorous safety norms, for carrying out in-depth safety review and conducting elaborate and effective regulatory inspections of the nuclear and radiation facilities. In its march towards attaining this status AERB had chartered its own paths and devised its own procedures to handle wide range of projects and challenging issues. AERB was fortunate to have at its helm very eminent persons who brought to bear their vast experience and expertise in different disciplines on the mature evolution of AERB. Each one of them left an indelible stamp of his personality on the fabric of AERB.

We started the AERB silver jubilee year celebrations by holding a simple function on 23 November 2007. The speakers at this function included Dr. Anil Kakodkar, Chairman, Atomic Energy Commission who himself has professionally supported AERB in a number of ways including being a member of our Safety Review Committee for operating plants. Except Dr. A. Gopalakrishnan, who unfortunately could not be present on this occasion, all past Chairmen and Vice-Chairmen of AERB spoke recalling the fond memories of their association with AERB. Excerpts of their speeches have been included in this book for their historical importance. The 'AERB Code of Ethics' and a 'Monograph on Probabilistic Safety Assessment' prepared by AERB staff were released in the function by Chairman, AEC and our new office building, 'Niyamak Bhavan-B' was inaugurated by Prof. A.K. De, the first Chairman of AERB.

This book is a brief historic account of the formation and growth of AERB over the past twenty-five years. Given the vast dimensions, both in range and content, of the responsibilities the Board has handled over these years, such an account cannot be in a simple linear format. An attempt has therefore been made to classify these activities into a few major groups and especially deal with those aspects that were challenging to the regulator. A few of the important issues or events which raised the concerns of the Board and sometimes drew public

attention have also been discussed. It is hoped that this book will offer the reader an insight into the ways in which the Board has been discharging its mandated functions.

I would like to use this opportunity to place on record our sincere appreciation and heartfelt thanks to all our colleagues in AERB, both past and present, who have worked hard and with conviction to bring this organization to the present level where it can be compared with some of the best regulatory bodies internationally. We also gratefully acknowledge the strong support that AERB has received from a number of organizations and the large number of experts who have helped us by way of participation in AERB Committees, expert groups, working groups, etc. and have advised us in a variety of ways to uphold the cause of safety.

S. K. Sharma
Chairman, AERB

PREFACE

Having completed twenty five glorious years in safety regulation, AERB is celebrating its Silver Jubilee this year. It was indeed in December 2006 that we had started thinking about celebrating the Silver Jubilee Year and invited suggestions from all AERB colleagues to do this in a fitting manner. Among the various suggestions we received, one was to bring out a commemorative volume, covering the history of AERB in the last 25 years. This book is the realization of that suggestion.

AERB was constituted on 15th of November 1983. However, the process of review and verification of safety had been an integral part of the Indian nuclear programme since the beginning. The credit for imbibing this aspect in all the projects and activities related to the use of nuclear energy and radiation sources goes to Dr. Bhabha. He ensured that any new project or activity before being implemented, underwent a safety review to ensure that it did not cause any harm to the worker, public or environment. This informal practice was later converted to a formal process by constitution of a standing expert committee for safety review (SRC) and subsequently to an independent safety regulation by way of formation of AERB.

I joined AERB in 1993. By this time AERB had already been in existence for about 10 years. I was fortunate to come into contact with several stalwarts, who were involved in the regulatory activities not only since the birth of AERB, but even earlier. It was through these interactions that I became aware of the efforts, dedication and foresight of several people, who were instrumental in development and growth of AERB. These interactions also brought to my notice the difficulties they faced during this growth period and the manner in which they were surmounted. I myself was greatly influenced by the hard work, vision and achievements of these architects of AERB and have found motivation and direction for my work in AERB. Going by

my own experience, I have sincerely felt that the current generation of young scientists and engineers of AERB and other organizations dealing with nuclear and radiation facilities, who would not have the benefit of such interactions, will greatly benefit by knowing and learning from the history of safety regulation in the atomic energy programme. It was with this conviction that the project for preparation of this commemorative book was taken up.

Having decided on the history book, an Editorial Committee with Shri A.R. Sundararajan, Former Director, RSD & SRI, AERB; Dr. K.S. Parthasarathy, Former Secretary, AERB; Dr. A.N. Nandakumar, Former Head, RSD, AERB and Shri Soumen Sinha, IPSD, AERB was formed on 26 February 2007 to conceptualize and prepare the Book. This Committee prepared a basic outline of the book and identified possible authors for each topic. The idea was that for each topic or chapter a senior person who has himself been a part of this history would be involved along with some younger AERB person who is dealing with the topic today. We then convened a meeting for apprising the authors about the structure of the book. We got a warm response from all of them. The major inputs to various chapters of the book have been provided by S/Shri S.D. Soman, S.P. Singh, G.K. De, Deepak De, N.K. Jhamb, T. N. Krishnamurthi and D.K. Dave. For chapter on IGCAR facilities the inputs were provided by Dr. Baldev Raj, Shri P. V. Ramalingan and Shri G. Srinivasan. Important contributions have also been made by the Heads and Directors of the Divisions of AERB and SRI and other colleagues in AERB. I would like to place on record my heartfelt gratitude to all of them for providing the essential inputs to these chapters.

The initial drafts that we received were significantly different in their scope, content and style of writing and it was essential to bring in some uniformity and continuity among different chapters. A preliminary editing of the materials was then carried out by Dr. A.N. Nandakumar. The main restructuring and harmonization of the chapters were carried out by Shri A.R. Sundararajan and Dr. K.S.

Parthasarathy. I would like to place on record our gratitude for their enormous efforts. Shri R. Bhattacharya, Head, IPSD was assigned the task for overall co-ordination and publication of the book. I would like to take this opportunity to thank all of them for bringing this book to its final shape.

The final round of scrutiny and polishing of the chapters was carried out by Shri S. K. Sharma, Chairman AERB. His emphasis on minute details is reflected all through the book. We always had the encouragement and support of Shri Sharma from the day one. I acknowledge his involvement with all gratitude.

The editorial team had selected about hundred photographs covering the important events in entire span of the last twenty five years. I have personally gone through each one of those nostalgic photographs and have selected fifty photographs among them for this book. I hope the photographs bring back the memories of the bygone days and also inspire the future generation.

To mark the start of the Silver Jubilee Year of AERB, we had organized a function on 23rd November 2007 when the Niyamak Bhavan-B building was also inaugurated. We had invited Dr. Anil Kakodkar, Chairman, AEC and all the past Chairmen and Vice Chairmen of AERB. It was a very memorable moment for all of us and in order to share their profound thoughts, their speeches have been transcribed and added to this volume.

This book gives a brief historic account of the evolution of Atomic Energy Regulatory Board from birth to its coming of age. AERB has been a unique organization. Since its inception, it has been catering to strenuous demands of wide ranging technologies. It has also a great societal responsibility. In discharging its mandate, it derived its strength by pooling the best professionals in the country. It had been led by stalwarts, who had their own rich experience in building and nurturing renowned institutions and had distinct styles of

administration. Clearly it is a daunting task to give a creditable account of its history marked by constant flux of persons and projects and regular agenda of issues and events. Although not a comprehensive volume, the book gives glimpses of the days gone by, the challenges faced and the way they were resolved during this long journey of 25 years.

This book is for all those who are in someway connected to the nuclear industry, in particular to the regulation of its safety. To those who have been part of AERB's activities, this will bring back delightful memories of their proud association. And to the younger generation engaged in regulatory activities, tracing the history of AERB's maturing towards an eminent status, will provide inspiration and motivation to continue on this path to achieve excellence. It is rightly said that looking back helps one to look clearly into the future.

S. K. Chande
Vice Chairman, AERB

Atomic Energy Regulatory Board
25 years of Safety Regulation

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REGULATORY FRAMEWORK: EARLY YEARS

Health Physics Activities

In 1948, the Atomic Energy Act was passed and in the same year the Atomic Energy Commission was constituted. In 1954, the Atomic Energy Establishment Trombay (AEET) was set up.

Raja Ramanna's group at TIFR provided film badge service to radiation workers. In 1956, this service and the newly started radiation surveillance programme were included in what was called Radiological Measurement Laboratory (RML), led by P.N.Krishnamoorthy. A.K.Ganguly who joined in 1955 led the Health Physics Division (HPD). Both RML and HPD reported to A.S.Rao who was then heading the Electronics Group. Shortly, RML became Radiation Measurements Section (RMS) which was reorganized in 1963 as the Directorate of Radiation Protection (DRP) for monitoring non DAE radiation installations.

In 1962, Atomic Energy Act was enacted repealing the Atomic Energy Act, 1948. AEET was subsequently renamed as Bhabha Atomic Research Centre (BARC) in 1966.

Even before the construction of facilities for handling radioactive materials in Trombay in 1958, scientists of DAE were handling small amounts of radioactive materials at the make shift laboratories in Tata Institute of Fundamental Research (TIFR) and at the Bombay Dyeing premises on Cadell road. There were indeed reports of a few safety related unusual occurrences from these activities. For instance in the Chemistry Division at Cadell road, on one occasion while N.Srinivasan and G.S. Tendulkar were working on the production of Uranium metal by fused salt electrolysis, there was a chemical explosion resulting in contamination of many rooms with uranium oxide dust. E.C. Allardice, the Controller, AEET, took S. D. Soman

from the head office of Atomic Energy Commission at Old Yacht Club to assess the situation. He locked all those rooms and handed over the keys to Soman and directed that unless Soman gave clearance, nobody would work in these rooms. Coming from Allardice there could not have been a stronger safety directive.

In another instance in TIFR, there was polonium contamination in Ramanna's nuclear physics laboratory. Soman was again given the responsibility to get the laboratory decontaminated. Incidentally, Soman also served as Chairman of AERB from 1990 to 1993.

Safety Review of Early Research Reactors

When DAE started the design and construction of its first research reactor Apsara in 1955, there was no formal safety analysis report. Designers of various systems of the reactor on their own ensured the safety of the design. They were guided by whatever information that was available in the published literature. Bhabha gave all the decisions and the directives related to the reactor. He used to be personally present to review the design and he also got it vetted by some of his scientist friends from abroad. While there was no formal clearance given for first criticality of Apsara, it had all the safety features that were required in a research reactor at that point of time.

Afterwards, when the second research reactor CIRUS, a joint venture between India and Canada came up, a design and safety report was prepared at the insistence of the Canadian Authority. The report had ten chapters; out of which seven chapters were on various aspects of design and remaining three were on safety. One chapter was on administrative controls including emergency procedures, the second on safety analysis on postulated accidents and their consequences and the third on waste management. These three chapters were prepared jointly by veterans like V. Surya Rao and S.L. Kati from Reactor Operations Division and A. K. Ganguly, S. D. Soman and V.V. Shirvaikar from Health Physics Division. In

one of his overseas visits, Bhabha talked about this safety report to John Cockroft in Harwell and requested N.G. Stewart, Head, Health Physics Division at Dounreay establishment to review the report and give his views. Stewart came to India, went through the document and submitted his comments. He also gave a very useful course of lectures on all aspects of radiation and nuclear safety. Later, Ganguly went to Canada with the final version of these chapters and got them approved. That was how a formal design and safety report for a nuclear reactor was prepared for the first time in India.

For ZERLINA reactor, S.D. Soman, V.S. Prabhakar and N.L. Char prepared a safety analysis report in the format of an AEET report. Some of the major considerations were the ramp reactivity addition, which the system could withstand, the maximum quantity of heavy water, which would be permitted in the storage tanks and the maximum rate at which the control rods could be withdrawn. These aspects were discussed in three well-received papers presented by V. Surya Rao in an IAEA symposium in 1962 on 'Reactor Safety and Hazard Evaluation Techniques'. That was the first time that papers on reactor safety from Indian scientists were presented in an International Conference.

In 1962 Bhabha set up a formal reactor safety committee with A.S. Rao as the Chairman and V. Surya Rao, V.N. Meckoni and A.K.Ganguly as members. This was of course a very senior level committee and had three working groups, one each for Apsara, ZERLINA and CIRUS. Any proposal would first go to the respective working group and then the groups would send their report to the main committee. There was also a program committee which reviewed different proposals for reactor utilization and irradiations in these reactors. These were finally got approved in the reactor safety committee. In addition to these committees, there was also a special committee on reactor control system. Any change in control system of these three research reactors would go to this committee and finally would get vetted with changes and deletions, if any, by the reactor safety committee. So one can notice the careful attention to safety

and existence of a scheme of multi-tier review of safety of reactors even at that time.

Other Nuclear Facilities

In mid 1964 the Plutonium Plant to reprocess irradiated fuel was commissioned. However a formal safety committee for the reprocessing plant was established only in 1966 under the chairmanship of Ganguly. Unlike in the case of reactors, the published data on reprocessing was scanty. So it was considered appropriate to gain some experience with the actual plant systems and their operation before preparing a safety report or any related regulation. By the time the Safety Committee completed its work and submitted the report, the next plant, Power Reactor Fuel Reprocessing Plant (PREFRE) was coming up at Tarapur. Another committee chaired by Soman was therefore constituted to review the safety aspects of PREFRE. He also chaired one more committee which reviewed the large radiological laboratory complex, which included radioisotope, radiochemical, and radio metallurgy laboratories. It can be seen that even though formal regulatory body did not exist at that time, all facilities were being subjected to a thorough safety review.

Siting of Nuclear Power Plants

When the Government gave the approval for construction of the country's first nuclear power station, DAE had to look for a proper site. Soon after selecting Tarapur in Maharashtra in 1960 as the first site, DAE constituted an apex Committee under M.N. Chakravarti, formerly of Railway Board, for selection of sites for future nuclear power plants. Health Physics Division of BARC played a pioneering role in this new task and developed a set of safety criteria for siting of nuclear power plants in the country. These criteria and related concepts were presented in many papers in an IAEA sponsored international conference on containment and siting of reactors and nuclear centres held in March 1963 at TIFR, Bombay. The siting criteria included inter alia the designation of 1 mile (1.6 km) exclusion

zone and 3 miles (4.8 km) sterilization or low population zone. The site selection committee adopted these criteria and selected on this basis, the sites for Rajasthan Atomic Power Project (RAPP) and Madras Atomic Power Project (MAPP). Many of these criteria were not only followed by subsequent site selection committees but also formed the core of the safety code on siting prepared later by AERB.

Radiation Protection in AEET

With the enactment of the Atomic Energy Act 1962, the Department of Atomic Energy received the mandate to enforce safety in all nuclear and radiaiton facilities in the country. The jurisdiction included the nuclear fuel cycle facilities as also the installations using radioisotopes and applications of radiation in medicine, industries and research.

In 1963, the Health Physics Division (HPD) brought out the Manual for Radiation Protection in AEET, a landmark document which served for several years as a standard for radiation protection for all DAE nuclear facilities. In one of the office orders, Bhabha had made it mandatory for all the nuclear facilities to follow this manual. It was a practice in those days, to have the safety requirements issued as office orders either by a Group Director or Director AEET. The health physicists posted in different radiation installations of AEET technically reported to Head, Health Physics Division. They carried out the radiological surveillance of the facilities and took proactive roles in securing from the operators compliance with the safety directives. More often than not, health physicists were also the member-secretaries for the operational safety review committees, unusual occurrence investigation committees and radiation over exposure investigation committees for these installations.

Radiation Protection in Non-DAE Facilities

In 1963, the Directorate of Radiation Protection (DRP) was constituted for monitoring the non-DAE radiation facilities with P.N.Krishnamoorthy as the Deputy Director of DRP. In 1973, both, the

HPD as well DRP were brought under the Chemical Group of BARC headed by A. K. Ganguly. After the promulgation of Atomic Energy (Radiation Protection) Rules, 1971, The Director of DRP was notified as Competent Authority. In 1972, DRP was renamed as Division of Radiological Protection (DRP). In 1973, K.G.Vohra took over as Head DRP. Head, DRP was notified as Competent Authority for the enforcement of RPR 1971. U. Madhavanath later took over as Head DRP in 1987.

The responsibilities of DRP included the radiation protection surveillance of hospitals, industries and research institutes, authorizing users to procure radioactive sources either from isotope Division of BARC or through imports, preparation of safety standards, development of primary and secondary standards for beam therapy, providing personnel monitoring services to all DAE and non-DAE installations and maintaining dose records of all radiation workers. During seventies, there was a quantum jump in the application of radiation particularly in medicine. DRP assisted various institutes in planning their radiotherapy facilities by taking into account safety aspects. Apart from these activities, DRP also developed radiation detection and measuring instruments, TLD for personnel monitoring purposes, biological dosimeters and carried out research in radiation biophysics.

In 1961 DRP started a one year post graduate training course in Hospital Physics and Radiological Physics. WHO supported this initiative by providing relevant books and the University of Bombay recognized this as a Diploma programme. Those who successfully completed this training course or Diploma in Radiological Physics were later recognized by DRP to function as Radiological Safety Officer (RSO) in major radiation installations such as radiotherapy units.

DRP organized several short term (two to four weeks duration) training programmes for medical and industrial applications of radiation. A few two-weeks training programmes for research workers

were conducted on a regular basis. Institutions were authorized to handle radiation sources if and only if they had personnel trained from DRP in the safety aspects of radiation. Several officers from DRP got trained in medical physics and radiation protection in USA, Canada, UK, Belgium and Australia. These personnel in turn helped in disseminating their knowledge by organizing and conducting training programmes at different levels. The regulatory role of DRP received country wide recognition because of the large number of radiation protection surveys and training programmes conducted by DRP.

DRP offered free services in leak testing of radium sources used for brachytherapy in 65 hospitals; the earlier stock dated back to 1930. It offered thremoluminescent dosimetry system for carrying out intercomparision studies on the radiation output of teletherapy units. This programme helped hospitals in delivering accurate doses safely to patients undergoing radiation therapy.

Regulation of Medical Applications of Radiations

DRP has been providing advice and other services to those X-ray installations and manufacturers, who approach them voluntarily. Personnel from DRP carried out radiological protection surveys of a few hundred medical X-ray installations in different parts of India. BARC through agencies under it, had organized regularly several programmes to train radiological safety personnel from different radiation installations. In the case of major installations, the team stayed at the site for several days. They used to prepare detailed reports on such campaigns. This helped the personnel who joined later to understand and appreciate radiation safety principles and practices in medical X-ray installations.

Application of radioisotopes for medical purposes started in the country as early as in 1951. Radioisotopes like P-32 were imported from Harwell, U.K. With the commissioning of Apsara reactor in 1956, the medical use of radioisotopes started increasing steadily.

Diagnostic techniques in nuclear medicine were followed by uses of radioisotopes such as I-131, P-32 in radiotherapy too. Attention was then drawn to radiation safety and related medico-legal aspects.

During early sixties, test monographs for a few radiopharmaceuticals appeared in international pharmacopoeia and in those of some countries. In India the Drug Control Administration considered clearing of radioisotopes under licence number 720. AEET started supply of radioisotopes in diverse forms such as ready-to-use preparations for oral use and for use as injectables, short-lived radioisotope generators to prepare ready-to-use organ imaging agents by intravenous use, cold kits amenable to instantaneous and quantitative incorporation of short lived radioisotopes for organ imaging etc. It soon became apparent that the production, testing and supply of radiopharmaceuticals must fulfill medico-legal aspects related to the manufacture and use of conventional drugs and radiological safety requirements.

The Department of Atomic Energy decided that specialists in the nuclear medicine field should deliberate on aspects related to the safety of premises, patients, workers and public. Director, BARC set up the Radiopharmaceutical Committee on February 23, 1968. The committee was asked to examine the production, practices, controls and the specifications of the radiopharmaceuticals supplied by the Isotope Division. The committee was expected to consider and recommend the incorporation of radiopharmaceuticals into the Indian Pharmacopoeia. The seven member committee had representation from the Directorate General of Health Services, Government of India, Delhi.

Simultaneously, Director, BARC set up a five member Nuclear Medicine Committee. The members were drawn from BARC (Medical Division, Isotope Division, Radiation Medicine Centre), Directorate of Radiation Protection, and the Directorate General of Health Services, Ministry of Health, Government of India, Delhi. The Committee was to

evaluate all proposals for research, diagnostic and therapeutic uses of radioisotopes and approve a list of doctors trained in radioisotope techniques for established diagnostic and therapeutic procedures. Other function of the Committee was to evolve procedures for giving standing clearances to established doctors for using standard products so that no delays are involved for urgent requests. It will, however, examine carefully the applications from every new user and for every new use of medical radioisotopes.

When DAE set up the Board of Radiation and Isotope Technology (BRIT) in 1989, it brought the Radiopharmaceutical Committee under the Board. The Members of the Committee included specialists in nuclear medicine and pharmacy. Commissioner, FDA or his nominee and Drug Controller (India) or his nominee were also made members. The terms of reference were broadened. The Committee approved modifications in procedures and also granted approval to conduct clinical trials before introducing a new product.

Through these procedures DAE achieved overall safety of practices in nuclear medicine, though it may be difficult to find direct legal basis for these early regulatory activities. However in 1977, the Director General of Health Services, Government of India notified that "radiopharmaceuticals" are exempt from the provisions of Chapter IV of the Drugs and Cosmetics Act 1940 as the actual mass of radioactive material in any radiopharmaceutical is too trivial to cause any toxic effect. The frequently used radioactive materials such as Tc-99m have very short half lives; it may not be feasible to study them for sufficiently long periods to evaluate the relevant parameters as is done for conventional pharmaceuticals.

Regulation of Industrial and Research Applications of Radiations

From the sixties, a few institutions started using radioisotopes and other sources in industry. BARC manufactured and sold a few types of industrial gamma radiography exposure devices. Since these sources were potentially dangerous, DRP initiated more formal

regulatory control over them. DRP organized training of personnel at both operating and supervisory levels. Exercising the powers vested with the Competent Authority under the Radiation Protection Rules 1971, Head DRP promulgated the Industrial Radiography (Radiation Surveillance Procedures) 1980. This gazette notification prescribed the mandatory requirements for safe radiography. DRP ensured that trained manpower is available for carrying out radiography.

Nucleonic level gauges, with a few exceptions, used radioactive sources of low activity. These were large in numbers and were distributed in petroleum, paper and textile industries. DRP held short term training programmes on the safety aspects of nucleonic gauges. Institutions could operate the radiation source devices only after they have trained personnel in place.

Isotopes such as P-32, C-14 and H-3 were used as open sources in research mainly in the field of agriculture and hydrology. DRP issued authorizations to receive such sources locally or through import after ensuring minimum safety requirements.

Safety Culture

One might wonder how good was the compliance to safety requirements in the early days of the atomic energy programme in the absence of a formal regulatory body. Thanks to the safety culture assiduously nurtured by Bhabha and sustained by subsequent Chairmen of the Commission, Health Physics Division and DRP were able to ensure a high level of safety in the design and operation of various facilities in the country. Yet another major contributing factor to this healthy situation was the extraordinary respect all had for Ganguly's knowledge, wisdom and guidance. Also whenever there was a safety issue not resolved at a lower level, Rao or Ganguly or Soman did not hesitate to take it up with the Chairman, AEC. So in a sense the safety departments, irrespective of their

name labels, always functioned as independent units from the very early days.

Major Inputs by: *S.D. Soman, K.S. Parthasarathy and A.R. Sundararajan*

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SETTING UP OF AERB

When Tarapur reactors built by GE, USA were ready for commissioning in 1969, there was no formal regulatory system yet, to approve the first approach to criticality. Sarabhai set up an independent committee under the chairmanship of A.K. Ganguly with members like N.Srinivasan and a few more officers from RED, BARC to review the commissioning activities at every step and advise him on the authorization of the next step. It was a challenging task for the committee, particularly because both the units of TAPS achieved criticality one after another within the same month. The same committee continued to review the safety of the plants during their operational phase too.

DAE Safety Review Committee (DAE-SRC)

When in 1971, Unit 1 of Rajasthan Atomic Power Station (RAPS-1) was getting ready for commissioning and operations, the existing committee for Tarapur was renamed as DAE Safety Review Committee (DAE-SRC) in February, 1972 and its scope was enlarged to include RAPS–1. In December, 1975 the scope of work of DAE-SRC was further enlarged entrusting it with the responsibility to deal with major safety policies and issues in all the constituent units of DAE. This included power reactors and research reactors as also all other fuel cycle facilities including UCIL, IREL, NFC, etc.

Recommendation to set up AERB

On July 23, 1979 Secretary, DAE constituted a Committee chaired by M.D. Karkhanawala, Chairman, DAE-SRC to study "the existing terms of reference of SRC, its functions, the modalities of reporting by the Units as well as the impediments faced by the Committee". The review of the terms of reference and the working of DAE-SRC became necessary "to ensure that not only safety consciousness is

inculcated, but that safe practices prevail in all the Units of the DAE including the public sector undertakings". After the tragic demise of Karkhanawala in a car accident, V.N. Meckoni, the then Director, Chemical Group, BARC took over as the Chairman of this committe in February 1980.

The Committee discussed the functioning of SRC, role of SRC vis-à-vis that of a regulatory body, impediments in the functioning of SRC and the authority to be provided to SRC. It also considered creation of a regulatory body "to effectively fulfill the responsibility of DAE for regulatory and safety functions envisaged under Sections 16,17 and 23 of the Atomic Energy Act, 1962". The report provided a comprehensive review of the existing organizational arrangements to provide safety coverage.

Though the Committee did not observe any lacunae in the ways in which DAE-SRC had been discharging its assigned responsibility of safety review, it did make the following important observation. "Since the activities of DAE and use of radiation sources in the country have increased, it is considered necessary to establish a separate body with the responsibility to carry out the regulatory and safety functions in an effective manner".

In its Report titled "Reorganization of Regulatory and Safety Functions" (February 1981), the Committee recommended creation of Atomic Energy Regulatory Board by the Atomic Energy Commission with powers to lay down safety standards and assist DAE in framing rules and regulations for enforcing regulatory and safety requirements envisaged under the Atomic Energy Act 1962. The Committee also recommended that AERB should be a statutory body under the Act (if necessary by suitable amendment of the Act) to give AERB a legal basis. The Committee stated that in order to enable AERB to function effectively and exercise its authority in an independent manner it should be constituted by and reporting to the Atomic Energy Commission and should consist of senior persons from DAE as well

as external members. In this manner public confidence in nuclear safety matter would be enhanced.

The Committee described the scope of the activities of AERB and SRC, their composition, functions and powers, functions of design safety committees to be set up by AERB, functions of operational safety committees to be set up by SRC, functions of Health Physics Division and functions of the Division of Radiological Protection. The report also described the facilities to be extended to AERB.

The present functions of AERB are almost verbatim taken from the report of the committee. The Committee recommended that AERB should lay down and monitor the observance of safety standards for siting, design, construction, operation and decommissioning of nuclear and radiological facilities in the country. SRC should enforce the safety standards stipulated by AERB in the operating units of DAE and undertake safety surveillance as well as review of proposed changes in design and safety related incidents in the operating units.

Besides forwarding the minutes of its meetings to AERB, SRC was required to submit periodic reports on the safety status in the operating units of DAE to AERB. SRC should review deviations from the safety standards laid down by AERB and violations of the technical specifications for operations and should take prompt and necessary enforcement actions. "In case AERB finds that enforcement action in any particular case is not adequate, it may take up the matter with AEC" the committee clarified.

The committee's farsightedness is commendable. Its recommendations were to ensure that the right expertise is available for AERB for its functioning. It also reflected the need for the participation of experts from other regulatory agencies such as the Central Electricity Authority, Central Pollution Control Board, Ministry of Labour and academic institutions to gain from their expertise and experience.

AERB was set up on November 15, 1983. A separate notification indicating the functions and responsibilities of DAE-SRC was issued subsequently. AERB's functions included enforcement of provisions of radiological protection in the radiation installations outside the DAE. For non-DAE units, the AERB would be assisted by the Division of Radiological Protection, Bhabha Atomic Research Centre. Violations of safety standards laid down by AERB were subjected to further review by the AERB. Appeals against decisions of the AERB would be with the Atomic Energy Commission.

A.K.De, formerly Director, Indian Institute of Technology, Bombay, was appointed the first Chairman of AERB. P.N. Krishnamoorthy, formerly Deputy Director, Directorate of Radiation Protection was appointed Member-Secretary. The other Members of the Board were V.N. Meckoni, Chairman DAE-SRC, B.D. Gupta, Head of Radiation Oncology, Post Graduate Institute of Medical Education and Research Chandigarh and E.C. Subba Rao, Director, Tata Research Development & Design Centre, Pune.

As per the constitution of AERB, Chairman, AERB has the power of Competent Authority to enforce rules and regulations framed under the Atomic Energy Act for nuclear and radiation safety in the country. AERB also has the authority to administer the provisions of the Factories Act, 1948 for industrial safety in all the units of DAE. AERB has been delegated with powers to enforce some of the provisions of Environment Protection Act, 1986 in DAE installations.

Organizational Structure of AERB

AERB started its work with its office located at the Anushakti Bhavan (Old Yacht Club) in 1983. A. K. De joined in January 1984. The first Board meeting was held on March 10, 1984. A formal organizational structure of AERB was approved by the Board on September 5, 1985 and came into existence on September 30, 1985.

The main responsibilities of AERB include regulation of nuclear, radiation and industrial safety in DAE installations, radiation safety in non-DAE installations and preparation of regulatory documents. These were being carried out by three Divisions, namely Nuclear and Industrial Safety Division, Radiation Safety Division, Computer Facilities & Analysis Division. Besides these Divisions, there were two more sections, namely Safety Research Training & Publication Section and Library Services.

A Committee set up on March 21, 1987 again with V.N. Meckoni as Chairman reviewed the functions and responsibilities of AERB. The Committee submitted its recommendations on May 15, 1987. As recommended by the Committee, DAE-SRC became a part of AERB as AERB-SRC and later as Safety Review Committee for Operating Plants (AERB-SARCOP). The functions and responsibilities of AERB were broadened considerably. AERB started carrying out its functions as per the original notification and also as per the recommendations of the Meckoni Committee. Following this the Board had four divisions namely, Nuclear Safety Division, Industrial Safety Division, Operating Plants Safety Division and Radiation Safety Division.

AERB's office was shifted to Vikram Sarabhai Bhavan, Anushaktinagar in 1988. Subsequently, AERB shifted to its own office building named as Niyamak Bhavan in Anushaktinagar on August 2, 1996. Recognizing the need for an in-house R & D facility where dedicated research can be conducted on issues of regulatory interest, AERB commissioned its Safety Research Institute (SRI) at Kalpakkam in 1999. Due to considerable expansion of AERB staff over the years, a new office building 'Niyamak Bhavan-B' was constituted and occupied in November 2007.

The AERB secretariat now has eight technical divisions and their functions and responsibilities are as given below.

Operating Plants Safety Division (OPSD)

- Safety Review and Safety Surveillance including Health Physics Aspects and Emergency Preparedness of operating NPPs and Research Reactors
- Regulatory Inspection and Enforcement in respect of all operating NPPs and Research Reactors
- Conducting Periodic Safety Review and Renewal of Authorization
- Licensing of the operating personnel and the management staff
- Review of Physical Protection aspects in operating plants
- Enforcement of Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987
- Co-ordination with International Atomic Energy Agency (IAEA) for the International Nuclear Event Scale (INES) based reporting of events and for the Incident Reporting System (IRS) operated by IAEA/NEA
- Secretariat of SARCOP

Nuclear Projects Safety Division (NPSD)

- Safety Review of Nuclear Projects
- Regulatory Inspection & Enforcement in projects under construction
- Issue of authorizations at various stages of the projects as per established procedures and protocols
- Review of physical protection aspects in projects

Industrial Plants Safety Division (IPSD)

- Safety Review, Regulatory Inspection & Enforcement and Licensing of Personnel in respect of all DAE Industrial Plants and Projects and front-end Fuel Cycle Facilities
- Implementation of Atomic Energy (Factories) Rules, 1996 and Occupational Health Aspects in all DAE Facilities
- Implementation of Atomic Energy (Radiation Protection) Rules,

2004 in front-end Fuel Cycle Facilities, Accelerator Units and Beach Sand Minerals Processing Facilities

Radiological Safety Division (RSD)

- Licensing, Surveillance and Safety Review of BRIT facilities and Non-DAE Radiation Installations including Accelerators and Irradiators
- Implementation of Atomic Energy (Radiation Protection) Rules, 2004 and enforcement of Atomic Energy (Safe Disposal of Radioactive Waste) Rules, 1987 in non-DAE installations
- Ensuring safety in Transportation of Radioactive Material in public domain
- Secretariat for SARCAR (Safety Review Committee for Application of Radiation)

Civil and Structural Engineering Division (CSED)

- Safety Review pertaining to Civil and Structural Engineering aspects of nuclear reactors, fuel cycle facilities, industrial and radiation facilities of DAE.
- Site evaluation of nuclear facilities
- Developing civil engineering safety criteria for design, construction and erection of NPPs

Safety Analysis and Documentation Division (SADD)

- Safety Analysis and Safety Studies for nuclear facilities
- Preparation of Regulatory Documents
- Library and documentation services

Information & Technical Services Division (ITSD)

- Secretariat for AERB Board
- Activities to promote and fund Safety Research Projects
- International relations including interaction with other regulatory bodies
- Public information and Media interaction
- Compilation and publication of AERB Annual Reports

- Human Resource Development
- Response to parliament questions and queries under Right To Information Act
- Knowledge Management

Safety Research Institute (SRI), Kalpakkam

- Development of models, methodologies and knowledge base required for quantitative assessment of risks associated with the operation of nuclear fuel cycle facilities
- Generation / collection of data needed for safety assessment.
- Providing a technical forum for joint research among NPP personnel, research groups and regulators, in safety related fields.
- Organising regular programmes of technical meetings and training courses for different target groups on a variety of topics for enhancement of safety performance.

AERB Committees

AERB is supported in its functions by a number of committees. Members of all the AERB committees are recognized experts with long experience in the relevant fields and come from DAE units, various Governmental organizations, academic institutes and industry. A large number of retired experts are also members of the various AERB Committees.

Apex Safety Review Committees

The apex safety review committees of AERB are the Safety Review Committee for Operating Plants (SARCOP) and the Safety Review Committee for Applications of Radiation (SARCAR).

SARCOP was constituted in June, 1988 with M. S. R. Sarma, (Executive Director, Operating Plants Safety Division, AERB) as the first Chairman to evaluate and enforce nuclear, radiological and industrial safety in all operating units including public sector undertakings of

the Department of Atomic Energy, for ensuring safety of the operating personnel, members of the public and the environment. SARCOP is supported by a number of specialist committees such as the Standing Committee on Reactor Physics, Committee on Steam and Water Chemistry, Committee on Control & Instrumentation and Computer Systems and Expert Group on Coolant Channel Safety for detailed review of issues pertaining to specific technical fields. In addition, there is a unit safety committee for each operating unit (or a group of units) for detailed operational safety review of individual units and advising SARCOP.

In 1987, AERB constituted a Committee known as Licensing and Appellate Committee. This committee was restructured in 1991 with a new name as Safety Review Committee for Applications of Radiation (SARCAR) with a view to streamlining the implementation of Radiation Protection Rules in all practices and organizations using radioisotopes and radiation sources in medical, industrial and research institutes. A. Nagaratnam, former Director, Defense Laboratory, Jodhpur was the first Chairman of the SARCAR.

Apex Advisory Committees

AERB has constituted a number of Advisory Committees that deal with nuclear safety, radiological safety, industrial and fire safety, and occupational health. In addition, there are Advisory Committees for Safety review of various Projects (ACPSR) and Advisory Committees for assisting AERB in its safety documents development work.

The Advisory Committee on Nuclear Safety (ACNS) was constituted in January, 1985. J. C. Shah (Former Chairman, Atomic Power Authority) was the first Chairman of ACNS. The primary function of ACNS is to advise AERB on generic issues affecting the safety of nuclear installations including siting, design, construction, commissioning, operation and decommissioning The Committee also reviews and makes final recommendations on the draft AERB safety

Codes, Guides and Manuals before they are put up to Chairman, AERB for approval. Similarly, the Advisory Committee on Radiological Safety (ACRS), Advisory Committee on Industrial and Fire Safety (ACIFS) and the Advisory Committee on Occupational Health (ACOH) advises AERB in the respective fields.

ACPSRs of various projects recommend to AERB issuance of authorization at different stages during siting, construction and commissioning of nuclear facilities including NPPs, after reviewing the submissions made by the plant authorities and based on the recommendations of the associated Project Design Safety Committees. AERB has constituted an Advisory Committee for preparation of Code & Guides on Governmental Organization for the Regulation of Nuclear & Radiation facilities (ACCGORN). There are also the Advisory Committees for Codes, Guides & Associated Manuals for Safety in Operation of NPPs (ACCGASO) and Safety in Design (ACCGD) as also the Advisory Committee for Safety Documents for Fuel Cycle Facilities (ACSDFCF).

Major Inputs by: *K.S. Parthasarathy and O.P. Singh*

3

SAFETY REVIEW OF BARC FACILITIES

Towards developing the various technologies for the envisaged nuclear power programme in the country, a number of facilities were established in Trombay in the early years. These included a thorium extraction plant, uranium fuel fabrication plant, heavy water production facility, research reactors, a fuel reprocessing plant, waste treatment facilities and a number of hot laboratories for radioisotope production, radiochemistry research and radiometallurgy studies. As mentioned earlier, the safety aspects of these facilities were looked after by Health Physics Division, BARC and Reactor Safety Committee in the early years and by DAE-SRC from 1972 onwards. After the formation of AERB in 1983, a number of safety committees were constituted for safety review of various BARC facilities under the jurisdiction of SARCOP. AERB was also associated with the licensing of plant personnel in all the critical installations. Subsequently, as per a decision of Government of India, the regulatory and safety review functions related to Bhabha Atomic Research Centre (BARC) were transferred from AERB to an internal safety committee structure of BARC in June 2000.

During the period 1983 to 2000, safety review of the following major BARC facilities was carried out by AERB.

Research Reactors

The first two research reactors in Trombay, Apsara and CIRUS, which were commissioned in 1956 and 1960 respectively did not have a structured safety review during the project phase. However for safety review of their operations Bhabha set up a formal reactor safety committee by an office order in 1962 with A.S. Rao as the Chairman and V. Surya Rao, V.N. Meckoni and A.K.Ganguly as members. Later when DAE Safety Review Committee (DAE-SRC) was constituted in 1972, it took over the responsibility for the safety review of all the

research reactors. This Committee formed a separate Unit Safety Committee for each category of plants.

Dhruva

During the seventies, a need was felt for a research reactor with higher neutron flux than CIRUS to meet the growing requirements for radioisotopes and also to provide scope for major science and engineering experiments related to the power programme. This led to the design, construction, commissioning and operation of a 100 MWt research reactor Dhruva. The construction of CIRUS and the experience gained in its operation and maintenance, coupled with the infrastructure built in the various research and development groups in BARC helped in designing and constructing Dhruva. DAE-SRC gave stage-wise clearance based on an in-depth review by the Dhruva Safety Committee (DSC) chaired by M.S.R.Sarma.

Ground breaking of Dhruva was done on May 17, 1974 and it attained first criticality on August 8, 1985. The design and engineering of this reactor had been a totally indigenous effort with several divisions of BARC participating in this task led by S.M. Sundaram, as Project Manager. For example, the Reactor Engineering Division of BARC did the design and the engineering of the pile block and the Reactor Control Division did the design and engineering of the reactor protection and regulating systems. The Design report of Dhruva was reviewed in depth by Dhruva Safety Committee (DSC) under DAE-SRC. Various Safety concerns were resolved by experimentation, tests, design modifications etc. Each and every clause of the technical specifications for operation was deliberated upon before approval of this document. DAE-SRC gave stage wise clearance for Fuel Loading, Heavy Water Addition, Initial Criticality and Power Operation.

While giving clearances for the first criticality, besides ensuring that all necessary systems were available for operation and their commissioning results were acceptable, DAE- SRC also stipulated that the first approach to criticality should be done in the presence

of designated senior experienced design group persons who were thoroughly familiar with the reactor systems.

During the review of the initial operation of the reactor, it was observed that due to excessive flow induced fuel vibrations, the fuel clad had abraded resulting in release of aluminium turbidity and uranium contamination in the heavy water coolant. DAE-SRC recommended that reactor operation be suspended till completion of clean-up of the system and incorporation of appropriate design modifications in the fuel to solve the problems.

Post-irradiation examination of the fuel showed excessive fretting wear of aluminum clad leading to exposure of the uranium metal. The analysis showed that the fuel clusters had been subjected to excessive vibration caused by the diametrical clearances between the fuel assembly and the guide tube, at the bottom where the coolant entered. It was also noticed that the natural frequency of the fuel assembly was close to the natural frequency of main coolant heat exchangers together with their support structure, causing resonant vibration of the fuel assemblies. All these deficiencies were rectified. Also the turbidity in the coolant was successfully removed by using a specially developed magnesium loaded ion exchange resin and a centrifuge system. DSC and DAE-SRC were monitoring the progress of the modifications made at various stages and after the problems were solved the reactor power was allowed to be raised in steps reaching the final design value of 100 MWt in January 1988.

CIRUS

After over thirty years of operation of the 40MWt research reactor CIRUS, detailed aeging studies of its systems, structures and components were performed and a refurbishing plan was submitted to BARC Reactor Safety Committee and SARCOP. The plan was reviewed in AERB which included the assessment of stored Wigner energy in the graphite reflector of the reactor, a thorough evaluation

of the major structures like the reactor containment, stack, ball tank, underground D.M. water storage tanks, sub soil piping etc apart from the in-core components like reactor vessel and endshields.

While the refurbishing work was in progress, the safety review of BARC facilities was transferred from AERB to an internal safety committee structure of BARC. As such AERB was not involved in clearance for restart of CIRUS. However, the reactor was successfully brought back in operation after this major refurbishing effort.

Reprocessing Plants

The first plutonium extraction plant was commissioned in Trombay in 1964. Based on the experience gained here, BARC constructed a power reactor fuel reprocessing plant (PREFRE) at Tarapur in mid seventies. Both these plants came under the review of SARCOP in 1987.

BARC sought the approval of AERB in 1994 for the construction of a power reactor fuel reprocessing plant at Kalpakkam (KARP) By the time the application was received in AERB, the construction of the plant was already in progress. An Advisory Committee for Project Safety Review (ACPSR) was constituted by AERB in 1994 with R. K. Garg, former, CMD, IREL as Chairman.

ACPSR noted that though the KARP design had been reviewed by an internal review Committee of Nuclear Recycle Group, BARC, it did not undergo a formal review by a Project Design Safety Committee (PDSC) of AERB. In the case of NPPs and research reactors, AERB has spelt out in its Safety Guide AERB/SG/G-1 all the requirements of AERB's consenting process, including guidelines on preparation of Preliminary Safety Analysis Reports, definition of various stages of authorization of plant construction and commissioning. In the absence such a regulatory document for fuel reprocessing plants, ACPSR had to evolve its own procedure for the consenting process.

In order to carry out a detailed safety analysis and review, ACPSR constituted thirteen specialist Working Groups to address various aspects of the plant like spent fuel handling and chopping, process instrumentation, conversion laboratory, electrical systems, mechanical systems, process equipment, piping, services and auxiliaries, civil engineering of critical structures, criticality safety, health physics, waste management, industrial safety and fire safety. The Advisory Committee also reviewed the safety of KARP under total power failure scenario, analysis of design basis accidents and hypothetical upper limit accidents, safety classification of the buildings based on radiological consequences, earthquake resistant design of safety related structures and the Technical Specifications for operation for KARP.

After the review by ACPSR, AERB issued the authorization for storage of MAPS spent fuel bundles in KARP fuel storage pool in May 1997, Cold Uranium Commissioning Runs in April 1998 and authorization for Hot Commissioning Runs in September 1998.

Advanced Fuel Fabrication Facility

BARC installed an Advanced Fuel Fabrication Facility (A3F) at Tarapur in 1989 for fabrication of mixed oxide (MOX) fuel sub-assemblies for Tarapur Atomic Power Station (TAPS). AERB constituted an ACPSR with K. Balaramamoorthy, the then Chief Executive, NFC to carry out the safety review of the project. ACPSR had several detailed discussions on the engineered safety features of the plant to ensure the containment of radioactivity during plutonium powder handling operations, criticality safety etc. Based on the recommendations of this Committee, AERB issued the authorization for regular operation of A3F in 1994.

Waste Management Facilities

In order to treat the radioactive waste arising from the operation

of the research reactors, reprocessing plant and other radioactive facilities in Trombay, BARC had established a few waste treatment plants. Similarly, Tarapur site also had waste treatment plants to take care of the wastes arising from operations of TAPS and PREFRE. All these plants came under the review of SARCOP from 1987 onwards. BARC in 1993 sought the approval for the construction of the following waste management projects

a) Solid waste Storage Surveillance Facility (SSSF)-Tarapur

b) Away From Reactor-Waste Management Facility at Tarapur

c) Waste Immobilisation Plant (WIP), Trombay

AERB constituted an ACPSR with M.K.T.Nair, Former Director, Nuclear Waste Management Group, BARC as Chairman. The Committee was assisted by six Specialist Working Groups, constituted for detailed review of the safety aspects of different systems/ areas, viz., civil engineering and structural safety, process safety and instrumentation, mechanical systems including remote handling and services, electrical systems, health physics and environmental safety, industrial and fire safety. Based on the review of this Committee, authorization was issued for storage of vitrified waste product canister overpacks in SSSF. The review process of these projects was handed over to BARC Safety Council in June 2000.

The rich experience gained by AERB staff through design and operational safety review of the various BARC facilities was extremely useful for their safety review work at the nuclear power plants and other nuclear fuel cycle facilities. It also helped in establishing a strong link between the staff of AERB and BARC that proved to be of great value as BARC is a strong multi-disciplinary organization with high level of expertise and it is the most important technical support organization of AERB.

Major Inputs by: *A. R. Sundararajan, T. N. Krishnamurthi and R. K. Chugha*

4

PHWR BASED NUCLEAR POWER PROJECTS

AERB was still in its nascent stage, when construction of the fourth nuclear power station in the country was coming up, intended for installation at Narora. However, the safety review of the design of the PHWR units NAPP-1&2 was being carried out by the Narora Design Safety Committee (NDSC) constituted in 1974 by the Power Project Engineering Division (PPED), the precursor to NPCIL. It is important to note that this project marked not only the development of first Indian design of 220 MWe PHWR units but also the start of the safety review at design stage itself. The designs and equipment of TAPP-1&2, RAPP-1&2, and MAPP-1&2 were largely based on imported units from USA and Canada respectively. The NDSC evaluated the plant based on its design basis reports (DBRs), safety analysis report (SAR) and design manuals. Its mandate extended to the review of commissioning (from hot conditioning of primary heat transport system upto completion of phase-C commissioning tests). NDSC reported its findings and recommendations to DAE-SRC.

By the time AERB was sufficiently staffed for starting its review activity (mid 1984), it took upon itself the continuation of safety review of NAPP-1&2 projects, in addition to the ongoing safety reviews of operating plants (TAPS-1&2, RAPS-1&2, MAPS-1&2). Both NDSC and DAE-SRC were required to report their findings and recommendations to AERB for confirmation. AERB organized its activities expeditiously in order to fulfill its mandate consistent with the prevalent world practices.

Around 1988, IAEA had issued its safety standards for assuring safety in nuclear installations, in forms of safety codes and associated safety guides. The IAEA Safety Code on "Governmental Organization for Regulation of Nuclear Power Plants", Safety Series No. 50-C-G, issued in 1988 provided the requirements for any regulatory body to organize its review and monitoring activity. Based on the various

international practices being adopted by USNRC, CNS, etc., AERB instituted a three-tier structure for safety review of nuclear power plant/projects (NPP) spanning major consenting stages.

Regulatory Documents for Consenting

M. R. Srinivasan, Chairman AEC called a meeting in January 1988 of senior officers of NPCIL and AERB on a request from A. K. De, Chairman AERB. The meeting highlighted the need for arriving at procedures in issuing authorizations at various stages of the project. Based on the inputs gathered at this meeting, the AERB Safety Manual on "Governing Authorization Procedure for Nuclear Power Projects/Plant (AERB/SM/NSD-3) was published in 1989. This seminal document provided a firm basis for defining regulatory requirements and the rationale for their application and enforcement. It clearly defined the stages requiring regulatory clearances as "Authorizations" and identified the required documentary submissions that were necessary for assessing the level of safety for the concerned authorization. This document also provided for interim clearances, within the overall activity of commissioning.

This was also the time when the impact of the Chernobyl accident was being felt by all the nations with respect to management of severe reactor accidents. After detailed review and extensive discussions with NPCIL, AERB issued two documents, namely, AERB Safety Manual on "Site Emergency Plan for Nuclear Installations (AERB/SM/NSD-1)", issued in 1986/87 and AERB Safety Manual on "Off-site Emergency Plan for Nuclear Installations (AERB/SM/NSD-2)", issued in 1988. For many years, the foregoing three manuals formed the basis of AERB's requirements with regard to regulatory review for projects and preparation of emergency preparedness plan.

In 2000, AERB issued the AERB Safety Code on "Regulation of Nuclear and Radiation Facilities (AERB/SC/G)", which defined the requirements of AERB's consenting process, its inspection

provisions for verifying compliance with conditions of the consents, and enforcement actions for nuclear and radiation facilities. For nuclear power plants, the term "Consent" replaced the earlier term "Authorization". A Safety Guide on "Consenting Process for Nuclear Power Plants and Research Reactors (AERB/SG/G-1)" was issued in 2007 in the light of experience of review and consents given earlier by AERB. This document besides specifying the consenting procedure, the assessment process, the documentary submission at each stage and the lead time for the submissions, also provided guidelines on preparation of various documents such as safety assessment report, safety evaluation report etc.

AERB has issued a series of safety codes and safety guides since its inception. These safety documents have been, by and large, non-prescriptive, and have been carefully drafted to be compatible with existing established professional codes of practice applicable to nuclear power plant systems like ASME, RCC series, etc. However, AERB also issued civil engineering standards for nuclear power projects, to bridge the gaps between Indian civil engineering codes of practice and requirements for nuclear structures with respect to design and inspection. For projects such as Kaiga-1&2 and TAPP-3&4, these standards appeared midway in the design and construction process. The ensuing review work compelled the designers to make mid course alterations to comply with prescriptive technical requirements of these standards.

Formation of Safety Review Committees

Once the required documents for getting the relevant Authorization/ Clearance are submitted by NPCIL, AERB constitutes a Site Evaluation Committee (SEC) for purpose of siting stage clearance and a Project Design Safety Committee (PDSC) for subsequent stages, drawing technical design experts from the respective fields. While Site Evaluation Report (SER) forms the basic input for site evaluation, documents like Design Basis Report and the Preliminary Safety

Analysis Report are the basic inputs to PDSC besides all the technical documents that are asked by the committee as and when needed. The PDSC so constituted would review the design from safety point of view and can recommend additional safety features, if required. The committee ensures compliance with the AERB codes and guides as applicable and also with the IAEA documents, as applicable. The committee liaises with the Civil and Structural Engineering Design Committee of AERB for review of Safety of Civil structures, in making its overall recommendation to AERB.

Three-tier Review Process for Consenting

In principle, the first level review is conducted by either the Site Evaluation Committee (SEC) and the PDSC. These committees are constituted from AERB and departmental organizations (NPCIL, IGCAR, BARC) with administrative and technical support by AERB. These committees, at times also constitute specialized working/ specialist groups, sub-committees and task-forces to examine any specific issue that could be referred to them. The group members are drawn from in-house and external organizations. These committees meet at frequent intervals to examine submissions, test results, etc. and present their recommendations for confirmation by the next level committee, viz., the Advisory Committee for Project Safety Review (ACPSR) as per the requirements. The ACPSR, includes experts from academic institutions viz. IITs etc, the Central Boiler Board, representatives from the Ministry of Environment & Forests and the representative from the Central Electricity Authority apart from experts from BARC, IGCAR, NPCIL and AERB.

There is a common ACPSR for all nuclear power projects of a given type. (i.e., one for PHWR & FBR and the other for LWR). The ACPSR conducts its review for confirmation only when the review by SEC and PDSC is complete and their recommendations are available. While ACPSR is free to examine any issue in its entirety, it generally provides assurance to AERB that the due process of safety review

have been conducted, and that PDSC concerned has followed safety norms and standards in its deliberations. Additionally, ACPSR performs a vital regulatory assignment of involving external experts to assure objectivity in its deliberations.

Recommendations of SEC and PDSC confirmed by ACPSR are presented to AERB for further action. Generally, these recommendations are for grant of a requested consent/clearance. However, these review committees are empowered to recommend stoppage of any work on a project that they feel could jeopardize safety.

The major stages of AERB's consenting process for Nuclear Power Projects are Siting, Construction, Commissioning and Operation.

Siting Consent

Siting consent generally is a single step action, that is, a site is accepted at one go if AERB's requirement for siting are met. It requires a general review of design basis and the Site Evaluation Report (SER) incorporating site characteristics and basic design information submitted by the applicant. In addition, Design Basis Information document is also reviewed in so far as it is related to siting .

Construction Consent

At this stage, the overall design safety, including plant layout, plant buildings/structures, reactor systems, electrical systems, instrumentation and control systems, accident analysis, radiation protection, waste management system, reactor auxiliaries, etc are reviewed. AERB has a unique method with respect to Consent for Construction. Construction Clearance can be given in a single stage or in 3 sub-stages, if utility so desires. These sub-stages are: (i) Excavation for main plant area, (ii) First pour of concrete for structures important to safety and (iii) Erection of major equipment. This stage requires review of Preliminary Safety Analysis Report (PSAR), supplementary Design Basis Report (DBRs), QA during design and

construction and construction schedule. The review process has been formulated accordingly. Experience with splitting of construction consent in this manner has been satisfactory as it facilitates early start of construction activities at site. Also, it facilitates site work concurrently with safety review.

Commissioning Consent

AERB grants regulatory clearance for several intermediate stages/ phases starting from hot conditioning up to raising reactor power to 100% rated power. Typically there are ten sub-stages for PHWR based NPPs. These intermediate stages are clearly identified and for certain important stages like first approach to criticality, full power operation etc, approval by ACPSR and the Board are mandatory. But for all stages, approval by PDSC and Chairman AERB are required.

Operation Consent

This stage involves routine power operations at rated power. Detailed test reports are reviewed to ensure that the unit is capable of sustained operation at rated power. The review of Final Safety Analysis Report (FSAR) which is the final version of PSAR incorporating as-built design and commissioning results had to be completed before the consent for operation is given. The objective of FSAR is to present the predicted response of the plant to postulated initiating event, to demonstrate with reasonable assurance that the Unit has capacity for preventing accidents and/or mitigating their effects sufficiently to preclude undue risk to public health and safety. AERB issues consent for continuous operation at rated power for a specified period like 5 years. Well before expiry of this period, NPCIL needs to submit the application for renewal of consent. The renewal of consent would be based on periodic safety review as specified by AERB in its Safety Guide AERB/SG/O-12.

It is recognized that the depth of review for each stage may be different depending upon the type/design of an NPP. This graded

approach is aimed at more efficient and optimized utilization of available resources. Design features for the purpose of the review, are classified as follows:

- Standard/proven design being repeat (e.g. Kaiga-1&2/RAPP-3&4)
- Design evolved from standard design (improved design/proven design, e.g. TAPP-3&4)
- First of its kind engineering i.e. new design (e.g. use of PLC, software based design PFBR/AHWR)
- Imported reactor (VVER-KKNPP)

While basic philosophy and principles of regulatory review had been clearly established long before, the method of review and assessment however has been unique for each Committee depending upon the category of the reactor design. The formulation and publication of the regulatory documents strengthened the review process and facilitated conducting consenting process comprehensively and objectively. The experience gained, the expertise built and the knowledge acquired from these reviews have clearly enhanced the decision-making capability of AERB over the years.

Projects Review: Certain Highlights

Narora Atomic Power Station Unit-1&2 (NAPP-1&2)

The process of review of NAPP was most intensive in terms of man-hours invested. This was due to the evolving nature of Indian PHWR design, and also as a consequence the evolving nature of regulatory review. Narora Design Safety Committee (NDSC) chaired by S. K. Mehta, the then Director, Reactor Group, BARC held 208 meetings from 1986 till NAPS became operational in 1992. Its findings and recommendations were considered and confirmed in meetings of ACPSR.

In the course of NAPP review, several important questions cropped

up, and these were addressed and resolved by joint discussions with NPCIL and BARC engineers. Some of the safety improvements made after the safety review include the following.

- Incorporation of Gravity Addition of Boron System (GRAB) for meeting requirement of sub-criticality margin during Station Black Out (SBO) condition. This feature was needed and used during the Fire Incident in 1993.
- Provision for reactor trip on "Low coolant flow in adjuster rods"
- Actuation of both shut-down systems on "More than one Secondary Shut-down System (SSS) bank not available"
- Provision of reactor trip on "More than one rod of Primary Shutdown System not in parked position"
- Provision of reactor trip on "No primary coolant pump/ shut-down cooling pump running"
- Provision of reactor Setback on "Emergency Core Cooling System (ECCS) in blocked condition with primary heat transport system temperature > 101°C"
- Delay in starting of closed-loop Primary Containment Filtration and Pump Back system (PCFPB) was incorporated based on results of thermal analysis of charcoal filters under accident conditions
- Provision for reducing compressed air ingress into boxed up containment
- Backup Nitrogen cylinders to compressed air storage tanks of air locks to maintain containment integrity under SBO condition.
- Incorporation of seismic monitors and seismic trip
- A thermo-siphon test was conducted on the reactor during commissioning phase to demonstrate adequacy of residual heat removal capability under SBO
- Programme for monitoring of position of garter springs around coolant channels and relocation of displaced garter springs to their designed locations

- Emergency Power Supply was found to be insufficient to meet all loads under certain Anticipated Operational Occurrences and Design Basis Events. Hence, a sequential loading scheme was evolved to meet these requirements
- Neutron shielding for the fuelling machine maintenance area was augmented by providing thermal neutron absorber materials on roll-on shields
- Design provision for purification of moderator under reactor shutdown, using boron saturated ion exchange columns.

Most of these modifications/improvements became an integral part of standard design that was repeated for future reactors.

Kakrapar Atomic Power Project Unit-1&2 (KAPP-1&2)

For Kakrapar Atomic Power Projects-1&2 (KAPP-1&2), DAE-SRC had constituted a Kakrapar Design Safety Committee (KDSC) in 1985. KDSC was initially chaired by S.K. Mehta then by S.C. Mahajan from 1992. It held 115 meetings from 1987 till KAPS became operational in 1996. Its findings and recommendations were considered and confirmed in meetings of ACPSR.

Testing of the high-pressure coolant injection as a part of the Emergency Core Cooling System (ECCS) showed deficiencies during commissioning. These deficiencies required modifications to procedures related to operation and surveillance of the ECCS. In view of similarities in their ECCS designs, these procedures were evolved, tested and applied to KAPP-1&2, NAPP-1&2 and also to RAPP-1&2 and MAPP-1&2 when high pressure ECCS was retrofitted as a part of safety upgradation during en-masse replacement of coolant channels.

In 1994, Kakrapar experienced unusually heavy rain for about 15 hours leading to flooding of KAPP site. At that time, KAPP-1 was operational but under shutdown state, and KAPP-2 was under commissioning. Water entered the turbine building basement, pump house and cable tunnels from turbine building and the switchyard.

This extensive flooding jeopardized the functioning of several systems important to safety. The incident was investigated by a committee constituted by NPCIL, and its report was reviewed by AERB. Procedures were drawn up for proper drainage of rain and flood waters at KAPP-1&2. The cause of this flooding event was due to clogging of discharge sluice gates of the nearby Moticher lake into Tapti river. As a result of this event, administrative measures were evolved for assuring adequacy of draining Moticher lake by the local authorities.

Following this the flooding potential at all operating power plants was re-assessed. Where such potential was determined, embankments were mandated around all structures of safety importance. In RAPP-1&2 a 'flood' DG was installed at higher elevation. For projects, adequate elevation of structures important to safety was mandated to avoid hazards of flooding.

The other important recommendations made during the safety review include the following.

- Requirement of continuous re-circulation flow instead of as-designed periodic purge flow of Annulus Gas Monitoring System was specified. Also, proper action-plan in case of development of leak in coolant tube or calandria tube was developed.
- Qualification and validation of software of Programmable Digital Comparator System (PDCS)

Kaiga Atomic Power Project Unit-1&2 (Kaiga-1&2) and Rajasthan Atomic Power Project Unit-3&4 (RAPP-3&4)

Project Design Safety Committee for Kaiga-1&2 (PDSC-Kaiga-1&2) was constituted in June, 1988. Rajesh Chandra, the then Head, RTD, BARC chaired this Committee for a very short duration. Later V. Venkat Raj, the then Director, HS&E Group, BARC and M.K. Ramamurthy, IGCAR chaired this Committee. The same committee carried out the safety review of RAPP-3&4 as the designs were identical for both

the projects. However, separate meetings were held whenever site specific issues of RAPP-3&4 were discussed in the early stages of review. PDSC-Kaiga-1&2 held 395 meetings until Kaiga-1&2 and RAPP-3&4 became operational.

Authorization for Siting for Kaiga project was formally given by AERB in 1991, after the site data had been examined and accepted by AERB's Site Evaluation Committee (SEC), and was confirmed by AERB's Advisory Committee for Site Evaluation (ACSE). This was the first site for nuclear power projects that was formally assessed by AERB for acceptance of the site. The earlier sites had been selected and accepted before constitution of AERB.

After an in-depth review of operating experience of NPPs in 1995, AERB recommended automatic actuation of the GRAB system. Conseqently a dedicated, process-independent Liquid Poison Injection System (LPIS) was introduced at all power reactors wich came after KAPP.

In that review of 1995, AERB also concluded that all nuclear power plants should have full-scope training simulators for training and retraining operators for coping with off-normal and emergency conditions. This was necessary to comply with the prevalent international practices, in the aftermath of Chernobyl accident. A training simulator was installed at Kaiga, though it had some limitations.

Some of the safety improvements made after the safety review include the following.

- Improvements in plant layout towards housing of safety related equipments/components in Safe Shut-down Earthquake qualified buildings
- Design provision of seismically qualified water storage at site to facilitate reactor decay heat removal at least for seven days

- Provision of Meteorological towers, Micro-Meteorological Lab and SODAR facility at site for activity dispersal studies.
- Alternate road for evacuation under postulated emergency condition
- Separation of safety related and non-safety related portions of PDCS
- Requirement of on-line testing facility, channel-wise, all reactor trip parameters
- Preparedness of RAPP-3&4 against the release of H_2S from HWP, Kota

Delamination of Internal Containment Dome of Kaiga Atomic Power Project

During the construction of Kaiga Unit-1, a major safety issue cropped up in 1994, when a large portion of concrete from the undersurface of the inner containment dome in Kaiga Atomic Power Project (Kaiga APP) Unit-1 fell down unexpectedly. The delamination of concrete from the undersurface had occurred during tensioning of prestressing cables . Nearly 40% of the surface area and the material which had fallen was estimated to weigh about 130 tons. Fortunately there was no loss of life or damage to any equipment except some minor injuries to fourteen contractor workers.

AERB sent an inspection team led by V. N. Gupchup, Pro Vice-Chancellor, University of Bombay and Chairman of Civil Engineering Safety Committee (CESC), along with P.C.Basu, Head Civil Engineering Section, AERB. Based on the initial evaluation report from the inspection team, AERB directed NPCIL to immediately suspend all civil construction activities related to the Inner Containment Structures (wall and dome) of Kaiga Unit-2 and Rajasthan Atomic Power Project (RAPP) Units-3&4. In addition, NPCIL was instructed not to take up any civil construction activity in the entire Reactor Building of Kaiga Project, Unit-1 without AERB clearance.

To carry out an in-depth review of all the issues involved and to

ascertain the root cause for the incident AERB appointed a senior level Experts Committee chaired by V.N.Gupchup. The Committee observed that prestressing cables were placed at close spacing in certain zones, particularly near the steam generator openings, causing excessive loading during the pre-stressing operation. This had resulted in delamination and collapse of a portion of the underside of the inner containment dome.

As a result of the investigation, a number of recommendations were made for re-engineering of the delaminated dome. Some of the major recommendations related to design improvements were

- to minimize the induced radial tension in the transition zones, the normal dome thickness to be increased gradually to the higher value of thickened portion around the SG openings
- to maintain stresses induced due to applied loads within allowable values specified in the codes
- to introduce radial reinforcement
- to avoid congestion and
- to take care of the constraints imposed in the design due to the construction practice adopted.

The Committee also recommended that for all design work including drawings and detailing, checking should be carried out by an independent peer consultants or by in-house experts. The Committee also advised implementation of appropriate quality assurance (QA) programme in design and construction.

The containment dome was successfully re-engineered and constructed. A number of changes were made in the original design based on the outcome of the investigation, safety evaluation of the re-engineered design and mock-up studies. The rehabilitated containment structure was accepted after successful proof test for structural integrity and integrated containment leakage rate test prior to commissioning.

Tarapur Atomic Power Project Unit-3&4 (TAPP-3&4)

A proposal to build a 500MWe PHWR was made in 1985. DAE-SRC constituted a Design Safety Committee (DSC-500) which had conducted 47 meetings from 1985 to 1990 to review the generic design of 500MWe PHWR for inland and coastal site. AERB constituted a Site Evaluation Committee in 1987 chaired by S.D. Soman to study the site evaluation reports of TAPP-3&4 for location of 2 x 500 MWe PHWR Plants. The site evaluation report of the Committee was reviewed by AERB Advisory Committee for Site Evaluation (ACSE). Based on the recommendations of the site evaluation committee and ACSE, AERB granted clearance in 1989. For the first tier review process, AERB constituted Project Design Safety Committee (PDSC) in 1990. PDSC had conducted a total of 387 meetings for this project. Anil Kakodkar, the then Director, RDDG, BARC and later L.G.K.Murthy, the then Director, H&SE, NPCIL chaired the Committee. Its findings and recommendations were considered in meetings of ACPSR.

Though AERB had granted construction consent for the TAPP-3&4 in 1993, NPCIL did not go ahead with construction immediately. After securing a revalidation of the construction consent in 1998, construction activities were started in 2000. TAPP-4 achieved first criticality within 5 years of start of construction i.e. in March 2005. TAPP-3 achieved first criticality in May 2006. TAPP-3&4 is an evolved design and has a number of new systems vis-à-vis earlier built 220MWe PHWRs; exhaustive safety review was performed at all stages of regulatory consents. Safety Committees and their specialist groups spent more than 8000 man-days in formal meetings during design safety review of this project.

During review of design and commissioning, a few issues of safety importance were identified. Some of the important recommendations made during the safety review include the following.

- Actuation of Moderator Liquid Poison Addition System (MLPAS) on failure (slow drop) of 2 or more shut-off rods

- Incorporation of logic to actuate both shut down systems on "low pressure in helium tank of shutdown systems # 2"
- Incorporation of third diesel engine driven fire water pump
- Provision for on-line testing of shut off rod clutch through partial drop of rod.
- Modifications to eliminate the problem of unwarranted actuation of Shut-down System No.2 due to single failure.
- Design changes to eliminate failure in Reactor Regulating System (RRS) due to halting of Output Processor Node (OPN) / Input Processor Node (IPN) resulting in reactor trips.
- Based on RRS stability analysis, cycle timings of IPNs & OPNs and control system gains were reduced appropriately to improve the system stability and avoid reactor trips on "High Bulk Neutron Power" due to occasional development of power oscillations in TAPP-4.
- Incorporation of backup Carbon Steel (CS) liner to SS liner of spent fuel storage bays (SFSB) to protect SS liner from corrosion due to chloride laden sub-soil seepage water rising along the rock-anchors.
- Review of design basis flood level at the site in view of experience at Kalpakkam during the event of Tsunami in December 2004.

Kaiga Generating Station-3&4 (KGS-3&4) and Rajasthan Atomic Power Project -5&6 (RAPP-5&6)

KGS-3&4 and RAPP-5&6 are "Repeat Design" of KGS-1&2 and RAPS-3&4 respectively with some differences in design and plant layout. PDSC was constituted for these projects in 2001 under the Chairmanship of S.M. Lee. The design safety review process for KGS-3&4 and RAPP-5&6 was focussed essentially on review of design differences in comparison to earlier built plants (viz. KGS-1&2 and RAPS-3&4), feedback from operating experience and observations made during regulatory inspections. KGS-3 achieved first criticality on February 26, 2007 and the unit was synchronized to the power grid in April 2008.

Kakrapar Atomic Power Project-3&4 (KAPP-3&4)

NPCIL is carrying out detailed design of 700MWe PHWR utilizing the experience of 540MWe PHWRs, TAPP-3&4. NPCIL has proposed to install two PHWR units at the Kakrapar site near the operating 220 MWe Units KAPS-1&2. Safety review towards granting siting consent for these Units is in progress. NPCIL has also submitted an application seeking clearance for site excavation, as the first sub-stage of construction consent. Accordingly, PDSC-KAPP-3&4 under the Chairmanship of A.K. Ghosh has started the design safety review.

Major Inputs by: *S.P. Singh, R.I. Gujrathi, P.C. Basu, S.A. Khan, S.T. Swamy, R.P. Gupta and V.R. Dhotre*

5

KUDANKULAM NUCLEAR POWER PROJECT

The three-stage power program of India based on Bhabha's vision which was aimed at utilizing the natural uranium in the first stage and the abundantly available thorium in the final stage did not rightly include the deployment of light water reactors (LWRs) requiring enriched uranium. But then around the year 1987 to meet the increasing demand for energy, DAE decided to go in for large capacity (1000 MWe) reactors. DAE opted to go in for Pressurized Water Reactors (PWRs) in view of the large worldwide operating experience for these reactors. After detailed evaluation, VVER type Russian reactors of 1000MWe capacity were chosen to be located at the earlier selected site of Kudankulam, near Kanyakumari in Tamilnadu. VVER–412 specially designed for India was a slightly modified version of VVER–320 which met all the licensing requirements of the Russian regulatory body, then called as Gosatomnadzor (GAN).

For AERB, which had just then completed the establishment of a well structured scheme of regulatory review for the PHWR type of reactors, the induction of VVERs posed a big challenge for many reasons. Even though the plant had a proven design which was licensable in the Russian Federation, AERB needed to carry out detailed safety review as part of consenting process for construction, commissioning and operation. For the first time an LWR design of a high capacity was being reviewed. AERB did not have its own codes and guides for PWRs and hence had to use relevant standards of IAEA and other international standards.

Cooperation between AERB and Russian Regulatory Body

It was well recognized that intense interaction between AERB and GAN, the Russian regulatory body would be essential to ensure a smooth and proper process of licensing the Kudankulam Nuclear Power Plant (KKNPP). First formal contacts between AERB and

GAN began during November 1988, when a team of Russian officials from GAN visited India and exchanged information with AERB. Subsequently, following a brief period of lull due to break up of USSR, project activities at KK did not start. Contacts restarted between AERB and GAN from 1999 onwards when a team of officials led by G.R. Srinivasan, the then Vice-Chairman, AERB visited the Russian Federation and had discussions with the GAN authorities. As desired by GAN, a formal agreement for cooperation in safety and regulatory areas was formulated during 1999. During the year 2001, a team of AERB officials led by S.K. Mehta, Chairman ACPSR-LWR visited the Russian Federation to have a direct discussion with the principal designers and visit the prototype plant Balakova Unit-4. During the year 2002, action was initiated by AERB to finalize the agreement for cooperation between the regulatory bodies, as the construction was in progress and the necessary regulatory clearances were being granted to the KKNPP. A team led by Yuri G. Vishnevsky, the then Chairman, GAN visited India in January, 2003. During the visit, he and S.P. Sukhatme, Chairman, AERB signed the final agreement on January 15, 2003.

The agreement provided for cooperation in the field of safety regulation in the peaceful uses of nuclear energy. The regulatory agencies agreed to familiarize themselves with the practices followed by the counterparts to ensure the safety of nuclear power plant personnel and the public and protection of the environment against any possible harmful effects of radiation. Mutual exchange of information and experience would cover regulatory documents used for design and for all subsequent phases of the nuclear power project, methodology adopted to validate computer codes and comparison of results against international verification programmes and requirements for qualifications, training and licensing of power plant personnel. Method of acceptance of design and its analysis with regard to seismic stability and environmental qualification, methodology of selection of materials for critical components, regulatory positions on

other matters related to the safety of nuclear power plants are some of the other issues, where AERB and the Russian regulatory authority would exchange information and experience.

In February 2005, a workshop was organized by AERB on "Information Exchange on Nuclear Safety" with participation from Russia and India. Indian side was represented by Members of ACPSR-LWR and the Specialist Groups involved in the safety review of KKNPP consisting of experts from BARC, NPCIL and AERB. A second workshop of similar nature was organized by AERB in March 2008. In order to acquire adequate knowledge in VVER Design, Safety and Operation, a few AERB officials participated in the licensing and training process along with NPCIL engineers in Russian Federation.

Design Safety Review of KKNPP

NPCIL had prepared in 1989, the Technical Assignment (TA) document for KKNPP covering the scope, broad design specifications and safety requirements including those of AERB. The TA was reviewed by the Project Design Safety Committee (PDSC-KK) constituted by AERB with A.K. Anand as its Chairman and its comments were also taken into account in revision of TA. AERB constituted an Advisory Committee for Project Safety Review for LWRs (ACPSR-LWR) in October, 1994 with S.K. Mehta as Chairman. This Committee had various specialist/expert members from both DAE as well Non-DAE organizations.

The Preliminary Safety Analysis Reports (PSARs) of KKNPP, Topical Reports and QA documents were submitted to AERB in 1999, which formed the primary basis for review and assessment by AERB.

The Safety Review of Pressurized Water Reactor (PWR) was being carried out in AERB for the first time. In view of this, AERB decided to adopt a somewhat different review scheme from the one given in "Governing Authorisation Procedure for Nuclear Power

Project/Plant (AERB/SM/NISD-1)". In place of PDSC-KK which was earlier set up during 1989, a Co-ordination Group (KK-CG) was constituted in January, 2000 and many Specialist Groups were formed consisting of experts drawn from AERB, NPC and BARC for review of the PSAR Chapters and some specific topics. Since then the role of PDSC has been performed by KK-CG along with the Specialists Groups (SGs).

NPCIL forwarded various PSAR chapters to AERB between March, 2000 and March, 2001. The chapters have been written as per the Format of USNRC-RG 1.70. In the absence of applicable AERB Codes/ Guides for PWRs, relevant standards of IAEA and USNRC were used during the review process. The AERB Codes and Guides were also referred for the applicable issues. Compliance with the Russian Normative Technical Documents (NTDs) and TA was ensured. GAN review comments on PSAR chapters were also considered during review by AERB. Further, in order to gain confidence, limited in-house design check exercises were also conducted.

During the course of review of PSAR Packages, the specialist groups also had discussions with the concerned experts of Russian Federation towards resolving certain design issues. In order to acquire thorough knowledge of VVER-1000 design, safety and operation, some AERB officials were also trained in the Russian Federation during the period 2003-04.

Regulatory Clearances

Siting

AERB issued clearance for siting of KKNPP with two VVER-1000 MWe units, at Kudankulam in November, 1989. This was based on review of the report of the Site Evaluation Committee (SEC) chaired by S.K. Mehta followed by review by Advisory Committee for Site Evaluation (ACSE) chaired by S.M.Sundaram and finally by the Board of AERB.

Construction

A Workshop on "Consenting Process for NPPs" was organized in July, 2001 by AERB and various aspects related to consenting process were deliberated with experts in the field and representatives of Utility. One of the recommendations of this workshop was to carry out review concurrently with the progress of construction activities. Accordingly, the various submissions to AERB were staggered and the clearances were issued in three sub-stages viz. Excavation, First Pour of Concrete (FPC) and Erection of Major Equipment (EE).

Excavation

The clearance for excavation was given in October, 2001. The clearance was issued subject to compliance of stipulations like restriction on surface mining of limestone within Exclusion Zone and Sterilized Zone and design of embankment for water storage reservoir as ultimate heat sink.

First Pour of Concrete (FPC)

SGs, KK-CG and ACPSR-LWR had reviewed the required PSAR chapters prior to issue of recommendations for FPC in March, 2002. Also, sample civil engineering design verification checks for reactor building were taken up. Also, safety review of design of metallic liner for Inner Containment Wall (ICW), soil-structure interaction for raft under seismic event, seismic analysis models for reactor building, accidental torsion effects under seismic event, core catcher design etc was carried out.

Clearance for First Pour of Concrete was given in further sub-stages as follows:-

- FPC for Reactor Auxiliary Building (RAB) of Units-1&2- March 22, 2002
- FPC for Reactor Building (RB) of Units-1&2 was given on April 9, 2002, after establishing 28 days compressive strength of concrete blocks – i.e., the Clearance for the bottom Raft Portion of reactor building (non-hermetic portion) was given

- Clearance for Construction of +5.4 m El slab was granted on April 23, 2003.
- Permission for Installation of Core Catcher Vessel and Construction Beyond +5.4m up to 17.0m Elev. for RB was given on November 27, 2003 after satisfactory review of design safety aspect of Core Catcher and after satisfactory resolution of issues that emanated from sample civil engineering design checks at identified locations of ICW.
- After satisfactory review of liner details around major penetrations (equipment, emergency and personnel airlocks), permission for construction beyond 17.0 m Elev. of RB was given on June 15, 2004

The above can be seen as an example of concurrent regulation without compromise with safety or affecting the project schedule.

Erection of Major Equipment (EE)

Specialist Groups, KK-CG and the ACPSR made a number of important observations during review of design related PSAR Chapter (Rev-1). Subsequently, NPCIL submitted PSAR (Rev-2) progressively from January, 2002. Nuclear Project Safety Division (NPSD) carried out the detailed review of these packages (Rev.2) to ensure compliance with the comments/ recommendations made on Rev-1 and the important issues/observations were referred specifically for consideration of respective SGs. Also, based on this review, salient pending issues, those need to be resolved prior to authorization for EE, were identified and referred to NPCIL. NPCIL submitted the responses on these pending issues in February, 2005 and these were also considered during review of PSAR packages (Rev.2) by respective SGs and the ACPSR. On the basis of the responses provided and commitment to provide the details on certain specific issues, in a progressive manner, Clearance for EE was granted for Unit-1 in August, 2006 and for Unit-2 in June 2007.

For PWRs, erection of Reactor Pressure Vessel (RPV) is considered as start of EE stage as per the AERB Guide AERB/SG/G-1 on 'Consenting Process for Nuclear Power Plants and Research Reactors'.

Salient Observations from the Review

During the course of design safety review of KKNPP, a number of challenging issues emanated. Some examples of such issues are as follows.

Safety Classification of System, Structures and Components (SSCs)

The philosophy of safety classification, adopted in KKNPP was different from that of IAEA/AERB. The Russian philosophy is element based whereas the IAEA philosophy is system based. During the course of discussion, it was noted that the Russian classification system was more conservative and a direct correlation with IAEA classification could not yield any additional improvement in safety.

Containment Liner

The containment liner design, especially the areas around penetrations, was reviewed in detail to ascertain the integrity of the liner under normal operating conditions and accident conditions. The effect of failure of anchor, fatigue life and deformation of the liner surface after pre-stressing of primary containment were specifically seen.

First Of A Kind (FOAK) Systems

The design employs a number of systems and Engineered Safety Features (ESFs) of novel design. One of the salient features of the design is incorporation of 'Four Train Safety Systems', thus increasing reliability. Another important feature is provision of both active and passive systems to prevent accidents and/or to mitigate their consequences. Passive systems such as Passive Heat Removal System (PHRS), Second stage ECCS accumulators, System for retaining and cooling of molten core (Ex-vessel Core Catcher) etc. have been provided for catering to BDBA. Quick Boron Injection System (QBIS) has been incorporated in addition to the active Emergency Boron Injection System (EBIS) for catering to Anticipated Transients Without Scram (ATWS) situations. All such systems were asked to

be adequately justified by submission of details of developmental tests/analysis and relevant reports. NPCIL obtained reports on these aspects from the designers and these were reviewed. It was further stipulated that such systems should be tested, and demonstrated to meet their design intents during commissioning. Some of the salient observations on FOAK systems are given in subsequent paragraphs:

Sharing of Safety System

A safety system designed for long term recirculation during LOCA and decay heat removal (JNA) is used for multiple functions namely (i) to remove core residual heat following reactor shut down, (ii) to provide cooling of spent fuel pool water and (iii) to perform low pressure ECCS function during LOCA. The JNA system has 4 trains each of 100% capacity and the trains are physically separated and independent with regard to supporting systems like power supply, cables etc. The JNA system performs safety as well as normal operation functions. Also, HX of each train of JNA system is shared by one train each of three other safety systems namely (i) Containment Spray system, (ii) High Pressure ECCS and (iii) EBIS system.

The aspect of use of a safety system for multiple purposes and sharing of its equipment with other safety systems were reviewed in detail under Anticipated Operational Occurrence (AOO), Design Basis Accident (DBA) and Beyond Design Basis Accident (BDBA) conditions. Based on the review, the design approach has been accepted by AERB subject to incorporation of suitable surveillance requirements for these systems during operation.

Passive Heat Removal System (PHRS)

This system has been provided to reject decay heat of reactor core to outside atmosphere, during Station Black Out (SBO) condition lasting upto 24 hours. The system can maintain hot shutdown condition of the reactor, thus, delaying need for boron injection. PHRS has four independent trains, each with three air-cooled

heat exchangers located along the periphery on the outside of the secondary containment. Three trains are designed to provide 100% heat rejection capacity with reactor in shutdown condition i.e. 2% of reactor rated power. Specially designed air inlet/outlet dampers are provided across heat exchangers of PHRS for controlling air flow over these HXs. Experience with specially designed air inlet/outlet dampers is not available. Functional tests for damper opening/ closing/modulation on steam pressure signal during commissioning as well as periodic tests will have to be done.

Second Stage ECCS Accumulators

Emergency Core Cooling System (ECCS) has four sub-systems, namely (i) high pressure emergency injection system, (ii) first stage hydro accumulators, (iii) long term recirculation and decay heat removal system (JNA) and (iv) second stage ECCS hydro accumulators. Second stage ECCS hydro accumulators have been designed to supply borated water for core cooling. The design envisages decay heat removal during BDBA condition of LOCA with SBO for 24 hours when the system operates together with PHRS. Performance of the system and especially of proper functioning of the special check valves would be ascertained during commissioning phase.

Quick Boron Injection System

Two systems, EBIS and QBIS are provided which can individually make the reactor sub critical by adding concentrated boric acid solution during an ATWS condition. This system would be tested during commissioning to establish its effectiveness and to ensure its performance is as per the design intent.

System for retaining and cooling of molten core

An Ex-Vessel core catcher filled with specially developed compound (oxides of Fe, Al & Gd) is provided for retention of solid and liquid fragments of the damaged core, parts of the RPV and reactor internals under severe accident condition resulting in melting of core and

failure of RPV. The filling compound provides volumetric dispersal of the melt. It provides sub criticality of the melt and prevents it from spreading beyond the limits of containment. The filler compound has been developed to have minimum gas release during dispersal and retention of core melt. Cooling water can be supplied on top of core catcher from water storage inside the reactor building by opening of a remotely operated valve as per the accident management procedure. By design, accumulation of leaked out water from primary coolant system and ECCS provides cooling of core catcher vessel from outside without any need for operators' intervention. Appropriate surveillance requirements for this novel feature will have to be worked out and incorporated in Technical Specifications for Operation.

Departure from Nucleate Boiling Ratio (DNBR) Algorithm

An on-line measurement of DNBR and reactor trip on low DNBR has been implemented in KKNPP. Various aspects of this design are under review by experts in the field.

Un-bonded pre-stressing system for Primary Containment (PC)

Un-bonded pre-stressing system has been used in KKNPP for PC. This is the first time that such a system is being used in any NPP. In this system, a strand of seven ply wire is surrounded by HDPE sheath with grease packed between the strand and the sheath. A cable consists of 55 such HDPE sheathed strands placed inside a metallic conduit. The gap between the conduit and HDPE sheaths is filled by cement grout prior to tensioning of the cable. Grease and HDPE sheath reduce friction during tensioning. In this system cable tension can be monitored and re-adjusted if required and broken strands can be replaced during the life of the plant.

Based on review, many mockup tests were asked to be conducted to demonstrate effectiveness of various activities such as threading of HDPE sheathed strand, grouting of vertical and horizontal cables, re-threadability of strand etc. Full scale mock-ups were carried out

and required changes were implemented during installation of the system. Considering the use of HDPE as sheath around metallic strands, life estimation for HDPE was carried out by accelerated ageing tests at Indian Rubber Manufacturers' Research Association as asked by safety committees. The test result has indicated 62 years of life at service temperature of 33°C.

Containment Isolation System

The containment isolation system contains two sets of valves in series, one pneumatically operated and another electrically operated with relatively large time for complete closure on ventilation ducts. Incorporation of electrically operated valves for isolation and higher closure time was accepted considering redundancy in power supply schemes, diversity of valve actuators and safety analysis.

C&I systems

Emergency Protection and Engineered Safety Features Actuation System, have common neutron sensors. Implication of this approach could be that emergency protection system and both systems to cater to Anticipated Transient Without Scram situations i.e. EBIS and QBIS can fail simultaneously. However, after a detailed review this approach has been accepted considering that there are separate sensors for two sets of 2 out of 3 coincidence logic.

Turbine Missile Impact

During the review and subsequently during the regulatory inspection, it was seen that certain safety related structures/ buildings [Main Control Room (MCR), part of secondary containment wall], are coming under Low Trajectory Turbine Missile (LTTM) strike Zone. Initially adequacy of safety for LTTM was demonstrated using probabilistic approach, which was not accepted by AERB. Subsequently based on deterministic assessment it was confirmed that there would not be any damage to MCR and Secondary Containment wall would not get penetrated.

Reactor Pressure Vessel (RPV)

The original design of RPV did not contemplate welds in the core region. However, the vessel now used has two welds in the core region. The effect of lifetime neutron fluence on these welds was evaluated and found to be acceptable.

The regulatory review of Kudankulam Nuclear Power Project gave AERB an immense opportunity to upgrade its expertise in variety of areas. Adopting a different scheme of review process, AERB could effectively carry out the multi-tier review process in a time bound manner. Clearly the experience gained in this project will be of great help in taking up review of future reactors, a number of which are likely to be of LWR type.

Major Inputs by: *Deepak De, R.I. Gujrathi, S.K. Warrier, S.T. Swamy and S.C. Utkarsh*

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IGCAR FACILITIES

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

Siting for Reactor Research Centre (RRC)

Sarabhai was convinced of the need for a separate centre dedicated to the development of fast reactor programme. His proposal for the establishment of Reactor Research Centre (RRC) included apart from FBTR, other associated facilities like Reactor Engineering Laboratory (REL) for sodium technology, Radio Metallurgy Laboratory (RML) for

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

Beginning of Safety Review

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

Constitution of RRC-CWMF Safety Committee

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

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

Difficulties Faced During the Safety Review

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

SC and SARCOP was established soon after.

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

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

The commissioning of FBTR was done in phases- initially without

the steam generators, then with the steam generators connected to the secondary circuit with sodium alone on the shell side of the steam generator and later with water valved into the tube-side of the steam generators. As of date, the IGCAR-SC has held nearly 250 sittings, i.e. an average of 10 sittings per year.

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

Safety Review Benefits

IGCAR has benefited by the regulatory process, in terms of honing the analytical and experimental skills at IGCAR. For example, the core configuration changes for inducting MK-II and high Pu MOX fuel demanded extensive out-of-pile characterisation of these fuels by BARC and IGCAR. They also required revision of safety reports, calling for further safety analysis using latest available codes. While reviewing the results of high power engineering experiments carried out in 1994-95, SARCOP stipulated reconciliation of the test results with the analysis. This led to improved realistic modelling of thermal-hydraulic codes, especially in the areas of natural convection in

primary and secondary sodium systems. Similarly, based on SARCOP stipulation, the core temperature anomalies arising out of the stuck position of the Core Cover Plate were analysed by the Thermal Hydraulics section, using different codes. This has given the impetus to plenum hydraulic studies in IGCAR. Several thermal hydraulic problems have been studied in water models in the engineering halls.

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

Other IGCAR Facilities

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

a large inventory of sodium, AERB constituted another review Committee chaired by L.V. Krishnan, Safety Research Group. T.N. Krishnamurthi of AERB co-ordinated the review activities of these IGCAR facilities. Once operational, these facilities came under the review of IGCAR-CWMF Safety Committee and SARCOP.

KAMINI Research Reactor

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

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

While conducting experiments at low power, it was observed that reactivity variations were taking place due to lateral movement of fuel towards the reflector. Based on the recommendation of the PDSC a core cage was installed to prevent the movement of fuel and arrest any increase in reactivity. It was noted that the locations of pulse detectors and current channels, which were used for the first approach to criticality and low power experiments, needed to be changed subsequently for meeting the requirement of high power operation. It was also noticed that the performance of current channels was not consistent. The problem was identified to be due to degradation of insulation resistance of the detectors, caused by the ingress of

moisture through the connector. At low power levels of operation, there was a gross mismatch between the power read by the panel meter and the power calculated based on the measurement. The difference was due to incorrect application of bulk shielding reactor data for attenuation of neutrons in water. The PDSC stipulated that flux power calibration should be done at 10 W. This was done and the mismatch was brought within the acceptable range.

Prototype Fast Breeder Reactor (PFBR)

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

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

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

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

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

Demonstration Fuel Reprocessing Plant (DFRP)

IGCAR is setting up DFRP to process spent fuels of FBTR and PFBR. This is a forerunner of the reprocessing facility in Fast Reactor Fuel Cycle Facility (FRFCF) to be setup at Kalpakkam. It is divided

into two concrete cell facilities called Head End Facility (HEF) and Process Plant Facility (PPF). After the review of the documents on the civil design and the site by CSED and PDSC-DFRP, clearance for civil construction of HEF was granted in September 2006. Most of the civil construction and installation of equipment and piping for the PPF have been completed at the time of construction of Kalpakkam Reprocessing Plant (KARP). Important recommendations from safety considerations included construction of diaphragm wall before the commencement of work of HEF, proper monitoring of men and materials to prevent contractor workers access to the waste tank and other areas.

Fast Reactor Fuel Cycle Facility (FRFCF)

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

Major Inputs by: *G. Srinivasan, P.V. Ramalingam, Baldev Raj, A.R. Sundararajan and A. Ramakrishna*

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FUEL CYCLE PROJECTS

After successfully establishing pilot plants for various components of nuclear fuel cycle in 1950s at Trombay, DAE in 1960s started installing units with larger capacities to run on commercial lines to meet the demands of an emerging nuclear power programme in the country. It was important to install plants which will produce large quantities of nuclear fuel and heavy water. Thus the Uranium Corporation of India Limited (UCIL) was established in 1967 at Jaduguda, in the then Bihar state. Similarly, Indian Rare Earths Limited, established as a private limited company in 1950 became a full fledged Central Government undertaking under DAE in 1963. A Nuclear Fuel Complex was set up in 1968 at Hyderabad for production of finished fuel assemblies for various reactors of DAE. In 1969 Sarabhai constituted Heavy Water Group which later became Heavy Water Board with a mandate to produce heavy water in large scale to meet the demands of many PHWRs that were on the drawing boards of DAE.

Uranium Corporation of India Limited (UCIL) Projects

UCIL started its first mining operation at Jaduguda in 1967 and commissioned in 1968 its uranium mill with a capacity of 1000 tons per day to produce the yellow cake (magnesium di-uranate). Safety of these operations was reviewed by Health Physics Division, BARC/DAE-SRC in the earlier years and later by SARCOP from 1987 onwards. One of the major safety concerns in the early days was high radon concentration in the Jaduguda mine. A Committee was constituted by DAE-SRC in June 1985 to review the Jaduguda mine ventilation system, with a view to reducing the annual average per capita radiation dose to the mine workers arising from radon and its progeny. The Committee recommended various steps to improve the ventilation system of the mine. In September 1991, AERB constituted a committee to review the progress in the implementation of earlier

recommendations and to review the radon concentrations and related aspects in the mine. The Committee observed that the improvements made were only marginal and recommended installation of a large fan to augment the air flow and a split ventilation system in order to provide fresh air to each of the working level. The average radon levels are now within the derived air concentration limits.

Narwapahar and Turamdih Projects

In 1988, UCIL sought the clearance for Narwapahar and Turamdih mines located in the Singhbhum Belt of Jharkhand and the ore processing plant at Turamdih. In 1992, the DAE decided to discontinue the Turamdih mining project. At the time of closing of Turamdih mine, the 8° Access Decline had reached at the upper horizon at a depth of 70 m from the surface and the 11° incline to be used for hoising of ore by conveyor had progressed about 336 m.

Narwapahar mine with mining access through declines and fully mechanized operations was expected to yield 1350 tons per day. AERB constituted a Project Safety Review Committee (PSRC) chaired by S. Sen, the then Director, Chemical Engineering Group, BARC and an Advisory Committee for Project Safety Review (ACPSR) for the project chaired by S.D. Soman, the then Director, Health Safety and Environment Group, BARC. The proposal was subsequently reviewed by the Safety Committee for UCIL and AMD (UASC) chaired by V.S. Keni, former Head, Chemical Engineering Division, BARC. In order to treat the extra load coming from Narwapahar, the existing mill at Jaduguda had to be augmented to an annual capacity of about 2000 tons of ore.

UCIL also proposed to extend the tailings pond by 30 hectares. Some of the issues which were discussed at length during the review of this proposal by the UASC chaired by S.K. Ghosh, Head, Chemical Engineering Division, BARC included seismic safety of the tailings dam, control of public access to the tailings pond area, performance

efficiency of the Effluent Treatment Plant (ETP) and control of internal exposures of the miners. Authorization for mining of ore from Narwapahar and its processing was given in August 1995.

In 2001, DAE had directed UCIL to re-open the Turamdih mine to augment the production of uranium ore. The project proposal was reviewed in great detail by the Safety Committee and authorizations were issued to UCIL in stages from 2001 to 2005. The final authorization issued in August 2005 was for mining and ore transportation to Jaduguda mill upto a production rate of 550 tons per day. Authorization for construction of Turamdih ore processing plant was issued in October 2003. Safety analysis of the tailings ponds for Turamdih was reviewed in great details by the Safety Committee and based on its recommendations construction of a check dam was recommended following the concept of defence-in-depth. The authorization for construction of tailings dam was given in July 2006. The commissioning results of the ore processing plant is currently being reviewed by USC.

Banduhurang, Bagjata and Mohuldih Projects at Singhbhum Belt, Jharkhand

Banduhurang mine, unlike the other mines, is the first open cast uranium mine in the country with an yield of 2400 tons per day. UCIL Safety Committee (USC) discussed at length the issues like the dust suppression measures, mine water treatment, etc. As per the deliberations, mine water from Banduhurang after treatment would be stored in an industrial water pond and could be used by the ore processing plant at Turamdih. The water from industrial pond would be discharged only during monsoon in the Kharkai river. AERB issued the authorization for the mining operation in March 2005.

Bagjata Mine is estimated to yield 500 tons per day of uranium ore. The project was reviewed by USC and ACPSR for Fuel Cycle Facilities

(ACPSR-FCF) chaired by R.K. Garg, former CMD, IREL. Issues like the transportation of ore, treatment of mine water and waste rock dumping were deliberated. Authorization for development of Bagjata mine was issued in April 2005.

Mohuldih mine is expected to produce 500 tons per day of uranium ore. The project was reviewed by Design Safety Review Committee for Uranium Extraction Projects (DSRC-UEP) chaired by S. Majumdar, former Head, Radiometallurgy Division, BARC and by ACPSR-FCF with particular emphasis on transportation of ore, health physics monitoring, ventilation scheme, storage and disposal of sludge from desilted pond. The authorization for development of the mines was issued by AERB in October 2007.

Tummalapalle Project, Andhra Pradesh

Tummalapalle mine located in Cuddapah district of Andhra Pradesh has a production target of 3000 tons per day. After regulatory review, authorization for the project was given at various stages. Approval was given by AERB in January 2005 for exploratory mining of 2000 tons of ore and its transportation to Jaduguda Mill for pilot plant study. UCIL applied for regular authorization for mine development in July 2007. The project was reviewed by DSRC-UEP and ACPSR-FCF. Issues like waste rock treatment, health physics monitoring, transport of sludge from desilting pond were deliberated. The authorization for development of mine was issued in February 2008.

Since Tummalapalle ore contains carbonate, alkali leaching of the ore was proposed. UCIL proposed to set up a Technology Demonstration Pilot Plant (TDPP), Jaduguda for carrying out extraction studies. The proposal was approved in August 2005. Based on the outcome of the studies, UCIL decided to set up an ore processing plant at Tummalapalle itself. The siting of the

processing plant was reviewed by DSRC-UEP and ACPSR-FCF. Siting clearance for the ore processing plant at Tummalapalle was issued in February 2007 with the stipulation to submit soil analysis report and approval from state government for water supply.

Nuclear Fuel Complex (NFC) Projects

Following the decision by DAE to establish the Nuclear Fuel Complex at Hyderabad in 1968, a number of plants were commissioned in 1970s. These include Zirconium Oxide Plant (ZOP), Zirconium Sponge Plant (ZSP), Zirconium Fabrication Plant (ZFP), Uranium Oxide Plant (UOP), Uranium Fabrication Plant (UFP). Like other radioactive installations of DAE, safety aspects of these plants were reviewed earlier by HPD, BARC/DAE-SRC and later by AERB-SARCOP from 1987.

For augmenting the production capacity to meet the increasing requirements of PHWR fuel inventories, NFC proposed in late eighties construction of number of plants. Important among them were New Uranium Oxide Fuel Plant (NUOFP), New Zircaloy Fabrication Plant (NZFP) and New Uranium Fuel Assembly Plant (NUFAP). AERB constituted a Project Safety Review Committee (PSRC) chaired by K. Subramaniam, the then Director (Technical), IREL for safety review of these plants.

NUOFP located within the NFC premises had a design capacity to manufacture 335 tons per year of UO_2 pellets for PHWR plants. During the safety review, main issues addressed were i) appropriate mechanization of handling of uranium powder operation, ii) design provision for containment of powder and iii) adequacy of ventilation system. Authorization for siting was given in 1990, approval for design in 1991 and for commissioning trials in 1998.

NZFP was designed for manufacturing 59 tons per year of Zircaloy tubes and components for PHWRs. The main issue during the safety

review was implementation of an appropriate effluent treatment scheme for spent pickling solution. For this project authorization for siting was given in 1990, for construction in 1991 after the design review and for commissioning the plant in 1997.

NUFAP had a design capacity of 300 tons of PHWR fuel bundles. Based on the review by the PSRC of all the engineering and safety aspects of the plant, AERB issued the authorization for the operation of the plant in 1996.

NFC has established a Zirconium Complex at Pazhyakayal, near Tuticorin in Tamilnadu to provide 250 tons per year of reactor grade zirconium sponge. A site authorization issued earlier by AERB in 1990 was revalidated and issued in 2003 after review of the site evaluation report by the NFC Safety Committee chaired by R. P. Singh, Head, Atomic Fuels Division, BARC. Major recommendation of the Committee included adequate safety margin over the design basis flood level and drainage slope, arrangement for alternate escape route for site, space for future expansion and mechanization for material handling. After review by ACPSR-FCF, authorization for construction was issued in November 2005.

In 2007 NFC carried out revamping of Zirconium Oxide plant from dissolution to precipitation section to increase the plant capacity from 300 to 500 tons per year with better instrumentation and control. The NFCSC reviewed the proposal. NFC had also proposed to carry out the revamping of the existing Uranium Oxide plant in 2008 to improve automation without increasing plant production capacity. NFCSC reviewed the proposal. The major recommendations were to enhance the structural stability of UOP building, segregation of active and non active scrap materials of the plant, development of piping specifications for new pipelines, laying of power cables as per standard, provision for single point entry to the plant and automation and improvement in the ventilation of the plant. The progress status of the revamping of UOP is being periodically reviewed by NFCSC.

Indian Rare Earths Limited (IREL) Projects

Indian Rare Earth Limited had been in operation with plants located at Trombay, Chavara, Manavalakurichi, Udyogamandal and Chatrapur. The mineral separation plants at Chavara and Manavalakurichi started during 1920s as private enterprises. IREL took over their operations in 1960s. The monazite processing plant at Udyogamandal for separating rare earths and thorium dates back to 1952, followed by Thorium Plant at Trombay in 1955. Thorium nitrate and nuclear grade thorium oxide were the main products of Trombay Plant, while uranium and rare earth salts were the other products. The process underwent partial modification in 1971 when solvent extraction was introduced. The mineral separation plant and thorium plant at OSCOM (Orissa Sand Complex) plant at Chatrapur started in the year 1986. The safety aspects of these plants were reviewed earlier by HPD/DAE-SRC and later by SARCOP from 1987.

Decommissioning of REP, Udyogamandal and Thorium Plant, Trombay

In 1988, the operations at the Rare Earths Plant at Udyogamandal were stopped due to structural weakness from ageing and corrosion. The decommissioning work was carried out during 1990-1991. It was for the first time that a commercial chemical plant processing radioactive material was decommissioned in the country. The Thorium plant, Trombay ceased operation in 1997 as the civil structures got weakened, due to ageing. The plant was decommissioned during 2000-2001. The residual contamination levels, results of decommissioning trials, environmental impact assessment were reviewed by AERB. The major activities which involved detailed review were areas related to safety which were recovery of sludge from tanks, decommissioning of tanks and other equipment, removal of floor and wall contamination, disposal of wastes and contaminated scraps.

MOHUR and HERO projects, IREL Udyogamandal

The Advisory Committee for Safety Review chaired by S.D. Soman reviewed the design and operational safety of Modernization of Helium Uranium Recovery (MOHUR) project. Besides experts from the DAE units, the Committee included Director of Mine Safety, Bhubaneshwar region as a member. The project proposed to process monazite to recover tri-sodium phosphate, rare earths chloride and thorium hydroxide concentrate. Along with these products the plant would also produce nearly 1.75 tons of Ammonium Diuranate and 3200 cubic metre of helium annually. Initially, in 1989 AERB issued provisional authorization to operate excluding the high pressure helium system. Safety aspects of the Helium Recovery Plant were further reviewed by ACPSR and based on the review, AERB issued authorization for continued operation of Helium Plant of IREL, Udyogamandal in February 1996. The same Committee reviewed and approved another proposal from IREL to set up a Heavy Rare Earths Oxide (HERO) plant at Udyogamandal for recovering pure samarium, gadolinium, yttrium and europium concentrates from rare earth chlorides.

One of the major safety concerns which emerged during the processing of monazite was storage of thorium hydroxide in the silos 1, 2 and 3, located close to river Periyar. These silos were general purpose storage sheds and not engineered for storage of radioactive materials as were the other silos. Environmental impact in the public domain consequent to a postulated failure of the silos and the already observed deterioration in the structure of these silos had been a cause of concern. At the instance of AERB, strengthening measures with respect to structural integrity of the silos were taken up. In 1999 IREL had proposed to retrieve the thorium concentrates from the silos. Reprocessing and storage was envisaged by water jets, transfer of slurry to road tankers, spray drying, pelletization, calcinations and storage in drums in

underground vaults. The project was recommended by IRE Safety Committee chaired by K.C. Pillai, Former Head, HPD, BARC with various stipulations. However, the project was abandoned by IREL mainly due to difficulties in retrieval by water jetting and high cost of the project.

THRUST Project, IREL, Udyogamandal

In 2002, a fresh proposal was put up to IRE Safety Committee for retrieval and processing of the thorium concentrate from the silos to recover uranium and thorium values after phasing out monazite processing operation. This project for Thorium retrieval, Uranium Recovery and Storage (THRUST) was taken up in two stages namely THRUST Phase-I under which the thorium concentrates would be retrieved from silo 1, 2 and 3 and THRUST Phase-II for the remaining silos. Based on the review by IRE Safety Committee chaired by D.S. Shukla, the then Head, CTD, BARC, SARCOP issued authorization for construction of the project in December 2002. The interim clearances for operation of the project were issued in two stages, initially for retrieval and processing of 300 tons of thorium concentrate on trial basis and subsequently for retrieval and processing of additional 1000 tons of thorium concentrate. These clearances were issued after extensive reviews and implementation of a number of modifications in the plant systems including total revamping of ventilation system, as stipulated by AERB. The final clearance for THRUST Phase-I operation was issued in 2005. Detailed review of THRUST Phase–II was carried out by IRESC chaired by V.K. Kansal, the then Head, Chemical Technology Division, BARC and SARCOP with respect to issues pertaining to ventilation and long term storage of thorium oxalate. After ensuring satisfactory compliance with safety requirements, SARCOP agreed in 2007 to permit THRUST Phase-II operation.

New Thorium Plant, IREL, OSCOM, Chatrapur

With the experience gained from Thorium Plant, Trombay, IREL

had proposed to set up a New Thorium Plant at IREL, OSCOM for processing of thorium oxalate for production of thorium nitrate and thorium oxide. The proposal was reviewed by a Project Safety Review Committee (PSRC) chaired by S. Sen the then Director, Chemical Engineering Group, BARC. PSRC reviewed the project from the point of view of plant performance, radiological and industrial safety aspects, effluent characteristics. Authorization for the plant operation was issued in 1992.

Monazite Processing Project (MoPP), IREL, OSCOM, Chatrapur

IREL, OSCOM proposed setting up a monazite processing plant with a capacity of 10,000 tons per annum at IREL, OSCOM. The Site Evaluation Report was reviewed by IRE Safety Committee and the authorization was issued in 2006. The detailed review for the construction of the project was carried out by Design Safety Review Committee for Uranium Extraction Projects (DSRC-UEP) and subsequently by ACPSR-FCF. The project was subjected to extensive review with particular attention to structural safety in view of the high frequency of cyclone at the site, disposal of wastes, radiological and environmental safety, etc. Based on the review, authorization was granted in 2007 for construction of the plant.

Beach Sand Minerals (BSM) Processing Facilities

Consequent to the Policy announcement by DAE in 1998 on exploitation of Beach Sand Minerals (BSM), private entrepreneurs also started mining, mineral separation, processing and value addition of the beach sand minerals. These BSM facilities preferentially separate the titanium minerals (ilmenite, rutile, leucoxene), garnet, sillimanite, zircon. Monazite is being exclusively separated by IREL plants. The BSM processing facilities were licensed by DAE under the Atomic Energy (Working of the Mines, Minerals and Handling of Prescribed Substance) Rules, 1984 after obtaining a No Objection Certificate from AERB. AERB teams carried out inspection of these facilities.

In 2004 Chairman, AERB constituted a Committee under the chairmanship K.C. Pillai, former Head, HPD, BARC to examine the radiological issues involved in mining and milling of beach sand minerals. In view of generation and disposal of monazite enriched tailings, Committee recommended that all BSM processing facilities should be licensed under the Atomic Energy (Radiation Protection) Rules, 2004. Consequent to delisting of the titanium minerals and zircon from the list of prescribed substances in January 2007, the BSM facilities handling these minerals no longer required license from DAE. However, to exercise control on the disposal of monazite enriched tailings, the BSM processing facilities would require license under the Atomic Energy (Radiation Protection) Rules, 2004 from AERB. As a consequence of this requirement, the IRE Safety Committee has been reconstituted as Beach Sand Minerals Safety Committee (BSMSC) in 2008 with V.K. Kansal as the Chairman to take over the safety review of all BSM facilities including IREL plants.

Heavy Water Board (HWB) Projects

By the time AERB came into existence, Heavy Water plants at Kota, Baroda and Tuticorin were already operational. The plant at Thal was nearing completion and was commissioned in 1986. The safety review of these plants was carried out by DAE-SRC and later by AERB-SARCOP from 1987 onwards. One of the important safety issues related to HWP, Kota was the potential impact of an accidental release of hydrogen sulphide owing to its proximity to Rajasthan Power Stations. At the instance of AERB, an assessment of the impact was carried out. The subsequent projects of Heavy Water Board reviewed by AERB are described below.

Heavy Water Project- Manuguru

Based on the experience gained from operation of Heavy Water Plant, Kota, Heavy Water Board had proposed to set up another hydrogen sulphide based heavy water plant at Manuguru, Andhra

Pradesh. For this project an Advisory Committee for Project Safety Review (ACPSR) chaired by R.K. Garg, Former CMD, IREL and a Project Design Safety Committee (PDSC) chaired by H. K. Sadhukhan, the then Director, Chemical Engineering Group, BARC were constituted by AERB. The project was also subjected to an in-depth safety review by an expert sub-committee of AERB in areas such as design of systems important to safety, quality assurance during construction and start up tests. Based on the recommendations of PDSC and ACPSR, generation of 430 tons of hydrogen sulphide was approved. Authorization for operation for Exchange Unit-II at 12 kg/cm^2 and operation of Units 1&2 of the Captive Power Plant were issued in 1990. Later in 1991, authorization for operation of both the Exchange Units-I &II at the design pressure and to charge hydrogen sulphide into the Exchange Unit-I for the purpose of film formation was issued. Currently, the safety review of the plant is carried out by HWP Safety Committee chaired by C.S.R. Prasad, Chemical Technology Division, BARC and SARCOP.

Heavy Water Project- Hazira

After Thal, the Hazira plant in Gujarat was the fourth ammonia based heavy water plant. The synthesis gas for the project would be drawn from the ammonia plants of Krishak Bharati Cooperative (KRIBHCO). The Site Evaluation Report was reviewed by the PDSC and ACPSR for Heavy Water Projects. In December 1990, based on the recommendation of these Committees, AERB authorized for continuous operation of streams A and B in 1991 with synthesis gas/ ammonia and potassium amide as a catalyst.

In the year 1992, PDSC while reviewing the commissioning status observed that the cable tray forgings located inside towers of the ammonia based plants have not been subjected to pressure testing from outside. These cable forgings are used for the purpose of taking the cables from inside the tower, which is under pressure. This is done through the glass seals located at the bottom of the cable

forging. The towers have been designed as per ASME Section VIII Division II. However, in the code there is no mention about the test requirements for components designed for external pressure, which is the case with respect to the cable forgings.

The American Society of Mechanical Engineers (ASME), Bureau of Indian Standards (BIS) as well as other organizations which have expertise on design and fabrication of pressure vessels were contacted to seek their views on the above problem. Discussions were also held with experts in the field from BARC. One of the solutions considered was that the cable forging could be subjected to a hydraulic test with internal pressure of 1.25 times the external design pressure. However, due to the presence of the glass seals at the bottom of the cable forging, any internal pressure would cause a leakage from the glass seals since they are designed to seal only when there is pressure applied from outside the cable forging. Since the cable forging could not be hydraulically tested internally, it was finally decided that the cable tray forging should be subject to an external pressure equal to 1.25 times the design pressure. HWP-Hazira has carried out hydro testing of cable tray forging as per stipulations of AERB.

Heavy Water Plant-Baroda Revival Project (BRP)

The Heavy Water Plant, Baroda, which was commissioned in mid seventies, was being operated for production of heavy water by extraction of deuterium from ammonia synthesis gas on mono-thermal Ammonia-Hydrogen exchange process. The operations of HWP, Baroda was suspended since beginning of 1999 due to suspension of supply of required high pressure feed synthesis gas from M/s GSFC and thus the Baroda Revival Project (BRP) was initiated by HWB as a technology demonstration plant to sustain operation of HWP independent of fertilizer plant. BRP is based on the deuterium exchange process between water and ammonia, where deuterium from water gets transferred to ammonia vapour and the Ammonia-Hydrogen monothermal isotopic exchange process is used

for further enriching the deuterium laden ammonia. HWPSC and SARCOP reviewed the Design Basis Report, Safety Report, Hazard Operability (HAZOP) studies, Fire safety provisions, Quantitative Risk assessment (QRA), Waste Management, Technical Specifications for operation, document for authorisation of operating personnel and In-Service Inspection (ISI) manual for equipment and piping. On the recommendation of SARCOP, AERB granted the license for operation of HWP-Baroda in June 2006. IPSD had also carried out a Chemical Exposure Index study and consequence analysis of ammonia leakage with the help of the software 'PHAST professionals' for this project.

Diversified Projects of HWB

In the recent years, due to fall in demand of heavy water by the PHWR based NPPs, HWB ventured into the production of various solvents, boron enrichment, etc. R&D pilot plant for development of technology for production of Di-2 Ethyl Hexyl Phosphoric Acid (D2EHPA) at Talcher was reviewd by the erstwhile Safety Committee for Heavy Water Operating Plants (SCHWOP) which later got renamed as HWPSC. Issues of In-Service Inspection procedure for glass lined reactors, pressurization and containment of phosphorous trichloride were addressed. Based on the review of SCHWOP, operational clearance was granted by SARCOP in July 2001. Similarly the proposal for setting up of the TBP facility with a capacity of 60 MT per year was reviewed extensively by HWPSC and SARCOP with emphasis on risk assessment, waste management and Technical Specifications for the operation. Regular operational clearance was given by SARCOP in December 2003.

The project for setting up of the Boron Enrichment Exchange Distillation (BEXD) Facility at Talcher was initially reviewed by HWPSC and later by Design Safety Review Committee for Diversified Projects (DSRC-DP) chaired by S.M. Rao, former DCE, NFC. Issues of availability of HF and Ether monitors, results of HAZOP studies and revision of Technical Specifications were addressed.

Based on the recommendations of DSRC-DP and ACPSR-FCF AERB granted authorization for the operation clearance in July 2008.

Recent Developments

In 2006, AERB published a document on 'Consenting Process for Nuclear Fuel Cycle Facilities and Related Industrial Facilities other than Nuclear Power Plants and Research Reactors' (AERB/NF/SG/G-2). The document outlined the regulatory requirements at various consenting stages of siting, construction, commissioning and operation for the fuel cycle facilities. Regulatory inspections of the fuel cycle facilities are being carried out during various stages of consenting as per the requirements laid down in the AERB document 'Regulatory Inspection and Enforcement in Nuclear Fuel Cycle and Related Industrial Facilities other than Nuclear Power Plants and Research Reactors' (AERB/NF/SM/G-2). In the recent years, AERB had also published safety guidelines on 'Safety in Thorium Mining and Milling', 'Radiological Safety in Uranium Mining and Milling' and 'Management of Radioactive Waste from Mining and Milling of Uranium and Thorium'.

After the operational consent is given, the operational safety review of these facilities are carried out by the units safety committees such as UCIL safety Committee, BSM Safety Committee, NFC Safety Committee and HWP Safety Committee and subsequently by SARCOP.

Major Inputs by: *T. N. Krishnamurthi, R. Bhattacharya, K. Ramprasad, V.V. Raut, H. Kulkarni, S. Bhattacharyya, S. Sinha and N.M. Chodankar*

Prof. A.K. De chairing the Board meeting at DAE in 1989

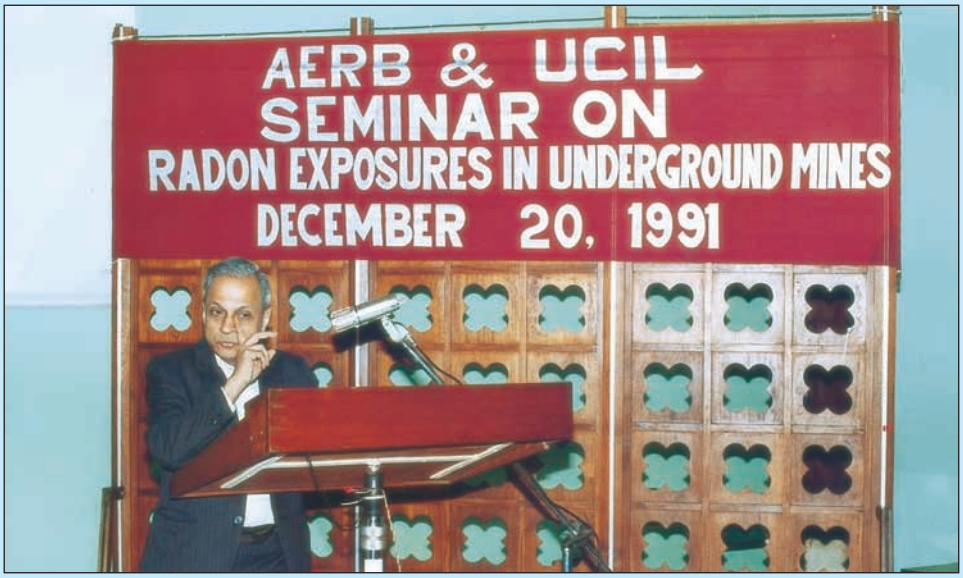
Dr. K.S. Parthasarathy, Prof. A.K. De and Dr. Raja Ramanna at the seminar held in March 1986.

Shri Sushil Kumar Shinde, Minsiter of Power, Delhi inaugurating the seminar on Nuclear Safety and Environment in Sepetmber 1987 jointly organized by AERB, The Institute of Engineers, Maharashtra State Centre and Maharashtra State Academy of Sciences. Also seen are Dr. P.K. Patwardhan, Dr. M.R. Srinivasan and Prof. A.K. De

Shri T. Subbaratnam, Dr. K.S. Parthasarathy, Shri S.K. Mehta, Dr. P.K. Patwardhan, Dr. R.D. Lele and Shri S.K. Chaterjee during the panel discussion of the seminar

Dr. M.R. Srinivasan, Chairman AEC addressing the IAEA-WHO-UNEP meeting in February, 1988

Prof. A.K. De addressing the scientists and engineers at BARC who participated in the safety review of NAPS

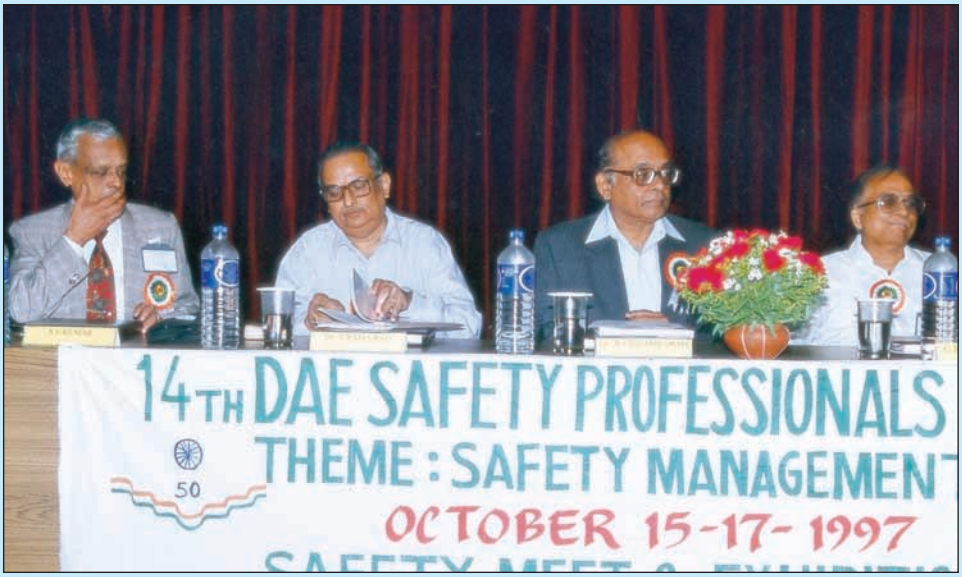


Shri S.D. Soman addressing the seminar in December, 1991

Dr. A. Gopalakrishnan with A. Krishnan at KAPS during December 1991

AERB Board members during Board Meeting at Kaiga in October 1997

Shri A.R. Sundararajan, Prof. P. Rama Rao, Dr. R. Chidambaram and Dr. P. Rodriguez during laying of foundation stone of SRI in February,



Shri S.V. Kumar, Prof. P. Rama Rao, Dr. R. Chidambaram and Shri G.R. Srinivasan during the 14th DAE Safety Professionals Meet in October 1997

Dr. Anil Kakodkar distributing the Industrial Safety Award in 1998.

Prof. A.K. De, Prof. Rama Rao and Shri S.D. Soman during AERB day function, November, 1998

Prof. A.K. De, Shri S.D. Soman, Dr. A. Gopalakrishnan and Prof. S. P. Sukhatme during AERB day function, November, 2002

Prof. S.P. Sukhatme, Chairman AERB inaugurating SRI guesthouse in 2002.

SRI guesthouse, Kalpakkam

Prof. S.P. Sukhatme, Chairman AERB inaugurating SRI Building in 2003.

SRI, Kalpakkam

Niyamak Bhavan-A

8

SAFETY REVIEW OF OPERATING NUCLEAR FACILITIES

Early Days

After the very first two reactors of DAE, Apsara and CIRUS went into operation Bhabha set up a formal reactor safety committee in 1962 with A.S. Rao as the Chairman and V. Surya Rao, V.N. Meckoni and A.K. Ganguly as members. When DAE-SRC was constituted in February 1972, it took over the responsibility for safety review of all research reactors. In December 1975 when DAE reconstituted the DAE- SRC, its scope was enlarged to cover all facilities, not only power reactors or research reactors but all other facilities as well in DAE family. That was the time when DAE was embarking on several major projects covering all components of the fuel cycle at different sites. DAE-SRC was to report to the Chairman AEC. Its first Chairman was A.K. Ganguly, the then Director, Health and Safety Group, BARC who had made pioneering contributions in the area of Health Physics and who enjoyed a great respect and admiration from one and all in the department. He had a very strong team too with members like R.K. Garg, S. D. Soman, B.S. Prabhakar, N. Veeraraghavan and P. Abraham who were all outstanding experts in their own areas of specialization. It is the strong foundation laid by these pioneers that has been responsible for the strong organization AERB built to carry out effectively its mandated responsibility of ensuring the safe operations of the DAE plants.

Prior to establishment of SRC, DAE had formed separate unit safety committees for individual reactors like PURNIMA I, PURNIMA II and plants like Plutonium Plant PREFRE, etc. The DAE-SRC was intended as an apex body for such safety committees overseeing the specific facilities. That was the first step in establishing a robust arrangement of multi-tiered safety review mechanism. The SRC's role was to evolve major safety policies and lay down guiding principles,

so that the safety standards and approaches followed remain uniform, across the different sectors of Atomic Energy operations in the country.

To begin with the SRC did not have a permanent office or premises. The Committee had its first meeting on January 6, 1976 at the office of its Chairman, Ganguly, at the sixth floor of Central Complex, BARC, Trombay. The initial decisions were on establishing the reporting criteria and the working procedures of the committee. Following the principle of fair representation of the stake holder's position, SRC adopted a policy of inviting representatives of the facility management and suitable peer specialists, whenever discussing matters relating to individual units.

In those initial days the SRC used to meet nearly on a monthly basis mainly to discuss the operational and radiological safety aspects of TAPS-1&2 and RAPS-1. The committee was also dealing with the safety review and clearances associated with the projects that were under construction at that time, RAPS-2, MAPS-1&2, Heavy Water Plant (Kota), FBTR at Kalpakkam.

While the operational domain of SRC was expanding, its secretariat and infrastructure were also growing. By the end of 1976, SRC had its own premises, a few office rooms in the fourth floor (south wing) of Central Complex of BARC. It also had a conference room for the committee, which came to be known as the SARCOP Conference Room subsequently. This office remained with SRC and later on with the Operating Plants Safety Division of AERB, till June 1996, when all the AERB offices were moved to Niyamak Bhavan. By the year 1976, SRC had established a secretariat having a few engineers / scientists and a handful of support staff led by P. Abraham. The secretariat had a decent library of scientific / technical publications concerning nuclear and radiation safety, sourced mainly from IAEA, ICRP and US-NRC.

Feedback of Operating Experience

By 1978, the SRC had established the requirement and format for reporting of unusual occurrences, which came to be known as the Safety Related Unusual Occurrence Reports (SRUOR) and presently known as the Significant Event Reports (SER). The purpose of this format was to set uniform criteria with respect to the events to be reported and the details to be included in the SRUORs, from different installations. SRC also wanted the system of event reporting to function as a means for obtaining a feedback from operating experience. SRC felt that there was a need to disseminate the information coming from different plants on the events encountered and the lessons learnt.

With these objectives, a decision was taken to set up a computerised databank in the SRC Secretariat. Even though DAE-SRC had installed a HCL-Honeywell Machine, then a state of the art computer system, it required enormous efforts to create a data base on unusual occurrences and SRC recommendations. There used to be those quarterly compilations on the SRUOR/UOR and the list of pending recommendations, being sent to all units of DAE. This sound tradition is being continued till date with several enhanced features.

This exercise became very handy when in 1984 India became a participant in the IAEA Incident Reporting System (IRS). This added a major boost to the efforts and inputs in the field of Operational Experience Feedback (OEF). We started getting detailed reports on the events that occurred in the overseas nuclear facilities, which provided an insight into the safety of our own facilities. Later India also became a participant in the International Nuclear Event Scale (INES), when IAEA launched it in 1990. The objective of INES was prompt communication of safety significance of nuclear and radiological events to the public.

With the experience of participating in these international programmes and with the data coming in from the events in Indian

NPPs, an in-house system of in-depth analysis of the SRUORs of Indian NPPs was started in the late eighties. It involved analyzing and categorizing the events from the perspectives of failed / affected systems and root causes. OPSD started issuing periodic reports (annual) on the analysis of events which is still continuing. Over the last two decades, with the enormous data gathered and analyzed, the system had provided significant insights which influenced the NPP designs, operational practices and the regulatory approach.

Radiation Exposures at NPPs

In 1977-79 high radiation exposures in the operating NPPs became an issue to be dealt with by SRC with the annual collective dose at TAPS reaching 5000 man-rem. There were also a few cases where annual exposure of individual workers exceeding five rem, the limit for individual exposure recommended by ICRP. At RAPS, there were a large number of persons who received exposures in excess of the investigation levels, though within the annual dose limit and there were delays in completing the investigations. Many of the exposures were due to internal uptake of tritium, which were attributable to non-use of protective equipment. Concerned, SRC took a review of the situation in both TAPS and RAPS.

At TAPS the problems were many; the background levels were high due to poor fuel performance in those days. Tube leaks in secondary steam generators also needed frequent inspections / repairs / maintenance that were man power intensive. When SRC's emphasis was "no annual individual exposure of more than five rem", TAPS's response was with the emphasis on "optimisation" and that a limit on individual exposure would result in increased station dose as it would become necessary for the station to bring in more persons from outside TAPS, who may be comparatively less familiar with the jobs. However, the SRC prevailed on TAPS to agree to have a limit of 4.25 rem on individual exposures and 4000 man-rem for the annual station dose as a first step towards gradual decrease to 1000 man-rem limit.

Despite the emphasis by the SRC and later by AERB and SARCOP and also the efforts by the stations, the collective dose at TAPS, RAPS and MAPS remained high with the exposure exceeding the recommended level of 1000 man-rem. The problems were aplenty. In TAPS, high radiation backgrounds resulted from poor fuel performance, and build-up of activation product Cobalt-60. There were also frequent incidents of tube failures in Secondary Steam Generators and leaks in the SS piping of primary system requiring repairs. In RAPS, the major contributors for the increased doses were poor fuel performance, the cracks in the end shield of RAPS-1, the increasing levels of tritium in PHT resulting in internal exposures and coolant channel ISI / creep adjustment activities. In MAPS also Cobalt-60 activity in PHT system was a major source of high radiation level. The other causes were spillages of heavy water and repair works following failure of moderator inlet manifolds in the calandria of both the reactors.

In 1988, then Chairman AERB, A.K. De constituted a committee under the Chairmanship of T. Subbaratnam, to investigate the possibility of reducing collective doses in the NPPs/installations. This committee, after completing its investigations and reviews, submitted its report in December 1989. The committee made a number of recommendations to achieve reduction in dose consumption at the NPPs. The important recommendations of this committee included stronger commitment from the management, coordination between operation, maintenance, design and health physics groups, appointment of ALARA coordinators at every station, optimization of manpower involved in radiation jobs, steps to improve fuel performance, reduction in tritium activity in PHT system in PHWRs and strengthening of training. The recommendations also included a number of plant specific improvements. The committee had also recommended a limit of 1000 man-rem for the twin unit stations, which were in operation at that time, viz., TAPS, RAPS and MAPS. The committee also recommended that the collective dose in new

220 MWe stations should be below 600 man-rem. The stations should work out and implement comprehensive action plans to achieve these targets.

The Board of AERB had discussed the report of this committee in its meeting in March 1990, and decided to take up the issue of reducing the collective doses at NPPs and implementing the recommendations of the committee, at the highest levels in the Department and NPCIL, i.e., with Chairman, AEC and Managing Director of NPCIL. The constant efforts within AERB and commitment from the top management of NPCIL a number of steps were implemented with the objective of bringing down the collective doses. The major ones were (a) steps to improve fuel performance, including stringent quality control during manufacturing, (b) development and implementation of chemical decontamination of systems to bring down radiation fields before major jobs, (c) steps to reduce internal exposures, (d) tools for automation and remotisation of maintenance activities, and (e) implementation of ALARA programmes. With the implementation of these measures over the years, exposures could be brought down to below 1000 man-rem, in the first half of nineties and to further lower levels in the subsequent period, in the older plants. Currently, while collective dose in TAPS and NAPS is below 500 man-rem, for all other twin unit stations it is below 300 man-rem a year.

Impact of Three Mile Island Accident

The accident at the Three Mile Island (TMI) NPP Unit- 2, on March 28, 1979 was one of the most significant events in the history of commercial nuclear power industry as it is often cited as a turning point in the global development of nuclear power. The aftermath of the accident led to sweeping changes in the emergency response planning, operator training, human factors engineering, radiation protection, and many other areas of nuclear power plant operations. It is worth noting that despite the severe damage to the fuel, the containment system performed adequately and no member of the

public received exposure in excess of the prescribed limits. But the accident also bared many shortcomings in the emergency response machinery and provided major lessons about the response of the public in an emerging accident scenario.

At this point of time, TAPS-1&2 and RAPS-1 were in operation in India. There were another five 220 MWe PHWR units under various stages of construction. In view of the widespread concern about the safety of nuclear power plants and the public around them DAE decided to undertake a thorough re-apprisal of the safety of the NPPs in the light of the lessons learnt from the TMI event. In June 1979, Secretary, DAE, H.N. Sethna constituted a Taskforce under the Chairmanship of M.R. Rao, the then Head, Reactor Operation Division, BARC, to study in detail, the safety aspects of TAPS and RAPS and come up with early recommendations. The report submitted by the Taskforce was discussed by SRC in an extended meeting, held during October 1979. The review focussed on the reliability and availability of the engineered safety features, human engineering aspects and emergency preparedness in the public domain. The Taskforce made a number of recommendations for the operating plants, RAPS-1 and TAPS as well as for the new plants under construction at RAPS-2, MAPP and NAPP. Recommendations were also made for other future plants yet to be built beyond NAPP.

It was recognized then that implementation of these recommendations could take considerable time as they involved many preparatory activities like working out detailed designs, engineering, procurement, civil construction, etc., which would require long lead time, and some of which required integration with the existing plant systems. Also some of these recommendations required detailed analytical studies or design reviews towards obtaining better understanding of the phenomena and for developing tools for analysis and validation, etc.

Many of the recommendations of the Taskforce were considered

important and it was felt that there should be a strong system for follow-up and enforcement from the part of SRC for systematic and timely implementation of the recommendations. SRC established a computerized database of the recommendations of the taskforce, to assist in monitoring of implementation status and follow-up.

This mechanism was later extended to cover all recommendations arising out of reviews by SRC and later by SARCOP. The staff of OPSD keeps track of these recommendations arising out of safety review. The status is periodically reviewed and updated based on the feedback coming from the plants and the periodic regulatory inspections. The status is periodically brought to the attention of the plants and the corporate organizations. The Operating Plants Safety Division, the unit Safety Committees and SARCOP periodically take stock of the progress and status of implementation. This exercise of stocktaking and review is an ongoing process. From time to time, the Board of AERB is kept informed of the outstanding status of implementation of important recommendations, and the enforcement measures undertaken.

Impact of Chernobyl Accident

Seven years later in 1986, SRC, had initiated another special safety review of Indian NPPs in the wake of the most severe nuclear accident to date, the one at Chernobyl. The review by the Taskforce re-emphasized the necessity of adhering to the already established principles of reactor safety in design and operation and maintaining good safety culture. As recommended by the Taskforce, the organization and procedures for on-site and off-site emergencies were strengthened at all the power stations.

RAPS-1 End Shield failure

Towards the end of 1981, RAPS-1 had to be shutdown due to leakage from its south end shield. After detailed investigations and elaborate repair programme when the unit was restarted in 1985, it

sustained yet another leakage. Finally the problem of south end shield stabilized in 1987. But after the leak repairs were completed in May 1987, the utility management opted to restrict the reactor operating power to 50% FP. All these repair works involving significant man-rem expenditure were closely monitored by DAE-SRC.

SRC: Transition to SARCOP (1983-1993)

In November 1983, when AERB was formed, V. N. Meckoni was the Chairman of SRC. Following him, P.R. Dastidar became Chairman of SRC in April 1984 and his term continued till May 1986. Subsequently M.V. Ramaniah served as Chairman of SRC, till June 1987, till M.S.R. Sarma became Chairman of SRC. All these years since inception in 1975, P. Abraham continued to serve as Member Secretary of SRC. In June 1987, N.K. Jhamb took over as Secretary of SRC.

Life Management of PHWR Coolant Channels

One of the main features in PHWRs is the provision of pressure tubes made of zirconium based alloy which serves as the fuel channel as well as the pressure boundary for the primary reactor coolant. Safety of the reactor system requires reliable performance of the tube throughout its design life as it operates at high levels of temperature, pressure and neutron flux. In 1983, a catastrophic failure of zircaloy-2 pressure tube took place at the Pickering NGS Unit-2, in Canada. This event had raised generic concerns on the integrity of pressure tubes in all the operating PHWRs. The cause was determined to be a complex phenomenon involving formation of brittle hydride blisters on the pressure tube. Cracks originating from these blisters resulted in catastrophic failure of the pressure tube. The channel G-16 had ruptured without a prior detectable leakage, thus not satisfying the "leak before break" criteria, one of the basic design principles depended upon for nuclear systems, to assure safety. The zircaloy-2 pressure tubes, during reactor service undergo degradation due to irradiation embrittlement and hydriding due to pick up of hydrogen in the pressure tube material, following a corrosion reaction between the pressure tube material and the reactor coolant.

The DAE-SRC reviewed the available information on the above failure and recommended for initiating a programme for health assessment and life management of pressure tubes in Indian PHWRs. In parallel, PPED was asked to develop detailed emergency operating procedures for dealing with such failures should they occur.

Pursuant to this, a major program was launched for coolant channel life management which involved enhancement in design as well as in-service inspection, health assessment and rehabilitation technologies. BARC provided strong research and development support in this regard. The efforts included development of technology and equipment for inspection of coolant channels and sampling of pressure tube material, analytical models for health assessment and prediction of residual life, technology and tooling for rehabilitation measures like repositioning of garter springs, creep measurement and adjustment, removal and reinstallation of pressure tubes, post irradiation examination of pressure tubes removed from reactor for evaluation of material properties. The main objective of the programme was prevention of blisters of unacceptable size in the pressure tubes. This could be realized thanks to the sustained efforts put in by the NPCIL and BARC under the close surveillance by SRC and later SARCOP. The success of the whole approach followed is evident from the fact that, the last of the reactors with zircaloy-2 pressure tubes, NAPS-2 and KAPS-1, were operated to almost 12 Effective Full Power Years, without encountering any pressure tube failures.

The issue of coolant channel safety, in particular for clearances for operation of RAPS-2 and MAPS-1&2, was the one single issue, on which the SARCOP had spent maximum time for reviews, during the nineties. The situation had changed only after an Expert Group on Coolant Channels was formed in 1998, bringing in all the personnel involved in various aspects of coolant channel life management. This Expert Group reviewed in detail all the safety issues related to relevant coolant channels, in both operating PHWRs and the ones under design / construction. Presently with all the zircaloy-2

pressure tubes phased out of operation, the focus is now on the life management issues of Zirc-Niobium pressure tubes.

Based on the findings of inspections and health assessments, each of the operating reactors went for en-masse replacement of coolant channels (EMCCR), wherein the old irradiated zircaloy-2 pressure tubes were removed from the reactors and replaced with new pressure tubes of better material, Zr-Nb, with four tight fit garter springs. RAPS Unit-2 was the first unit, which went in for the EMCCR, in 1994, after completing 8 Effective Full Power Years (EFPY) of operation. Subsequently, MAPS-2 underwent EMCCR in 2002 after completing 8.5 EFPYs, followed by MAPS-1, in 2003, after completing 10.1 EFPYs. NAPS-1 underwent EMCCR in 2005, after completing about 10 EFPYs. NAPS-2 and KAPS-1, last of the reactors with zircaloy-2 pressure tubes are presently undergoing EMCCR, after completing nearly 11 EFPYs.

A dedicated Review Group was constituted by SARCOP for detailed review of all aspects related to the EMCCR campaign. The regulatory aspects included (a) identification of clearance stages for the activity, (b) review and qualification of various tools, procedures and personnel, (c) inspection, health assessment and qualification of the components that will be retained for further operation, (c) issues related to handling and disposal of the radioactive components removed from the reactor, (d) collective dose budget and performance, (e) aspects related to preservation of other plant systems during the extended outage period, (f) design safety review of the components being replaced.

Formation of SARCOP and OPSD

After the reconstitution of SRC in June 1987 by Secretary DAE, the committee started functioning under the Chairmanship of M.S.R. Sarma. It was during this time, the practice of holding the meetings on Wednesdays, unless in case of any urgent requirements, came into being. A year after its reconstitution of June 1987, the SRC had its last

meeting, meeting no. 365, on June 1, 1988. The reorganization of AERB, which came two days later, saw many changes in the organizational and functional arrangement of the safety review committees. The changes involved converting what was the secretariat of the SRC, along with its staff and premises as the Operating Plants Safety Division (OPSD) with M.S.R. Sarma as its Executive Director and constituting a new Safety Review Committee for Operating Plants, famously known as SARCOP, in place of the erstwhile SRC. The Executive Director OPSD was to be the full time ex-officio Chairman of SARCOP, who would be reporting to Chairman AERB. The OPSD was made responsible for implementing the decisions of SARCOP, through issuance of clearances, periodic audits and inspections and enforcement actions with respect to the operating plants. All the unit safety committees, which were working under the SRC, were also brought under this umbrella arrangement. Though this was a major organizational change, the functioning of the safety review and enforcement mechanism for operating facilities continued in a seamless manner. M.S.R. Sarma served as Chairman of SARCOP and Executive Director, OPSD, until his superannuation in August 1991.

A number of issues and incidents pertaining to the NPPs, research rectors Dhruva and FBTR, Fuel Cycle and Waste Management Facilities were deliberated in SARCOP. During this period, SARCOP made a number of visits to the plant sites and held discussions with the plant personnel. There were many important issues taken up during this period, such as the fuel handling event at FBTR and the rehabilitation activities, incidents of failures of shut off rods in Dhruva reactor, fuel failures in Dhruva, inspection and health assessment of feed water nozzle of TAPS reactors, incidents of leakage of hydrogen sulphide gas at heavy water plants at Manuguru and Kota, review and revision of emergency preparedness plans, the safety criteria for PFBR, high collective dose consumption at the NPPs, incidents of fire in the boiler rooms in RAPS and MAPS due to oil soaked insulation and poor house keeping, flooding of low lying areas in BARC Complex due to heavy rains in June 1991, etc.

Failure of Calandria Inlet Manifolds in MAPS Reactors

During 1988-1989, MAPS encountered a heavy water leak inside calandria vault. The leak was from the PHT system, apparently due to leakage from a pressure tube. Extensive investigations revealed failure of the moderator inlet manifolds, a device meant to bear the brunt of high velocity jet of moderator entering the calandria and to distribute the flow evenly. The leakages of calandria tubes and pressure tubes experienced were caused by the impact of the moderator jets and the pieces of the failed manifold. The interim solution to continue the reactor operation involved a major modification in the moderator flow configuration; virtually reversing it inside the calandria; using the old outlet as new inlet, blanking the old inlet and using the dump tank as new outlet. The flow rates and flow velocities were reduced to reduce chances of further failures. To ensure margins on various parameters, the reactor power was derated to 75% FP.

SARCOP and the RAPS-MAPS Safety Committee had reviewed a number of issues associated with the above, viz., changes in the moderator flow and level control logics and its impact on safety, effect of modified flow configuration on the calandria tube rolled joint temperature and health of the rolled joints, temperature distribution inside calandria and the margins available in the modified configuration, permissible reactor power, rehabilitation of the failed manifolds to obviate secondary failures, etc.

Bifurcation of Technical Specifications

Another important initiative came in this period was the bifurcation of technical specifications for operation of TAPS, RAPS and MAPS. The technical specifications documents specify the requirements with respect to aspects such as safety limits, limiting safety system settings (LSSS), limiting conditions for operation (LCO), surveillance requirements and administrative controls, which had varying significance with respect to safety. Moreover, it was also felt that

some of the requirements specified in sections other than the safety limits and LSSS, might not be of real importance to safety. There were views that with such clauses present in the technical specifications, strict enforcement of the technical specifications might be difficult as reactor shut downs might become unavoidable for reasons which may not be really important to safety. With this backdrop, SARCOP initiated an in-depth review of technical specifications of the then operating rectors, TAPS, RAPS and MAPS, in 1990. Based on the review and the operating experience available, the technical specifications documents were bifurcated into (a) Technical Specifications, which contained the mandatory provisions which needed to be strictly adhered and the utility would be accountable to the regulator and (b) Station Policies, which comprise of the less important and desirable requirements as well as the good operating practices, which should be enforced by the operating organization itself. The change essentially involved transferring the requirements, which did not have any direct implications on safety or the safety related systems and the sections on administrative controls and details of surveillance requirements, to the station policies. While this exercise of rationalizing the technical specifications did help in improving adherence to the technical specifications, cases of deviation do take place albeit with prior permission of SARCOP, in most cases. There were however certain deviations from the station policies in these stations, the responsibility of follow up of which was with the NPC Headquarters, with periodic reporting to SARCOP.

There were requests in the subsequent years from NPCIL seeking similar bifurcation of technical specifications of NAPS onwards. However the assessments and opinion in OPSD and SARCOP were that such bifurcation had not significantly improved adherence to Technical Specifications and the mechanism in NPCIL for enforcement of station policies was not strong enough and formal. Therefore, the requests for bifurcation of technical specifications of other stations were not acceded to.

Special Review Committees

AERB had set up a number of Committees chaired by senior professionals to review in detail some of the issues concerning the operating NPPs. Important among these were as follows.

Review of unusual incidents at RAPS (1980-84)

Chairman AERB set up a Committee in 1984 chaired by P. Rama Rao, the then Director, Defence Metallurgical Research Laboratory to review the unusual occurrences in Rajasthan Atomic Power Station during 1980-84 for identifying issues related to equipment material and fabrication procedures, etc., that were generic in nature.

The Committee identified the generic issues that needed special consideration like reliability and availability of emergency power supplies, adherence to operating procedures and maintenance practices, need for procurement of equipment of proven quality, layout of equipment and amenability for easy maintenance, etc.

Of the 547 incidents and 115 outages included in the report, 89 incidents and 43 outages were reviewed by the Committee as the major ones. The Committee observed that the station management had put in considerable efforts in bringing the unit to an improved level of operation and maintenance as reflected by the good performance of unit-2 in 1985 and its continued record performance in 1986.

Review of operational safety at TAPS

In July 1985, Chairman AERB set up a Committee chaired by K. Sri Ram, IIT Kanpur, to review the operational safety aspects of Tarapur Atomic Power Station. Based on the review, the committee concluded that the health of plant was satisfactory for continued operation. The committee noted that the Station management was responsible and technically alive and alert in so far as assuring personnel, plant and public safety were concerned.

The recommendation of the committee addressed formalization

of quality assurance practices, improvements in the enforcement of industrial safety and enhancing the infrastructure availability for fire safety.

Review of QC and QA at NPPs

Chairman AERB constituted a committee in 1985 chaired by B.S.Magal, IIT, Bombay to review quality control and quality assurance for nuclear power plants. The committee made a number of recommendations after reviewing the then prevailing mechanisms for quality control, quality assurance, inspection practices and their enforcement in the manufacturing of critical components for the nuclear power plants. The committee had also made recommendations regarding qualification training of QA and QC personnel and in-service inspection procedures followed in nuclear power plants and projects on safety systems.

Review of operational safety at RAPS and MAPS

In September 1989, Chairman AERB appointed a Committee chaired by N. Srinivasan, former Chief Executive, HWB to review the operational safety of RAPS and MAPS. The committee exhaustively reviewed the management, organization and administration, training, operation, maintenance, fuel handling, technical support, radiological protection, emergency preparedness, etc. The Committee made many recommendations in each of these areas which were implemented over a period of time and monitored by AERB.

Directives on Dose limits

In 1990, the ICRP came out with its recommendation, ICRP-60, wherein an additional dose constraint of 100 mSv averaged over a period of five years was suggested as against the earlier recommended standalone annual dose limit level of 50 mSv in a year (ICRP-26). Pursuant to this AERB decided to progressively bring down the dose limits applicable for Indian Facilities. In 1991, AERB reduced the annual dose limit to 40 mSv, followed by 35 mSv in 1992 and 30 mSv

in 1993. The Safety Directive issued by Chairman AERB in March, 1994 also had the limit of 100 mSv averaged over a five year period in line with ICRP recommendations.

SARCOP: The Consolidation (1991-97)

Following M.S.R. Sarma, S. Vasant Kumar served as Chairman of SARCOP and Executive Director, OPSD between September 1991 and October 1998. In 1997, he went on to become the first Vice-Chairman of AERB. There were many important events and developments during this period. Two new NPPs graduated to the fold of Operating Plants. In 1992, the NDSC completed the reviews associated with the design, construction and commissioning of NAPS reactors, first of the standardized 220 MWe PHWRs. AERB had then handed over the responsibility of safety review and surveillance to OPSD and SARCOP. The handing over involved essentially a meeting between SARCOP and NDSC, where the SARCOP and OPSD officers were briefed on the reviews done and the outstanding issues requiring follow up and a comprehensive formal document, bringing out the detailed historical and technical aspects of issues for follow up. Five years later, the safety review responsibilities of KAPS were also given to OPSD and SARCOP after satisfactory review of design, construction and commissioning stages by the KDSC (KAPP Design Safety Committee) and ACPSR (Advisory Committee on Project Safety Review), in 1997.

Technical Specifications for Other Nuclear Facilities

Previously only the NPPs, research reactors, heavy water plants and fuel reprocessing plants were having technical specifications. The basis of regulatory actions for facilities such as Nuclear Fuel Complex (NFC), Indian Rare Earths (IRE) at UCIL were essentially the Atomic Energy (Factories) Rules and the broad guidelines or principles of industrial hygiene. In 1993, SARCOP undertook the exercise of preparation of Technical Specifications for NFC, IRE and UCIL facilities. The objective was to develop a more precise basis of regulation for these facilities and their activities. It was a difficult

process to shape up the technical specifications for such facilities. The plant personnel, who were to prepare the specifications, were not familiar with the concept of technical specifications as viewed in the context of reactors or other similar facilities. After considerable efforts by the working groups and the unit safety committees, SARCOP could issue a very compact and concise document containing only requirements concerning radiological, industrial and environmental safety. These technical specifications now form a formal basis of safety requirements and regulatory reporting for these facilities.

Narora Fire Incident

March 31, 1993 saw an event, which caused a significant change in the manner in which issues of potential for common cause failures and quality assurance were approached by AERB and also significantly altered the style of regulatory functioning of AERB. The event involved a major fire in the turbine building of NAPS unit-1, that resulted in a total loss of power to the unit for over 17 hours.

The incident was initiated by failure of two turbine blades in the last stage of the low pressure turbine, which resulted in severe imbalance in the turbo-generator leading to rupturing of hydrogen seals and lube oil lines, leading to fire. The fire spread to several cable trays, relay panels, etc., in a short duration. The operating crew responded by tripping the reactor by manual actuation of primary shutdown system within a minute of the turbine failure and also initiated fast cool down of the reactor. The fire had spread through the generator bus duct in the Turbine Building (TB) and through cables into the Control Equipment Room (CER), where fire barriers had given way. There was heavy ingress of smoke into the control room, mainly through the intake of ventilation system, forcing the operators to vacate the control room. Loss of indications due to burning of control cables rendered the supplementary control room also unusable. There was widespread damage to the power cables as well as the control cables. Hence, even though the power sources were available, neither the power supply from the grid nor from the

diesel generators or from the batteries was available to the essential equipment. This resulted in a complete loss of power supply in the Unit after about 7 minutes of the incident that continued for a period of 17 hours. During this long blackout, operators injected firewater into the secondary side of Steam Generators, with the objective of removal of decay heat from the core through thermo-siphoning in the primary side.

There was no radiological impact of the incident. The major fire was put out in about 90 minutes. The event was rated in the INES scale at level-3, mainly on account of the degradation of defence-in-depth of engineered safety features during the incident. This was one of the most serious events that the Indian nuclear industry came across till date. Soon after the event, AERB constituted an investigation committee under S.K. Mehta, then Director Reactor Group, BARC, who had also been the Chairman of NDSC earlier. Three months later the investigation committee submitted its findings and recommendations, which set in motion a spate of follow up action across the NPPs, both under construction as well as in operation.

The most prompt one was to take up immediate inspection of turbines in all the operating NPPs, which was followed by modifications in the LP turbine blade root design. The inspections indeed revealed presence of cracks in the blade roots in MAPS units. AERB had also insisted that all NPPs must establish and comply with limits on permissible vibration levels, operable grid frequency range and generator hydrogen make up rate. It also insisted the NPPs to follow a regime of pre-service inspection and in-service inspections for the turbines after specified service periods.

Based on the recommendations of the investigation committee, a large number of modifications and improvements were mandated in all NPPs, addressing various aspects covering design, operation and administrative and surveillance practices. One study was with regard to the susceptibility of the existing design and layout of NAPS,

to common cause failures (CCF), mainly due to fire as an initiating event. Consideration was given to formulate preventive measures for avoiding CCFs, as well as to the need for additional mitigating measures for assured core cooling under station blackout situations. The review, initially carried out for NAPS, was subsequently extended to cover all other operating stations and the ones, which were under construction at that time (RAPP-3&4 and Kaiga-1&2). There was a close follow up from SARCOP and OPSD, for timely implementation of the recommendations at all stations. This included a number of inspections of the plants by OPSD and AERB inspectors for verification of the 'on ground' status. The actions taken at various plants pursuant to the NAPS-1 fire incident resulted in definite improvements in the areas of prevention and mitigation of fires, plant survivability against common cause failures and emergency operating procedures to deal with station black out situations.

NAPS Unit-2, which was under annual shutdown at the time of fire incident, was not affected by the fire incident. Restart of NAPS-2 was however permitted by AERB, only after implementation of the recommended modifications. The unit was restarted in November 1993.

The fire in Unit-1 had caused serious damage to the turbo generators, the cables and nearby equipment. There was significant damage to the civil structures in the turbine building including the TG foundations, requiring very focused efforts with respect to damage assessment, development of restoration methodology and its implementation and confirmatory tests to assess fitness of the structures. Recognizing the special attention required in this regard, AERB constituted a committee of experts in Civil Engineering to carry out review and advise AERB on various aspects related to the rehabilitation. This committee went on to become the Civil Engineering Safety Committee for Operating Plants (CESCOP), a standing committee to look after the civil and structural engineering issues of operating plants.

Restart of NAPS-1 was permitted only in December 1994, after restoration of the plant systems / structures and implementation of all the outstanding recommendations of NDSC and SARCOP.

Prior to the NAPS-1 fire incident, there was no systematic programme for conducting regulatory inspection of facilities by AERB. The inspections were essentially a sort of reactive, need-based affair, mostly following some events occurring in the plants or projects. Investigations into the NAPS fire indicated that certain recommendations of NDSC made during the design reviews, particularly with respect to cable routing, were not fully implemented at NAPS. This observation, led AERB to take steps to strengthen the quality assurance organizations in the NPPs and to establish a special group in AERB, the Directorate of Regulatory Inspection and Enforcement (DRI&E), to carry out regulatory inspection and audit of the NPPs and other facilities on a regular and periodic manner.

SARRA: A paradigm shift towards Periodic Safety Reviews

An important development that took place during this period was the introduction of SARRA reviews for the operating NPPs, which could be termed as a step towards the periodic safety reviews. The operational safety reviews thus far consisted of the regular reviews, which focused mainly on the issues of compliance to technical specifications, operational events, and radiological and industrial safety performance, emergency preparedness, operational experience feed back, etc., and the special reviews undertaken following certain events / developments (some examples of the special reviews were described earlier). An elaborate multi-tiered system of safety committees was in place for conducting these routine and special reviews.

Multi-tier review mechanism

The system for review of operational safety put in place consisted of a hierarchy of Safety Committees, starting right from the plant level, at corporate level and at the level of the regulatory body. At the

bottom of this hierarchy are the Station Operation Review Committee (SORC) / Plant Operation Review Committee (PORC) or simply the Plant Safety Committees, with membership including the plant management and O&M personnel, which would review the issues of safety concerning day-to-day operation of the plants. At the next level are the unit safety committees (corporate level), which oversees a group of plants of similar attributes, with membership from the peer groups viz., the technical support organization, AERB, the designers and representation from the plants concerned. Above these committees is the Safety Review Committee for Operating Plants (SARCOP), the apex committee for safety review and enforcement for all the facilities. The system works on the principle of 'management by exception'; wherein the issues of greater significance are reviewed at the higher-level committees. The committees remain accountable to AERB, in all their reviews. These committees also receive inputs from a number of expert groups / standing committees on specific technical issues.

This unique concept, stemmed from the philosophy that self-regulation is the best form of regulation and signified a high degree of safety culture, right across all the organizations involved. The underlying logic for this system comes from the fact that the persons nearest to the problem area are best equipped to identify, assess and seek solutions; and given the necessary support, they are best equipped to resolve the problem. The problems identified, the assessments made and the solutions proposed are all subjected to peer review in all the Safety Committees. The decisions of these committees are accepted by OPSD and AERB, after ensuring that, they are in line with the safety goals, principles and requirements laid down by AERB and the mutually agreed acceptance criteria. The primary responsibility for safety rests with the plant management but it is accountable to the safety committees and AERB.

Introduction of SARRA

Internationally there were concerns on the safety of the existing

NPPs, mainly on account of ageing issues and view of the evolving safety standards and concerns, in the early nineties. IAEA had prepared a document on 'Common Basis for Judging the Safety of Nuclear Power Plants built to Earlier Standards' and IAEA Safety Guide on Periodic Safety Review of Operational Nuclear Power Plants. With these developments in the background, in 1993, AERB decided to establish a system of 'Authorization for Operation of NPPs'. It was envisaged that the authorization for operation should have validity of a maximum of five years, beyond which the NPP would have to carry out a self-assessment according to the laid down procedure, prepare a Safety Assessment Report for Renewal of Authorization (SARRA) and submit it to the AERB for review. Detailed guidelines were given by AERB, bringing out the objectives and guidance for conducting the self-assessment and preparation of SARRA. The reviews were to cover performance of the plant and operational problems, events, in-service inspections, radiological safety including exposures and releases, environmental impact, reliability of plant systems, plant modifications, status of implementation of regulatory recommendations, status of documentation, generic safety issues and public concerns.

SARRA of Older Plants

The first round of SARRA review was conducted for the older NPPs, TAPS, RAPS and MAPS in 1993. For NAPS, it was done in 1996. The unit safety committees reviewed the SARRA and the issues identified for resolution and remedial actions. When the SARRA for the older plants was taken up, it was realized that guidelines had not provided for any systematic approach for addressing issues related to ageing and shortcomings with respect to 'current safety practices'. For TAPS, RAPS and MAPS, there were issues like absence of high pressure emergency coolant injection systems, safety related systems being shared between units, inerting of primary containment of TAPS, issues related to life management of coolant channels, problems of embrittlement of end shields, etc. Almost all of these issues were

already known and there were recommendations made in the past, from SRC and SARCOP and also by the TMI and Chernobyl Taskforces. As part of the SARRA review, SARCOP brought up all such issues to the consideration of the Board of AERB.

The Safety Issues

Pending resolution of the issues brought up during SARRA, AERB did not take any decision regarding renewal of authorization. AERB however was getting concerned about such issues remaining unaddressed and the trend of certain important recommendations made by SRC and SARCOP pertaining to many of the plants, not only NPPs, remaining pending for a very long time. In this backdrop, AERB prepared a compilation of the important safety issues remaining unresolved in the DAE installations, in 1995, with the objective of bringing the status of the issues to the notice of the Atomic Energy Commission. The compilation of 135 issues applicable to a range of installations came to be popularly referred in the media as the "AERB Safety Issues". Following this, a number of Taskforces were formed in all the facilities to devise and implement action plans for resolution of the issues which were classified into four categories.

Category-1: Hardware Related Issues requiring replacement of defective components.

Category 2: Ageing related issues needing elaborate studies to assess the healthiness of various components as well as possible replacement of components which have been showing signs of deterioration.

Category-3: Issues involving analytical studies or computer based calculations on certain systems to assure that the earlier designs are safe.

Category-4: Upgradation Related Issues- Plants that have been built to earlier safety standards require an upgradation according to the current safety standards and this may involve assessment and modification.

With substantial efforts put in by the concerned facilities, these safety issues could be satisfactorily resolved in the next few years.

SARRA of NAPS

The SARRA of NAPS taken up in 1996 could be completed without much difficulty, as it was a relatively new plant, devoid of any issues of ageing and/or changing standards. The issues were mainly of management operational problems. Based on SARRA, its authorization for operation was renewed for five years.

Based on the experience of SARRA, AERB initiated preparation of two new safety guides on (a) Renewal of Authorization for Operation of NPPs (AERB/SG-O-12), which had given the requirement of an elaborate Periodic Safety Review (PSR), as prerequisite for renewal of Authorization and (b) Life Cycle Management of NPPs (AERB/SG-O-14).

Incidents: 1993-1998

The period between 1993-1998 saw certain incidents at the facilities other than NPPs and some enforcement actions being taken by SARCOP. The major ones pertain to: (a) Leakage of radioactive effluent containing Caesium-137 from the regenerant concentration tank (TK-9) of Waste Immobilisation Plant (WIP), Tarapur, in May 1995, (b) Fatal accidents of workers at the IREL's sand mining facilities at Manavalakurichi, Chavara and OSCOM, (c) Failure of the Zirconium Reduction Retort at the Zirconium Sponge Plant, NFC, (d) Fire incident in the ventilation duct of Zirconium Fabrication Plant, NFC, (e) Fuel handling incident of April 12,1994, at the CIRUS research reactor in BARC, (f) Incident of an irradiated fuel getting stuck at the dissolver port in Plutonium Plant, BARC, on March 18,1994, (g) Fire incidents at HWP, Baroda on June 22, 1994 and Heavy Water Plant (Tuticorin) on February 14, 1995, (h) Incidents of leakage of Hydrogen Sulphide gas in September 1996, at HWP (Kota), (i) Fire incident

on March 14, 1998 at HWP Kota, involving burning of nearly 800 drums of sour oil stored at the site; and (j) problem of build up of tritium activity in Moticher Pond at KAPS site.

Failure of Zirconium Reduction Retort, NFC

SARCOP suspended operations of all the retorts at Zirconium Sponge Plant of Nuclear Fuel Complex because of an incident in which the top cylindrical body of a retort got separated from the bottom dished end and fell down. The failure was due to the poor quality of fabrication; the circumferential weld joint of the retort cylindrical body to the dished end had lack of fusion at some places, underwent sensitization and intra granular stress corrosion cracking. It appeared that radiography of the weld joint was not carried out. SARCOP permitted NFC to resume operation of ZSP using retort No.12Q with the stipulation that the retort shall be examined after 3 reduction runs by radiography, ultrasonic testing and in-situ metallography to assess any deterioration and further operating life. Clearance for further operation was based on the review of the results of these examinations.

Hydrogen Sulphide Leak: HWP (Kota)

At the HWP, Kota, three incidents occurred in quick succession: overflow of solar evaporation tank containing sodium sulphate, leakage of hydrogen sulphide gas and tube leak of a heat exchanger which resulted in hydrogen sulphide concentration in the nearby equipment area upto 50 ppm. While reviewing, SARCOP observed that these incidents have originated from procedural deficiencies, insufficient investigations, insufficient analysis of the root cause, inadequacies in surveillance programme and training as reflected by poor operator response in mitigating the consequences of the incidents. Taking serious view of the overall situation, SARCOP directed on October 16, 1996 that the plant shall be shutdown and an action plan drawn up urgently and implemented to rectify the deficiencies; HWP (Kota) would be allowed to restart only after a

review of the actions carried out and assurance for safe operation of the plant is obtained. The plant remained shut down on account of this directive till clearance was given on December 12, 1996, after satisfactory implementation of the corrective measures.

The Last Decade: Challenging Times

The period since 1998 had been very important in the history of regulation of operating plants in India. There were many important initiatives and developments during this decade. Four new NPP units entered the fold of operating NPPs under safety review coverage of SARCOP and OPSD, namely Kaiga Generating Station (KGS)-1&2 and RAPS-3&4, between 1999 and 2000. This was followed by the TAPS-3&4, the 540 MWe PHWRs, in 2006. There were a number of NPPs of older design, which were to be dealt with, particularly the NPPs at TAPS, RAPS and MAPS. These plants required careful reviews and assessments from the considerations of ageing and issues of life extension and long term operation.

Following S. Vasant Kumar, in October 1998 G.R. Srinivasan became the Chairman of SARCOP and the Vice-Chairman of AERB. He continued to serve in these capacities till his superannuation in December 2002. In April 2000, S.K. Chande replaced Naresh Kumar Jhamb, as the Member Secretary of SARCOP. In January 2003, S.K. Sharma took over the position of Chairman SARCOP and Vice Chairman AERB. He continued in these capacities till July 2004. He was followed by S.K. Chande, the present Chairman of SARCOP and Vice-Chairman AERB. Along with this R. Venkataraman became the Member Secretary of SARCOP.

In 2000, the Department of Atomic Energy had effected a reorganization, in which the safety review and regulatory responsibilities concerning the BARC facilities, which were involved in the strategic activities, were transferred to an internal safety review structure within BARC. With the internal reorganization of AERB

happened in the same year, the responsibility for all aspects of safety surveillance, including regulatory inspections, with respect to NPPs and IGCAR facilities being given to OPSD and the same for Industrial and Nuclear Fuel Cycle Facilities being given to the Industrial Plants Safety Division (IPSD).

En-masse Coolant Channel Replacement and Safety Upgradation of RAPS-2

Between 1995 and 1998, RAPS Unit-2 underwent the en-masse coolant channel replacement (EMCCR), wherein the old Zircloy-2 pressure tubes were replaced with pressure tubes of Zirc-2.5% Niobium material, with four tight fit garter springs. The EMCCR was a major activity, involving cutting, removal and disposal of highly active, irradiated pressure tubes from the reactor core and re-installation and qualification of new pressure tubes, akin to a part decommissioning and part construction operation, worse being done with significant background radiation levels, was being undertaken for the first time in India. The job was expected to last for more than three years. The activity required development of procedures, tools, waste management methods and facilities and elaborate acceptance criteria. The entire job of EMCCR was carried out under close regulatory control and supervision of the RAPS-MAPS Safety Committee and SARCOP.

A dedicated Review Group was constituted by SARCOP for detailed review of all aspects related to the EMCCR campaign. The regulatory aspects included (a) identification of clearance stages for the activity, (b) review and qualification of various tools, procedures and personnel, (c) inspection, health assessment and qualification of the components that will be retained for further operation, (c) issues related to handling and disposal of the radioactive components removed from the reactor, (d) collective dose budget and performance, (e) aspects related to preservation of other plant systems during the extended outage period, (f) design safety review of the components being replaced.

SARCOP had asked NPCIL and RAPS to implement the safety related upgradations and health assessment related activities, identified / recommended as part of the safety reviews carried out in the past, during the long outage of EMCCR. This subsequently became the norm for all the plants going for EMCCR. In RAPS-2, a number of upgradations and inspections were carried out during the EMCCR outage. The important ones were,

- Incorporation of high-pressure emergency injection system to ECCS
- Provision of Supplementary Control Room
- Provision of additional Diesel Generator for catering to essential safety related loads in case of floods
- Segregation of Power and Control cables
- Inspection of elbows in PHT feeders and repair of feeders having reduced thickness margins
- Inspection and assessment of health of Steam Generator
- Provision of dedicated instrument air for essential loads in case of SBO and provision to isolate air supply to non-essential loads inside Reactor Building, in case of LOCA, to avoid re-pressurisation of RB
- Provision of additional relief valve for Bleed Condenser.

The regulatory reviews and clearances for recommissioning and restart of the unit after the EMCCR and upgradations were done in a manner, which was very similar to the processing of regulatory clearances for a new reactor. The EMCCR and upgradation jobs of RAPS Unit-2 were completed in April 1998. On May 5, 1998, when the commissioning activities were in progress, one of the moderator heat exchanger of the unit developed a tube leak, resulting in release of nearly five tons of moderator heavy water containing about 2600 TBq of tritium activity to Rana Pratap Sagar Lake. When the tube failure took place, as the condenser cooling water pumps were not in operation, there was no dilution of the released activity, resulting in pockets of excessive tritium activity in the water body. Though

the activity released to the environment exceeded the technical specification limit prescribed for RAPS, the total radiation dose to the members of public due to this release was estimated to be about only 2% of the limit prescribed for the member of public. Following the event, SARCOP / AERB held up restart of the unit for nearly a month, pending investigations of the cause of the tube failure, detailed inspections, restoration and re-qualification of the heat exchanger.

As a result of this incident, SARCOP started enforcing measures such as (a) augmented in-service inspection of the heavy water heat exchangers at RAPS (b) early replacement of the defective heat exchangers and (c) sampling and analysis of the process water at increased frequencies.

Dealing with the Y2K Problem

At the turn of the century, "Y2K fever" appeared globally and nuclear industry was no exception. A small mistake of an earlier era practice of using only two digits to represent the year 19XX, carried forward by the computer programmers, was threatening to pose a serious problem. The millennium computer bug held the potential to disrupt the operations of infrastructure and public service systems wherever embedded computer systems were used which might calculate the change of date as 1900 instead of 2000, on transition into the 21st century. IAEA like many other international bodies made concerted efforts to raise Governmental and public awareness about Y2K issues and to exchange more and more information and experience, to head off the problems and to help set up contingency plans. Its public information system directory included Agency's Action Plan, a technical guidance document on nuclear safety for achieving Y2K readiness and technical documents related to nuclear and radiation facilities.

Towards the end of the year 1998, SARCOP initiated a programme for dealing with the issues of Y2K in Indian NPPs, Research Reactors

and Heavy Water Plants. The plan involved compilation of inventory of Computer Based Systems, their safety classification and Y2K readiness status, assessment, remediation and contingency planning, in line with the IAEA guidance on Y2K compliance. These activities were undertaken within the close coordination and supervision of a dedicated Y2K Committee constituted by SARCOP. The simplistic approach for dealing with the apparently complex issue of Y2K in the context of nuclear and radiation facilities was to treat it as a potential common cause failure which could affect the computer based plant systems.

AERB also established a nodal contact point for monitoring the status at all plants and facilities and to deal with any developing situation, at its Headquarters in Niyamak Bhavan, on the night of Y2K rollover. All members of AERB Y2K committee and experts from BARC, NPCIL and HWB were present at nodal contact point. The control room at nodal contact point was activated from 2000 hrs on 31st December 1999 to 0300 hrs on 1st January 2000 and the Y2K rollover status of all the plants were closely monitored. The monitoring involved predefined checks on the relevant systems at all plants, before and after the rollover. Contrary to the fears, the Y2K rollover occurred smoothly in all the DAE nuclear plants and Facilities without any event. The nodal contact point also functioned as a point for exchanging information on status of operating NPPs with international counterparts including the CANDU regulators and the International Y2K Early Warning System (YEWS) of USNRC. The AERB nodal point received advance information on Y2K transition in Eastern Countries like Korea and Japan, where the transition to the new millennium occurred several hours earlier. After successful Y2K rollover in India, an 'all normal' message was sent to the YEWS and CANDU regulators, through e-mail.

The Y2K rollover was smooth but it raised many a technology management issues, pot holes and challenges to uncover and resolve, in dealing with this black box technology and role of the regulatory

bodies, to contain and control the cyber space infrastructure problems. It raised issues of bugs hidden in the embedded systems and the need for thorough validation and verification of software based systems. It also gave a feel of the complex problems the high technology systems, wherein the operating staff may feel helpless in dealing with unforeseen situations, due to lack of full understanding of the underlying technology.

Comprehensive Safety Review of TAPS-1&2 for Long Term Operation

As said earlier, the first round of SARRA reviews carried out for TAPS-1&2 reactors raised many issues. In the year 2000, after completing more than 32 years of operation, SARCOP and AERB directed TAPS to undertake a comprehensive assessment and review of safety for continued long-term operation of the units taking account of the actual condition of the plant vis-à-vis prevailing safety requirements. The review was required to address the aspects such as the design basis, safety analysis, operating experience and ageing management and residual life assessment. Subsequently AERB asked NPCIL to carry out a level-I Probabilistic Safety Assessment (PSA) and seismic re-evaluation also, as part of the comprehensive review.

The reviews were done based on the guidelines/approach as outlined in the AERB Safety Guide on Renewal of Authorization for operation of nuclear power plants (AERB/SG/O-12), which was then under draft stage. In addition, guidance from the NPC Headquarter instruction on 'Ageing Management of NPP components, systems and structures important to safety' and the IAEA INSAG-8 on 'Common Basis for Judging Safety of NPPs Built to Earlier Standards' and the USNRC standard review plan for review of safety analysis reports for NPPs (NUREG-800) were also utilized. A large number of reports were prepared based on these reviews, which were subsequently reviewed by TAPS Safety Committee and SARCOP. Some of the salient findings of the reviews are as follows.

Review of design basis and safety analysis

For review of design basis, each system was reviewed against the applicable general design criteria specified by US NRC. The review also covered aspects such as conformance with single failure criterion/ redundancy, defence-in-depth, physical and functional separation of components and common cause failure vulnerabilities. These assessments considered the effect of non-conformances on safety function capability, frequency of initiating events and the associated potential consequences. Insights from the results of a Level-1 PSA were also used for these assessments.

The safety analyses were redone using current analytical methods and state of art analytical tools, for enveloping cases of postulated initiating events (PIE). The safety report was updated to include these fresh analyses and the design modifications/ back fits. The revised analysis showed that the safety criteria were met with good margin for situations within the design basis. This scenario did not pose any potential threat to the containment integrity, as the hydrogen generation would be insignificant. The safety analysis also showed that inerting of containment might not be necessary for Design Basis Accidents (DBA).

The modern day safety requirements for NPPs call for consideration of severe accidents. For addressing this aspect for TAPS, a scoping analysis was carried out with the objective of identifying the scenarios requiring detailed realistic assessments, experimental work and development of severe accident management strategies. Based on this scoping analysis, further work in this direction is presently in progress.

Ageing management and operational performance

As part of this review, an exhaustive ageing assessment and management programme was worked out for the system, structure and components (SSCs) of the units.

First order assessments based on the results from examination of the surveillance specimens indicated that the Reactor Pressure Vessel material had adequate fracture toughness to assure safety of the pressure vessel. To address the issue of health of uninspectable welds of the reactor vessel, programmes were initiated for conducting a detailed fatigue analysis of the reactor vessel and also development of techniques and tooling for facilitating remote inspection of some of the welds in the reactor vessel. The other non-replaceable components viz., the primary containment, reactor building, the suppression pools, common chamber, and other civil structures were accessible for inspection and were found in healthy state. Detailed programmes have been finalised for taking up periodic inspection and health monitoring of these and all the other important SSCs, as part of the ageing management programme.

Seismic re-evaluation

Seismic re-evaluation of structures, systems and components (SSC) of TAPS was carried out for the latest ground motion parameters derived for the TAPS site. Re-evaluation of safety systems and safety support systems was done using seismic margin assessment method considering the ductility and damping factors given in IAEA Safety Reports Series No. 28 on 'Seismic re-evaluation of existing nuclear power plants'.

Based on these reviews and assessments, which were completed in 2003, requirements for safety upgrades were identified. The important ones among them were

- Extensive modification in the emergency power supply system for the station that included three new diesel generators of higher capacity and unit-wise segregation of power supplies to obviate common cause failures
- Segregation of some other shared systems such as shutdown cooling system and fuel pool cooling system;
- Addition of an independent set of CRD (Control Rod Drive)

pumps to strengthen the emergency feed water supply to the reactor;

- Addition of a supplementary control room; and
- Extensive upgradation of fire protection system.

These upgradations were implemented in the station during a planned long shutdown of both units of TAPS-1&2, between October 2005 and February 2006. Based on the findings of the comprehensive review and the safety improvements achieved through the upgradations and ageing management actions, which had satisfactorily addressed the outstanding safety issues, AERB renewed the authorization for operation of TAPS units in February 2006.

En-masse Coolant Channel Replacement and Upgradations in MAPS Units

During the EMCCR work at MAPS-1&2, several important upgradation were undertaken to enhance the safety of the units. These included:

1. Retrofitting of high pressure injection in Emergency Core Cooling System
2. Incorporation of Supplementary Control Room
3. Incorporation of sensitive leak detection system for coolant channels
4. Up-gradation of fire/smoke detection system
5. Installation of fire barriers, fire walls/doors in critical areas
6. Segregation of power and control cables for safety related systems

Taking advantage of these long outages, MAPS had also taken steps to implement some modifications, with the objective of improving performance and availability of the Units. The important among these were:

a. Replacement of steam generators, in view of the tube leaks making a significant part of the heat exchanger section unavailable and discovery of age related degradation caused by under deposit pitting corrosion of the tubes.

b. Installation of Spargers for moderator inlet to the calandria, to restore the design intended moderator flow configuration.

Subsequent to these upgrades and after detailed assessment of margins and regulatory reviews, AERB permitted operation of MAPS units up to 100% FP.

NAPS Safety Upgradation

The NAPS unit-1 underwent EMCCR during the period November 2005 – December 2007. Here too there were many upgradations / modifications implemented during the outage, the important ones being:

1. Replacement of PHT feeders
2. Provision of venting of end shields to obviate degradation of shielding efficacy during operation.
3. Installation of back up dew point sensors in Annulus Gas Monitoring System (AGMS), to improve reliability of pressure tube leak detection system
4. Upgradation of fire detection and alarm system
5. Replacement of existing moderator pumps with canned rotor pumps
6. Replacement of motor-generator sets with solid-state inverters
7. Replacement of existing analog type process controllers with microprocessor based controllers
8. Replacement of existing liquid poison tanks of Secondary Shutdown System

Periodic Safety Review (PSR)

As mentioned earlier, following the experience of SARRA reviews, AERB initiated preparation of a Safety Guide on Renewal of

Authorization for Operation of NPPs (AERB/SG-12). The Safety Guide was published in the year 2000. In the year 2002, AERB had formally instituted a programme for renewal of authorization for operation of NPPs based on a detailed Periodic Safety Review (PSR), as per the requirements laid down in the Guide. The programme envisages conduct of PSRs for every NPP at a periodicity of once in ten years as of present. However, taking into account the legal considerations governing issue of authorizations, which stipulates a maximum validity period of five years for the authorizations, the programme provided for a limited scope review called Application for renewal of Authorization (ARA), for the renewal intervening the PSRs.

The requirements of PSR stipulated in the AERB Guide are much in line with the IAEA Safety Guide IAEA/SG/O-12 on Periodic Safety Review. The PSR envisages safety assessment, covering a number of safety factors, eleven of them, taking account of the aspects such as improvements in safety standards and operating practices, cumulative effects of plant ageing, modifications, feedback of operating experience and development in science and technology. As per the requirement of PSR, the utility is required to carry out a comprehensive review covering the identified safety factors. The purpose of the review by the utility is to identify strengths and shortcomings of the NPPs against the requirements of current standards. Modifications or upgrades required to compensate for safety significant shortcomings should also be proposed as part of review. The report on the PSR is subjected to regulatory review, in the multi-tier review process established in AERB, for satisfactory resolution of the shortcomings.

The ARA on the other hand requires only a limited scope review of certain important aspects of plant operation such as safety performance, operating experience feedback, in-service inspection and major modifications carried out during the reporting period. The intent of such a review is to detect and monitor the trends of early signs of degradations, if any.

As per this programme, the Periodic Safety reviews of NAPS, KAPS and MAPS units were carried out in the years 2003, 2004 and 2005-06 respectively. These PSRs demonstrated that the safety status of these plants is satisfactory and there were no major shortcomings with respect to the current safety requirements / practices which have significant safety implications. However, based on the issues arising out of these PSRs, many improvements were initiated. Important among these were:

- Revision and updating of Safety Analysis, using state of art analytical tools/methods, addressing the current plant configuration and current list of initiating events
- Development and implementation of systematic programmes for Ageing Management and maintenance of Equipment Qualification
- Development and Implementation of action plans for reduction of Collective Dose
- Revision of Technical Specifications based on the operating experience
- Optimization of In-service Inspection Programme
- Seismic Re-evaluation of old generation PHWRs (RAPS and MAPS)

Impact of Tokai-mura accident

On September 30, 1999, a criticality accident occurred in the nuclear processing facility at Tokai-mura, Japan, in which three workers received very high radiation doses, resulting in the death of one of them. The accident occurred when the workers added about 16 kg of enriched uranium containing 18.8% of uranium-235, in a single tank, instead of the maximum permitted quantity of 2.4 kg, in violation of the approved procedure. SARCOP reviewed this accident and its relevance in the Indian context, in particular to the plants engaged in fuel fabrication and spent fuel reprocessing. SARCOP noted that these plants in India are designed conservatively with adequate safety margins to ensure that criticality incidents do not occur

during operation. They are operated by duly trained and authorized operators as per approved procedures. In addition, continuous monitoring by the Local Safety Committee and periodic inspections by AERB ensured safe operation of the plant. However, as a prudent measure, SARCOP directed these plants to carry out a formal review of the design, procedures, internal audit, documentation, training and administrative controls to ensure criticality safety of the plant.

Incidents: 1999-2007

This last decade saw many interesting developments, events, issues and enforcement actions. The important ones among these were the incident of radiation overexposure of a person at RAPP Cobalt Facility (RAPPCOF) on October 15, 1999, following which the facility underwent intense scrutiny and safety upgrades, Steam Generator tube leaks in NAPS and KAPS units, incident of partial flow blockage in one of the coolant channels in RAPS -3 in May 2002, The Bhuj earthquake of January 26, 2001, the impact of Tsunami on December 26, 2004 at MAPS, the reactor power oscillations and modifications in the reactor regulating system in TAPS-3&4, the incident of red-oil explosion at New Uranium Oxide Fuel Plant (NUOFP), NFC on November 17, 2002, incident of failure of ash pond and failure of coal transfer rope way at HWP- Manuguru, etc. All these events were closely monitored by AERB. Some of these events are listed below.

Over Exposures at RAPPCOF

On October 15, 1999 two employees received external gamma radiation dose of 438.8 mSv and 40.5 mSv respectively at RAPP Cobalt Facility (RAPPCOF) at Rawatbhata. These persons were involved in taking out a shielding flask from the hot cell wherein 63 kilocuries (2.33 PBq) of cobalt-60 source sub-assemblies were lying unshielded on the hot cell table. The operator had opened the shielding door of the hot cell without noticing the presence of unshielded sources on the cell table. The employees got exposed to radiation from the open

source in a short span of time before they realized the presence of the unshielded source in the cell. A Special Committee constituted by AERB investigated the incident. The Investigation Report indicated gross deficiencies in hardware, safety interlocks and radiation monitoring equipment; lack of procedural and administrative controls, lack of health physics coverage, lack of adequate training of personnel and inadequate documentation. In the light of these findings, SARCOP directed that the operation of the facility should remain suspended. Resumption of operations at the facility was permitted only after incorporating a number of safety related modifications, retraining and re-authorization of all plant personnel and a thorough review of the facility for safe operation.

Red Oil Explosion at NFC

During the early hours of 17 November 2002, an explosion occurred in the evaporator section of the solvent extraction plant of New Uranium Oxide Fuel Plant (NUOFP), NFC. No persons were injured. A preliminary review of the incident was done by SARCOP and subsequently Chairman, AERB constituted an investigation committee under the Chairmanship of S.K. Ghosh, Head, Chemical Engineering Division, BARC. SARCOP directed that till the investigations were completed and corrective measures were taken, operations in the wet section of NUOFP should remain suspended.

As per the investigation committee's report, the carry over of organic solvent into the evaporator along with the use of steam higher than set pressure resulted in rise in the temperature of organic-nitrate complex above 130 deg. C, taking the reaction into a run away mode and thereby leading to red oil explosion. SARCOP reviewed the report and endorsed the recommendations made by the committee. Only after the inspection by a team constituted by SARCOP, the permission to restart the operation was granted. Presently, process modifications have been carried out to eliminate the chances of red oil explosion.

Failure of Ash Pond at HWP, Manuguru

On January 17, 2004, there was an incident of breach in the bund of ash pond number 1 at HWP, Manuguru, resulting in escape of fly ash slurry from the pond into the public domain. About 19.5 acres of cultivated land and 8.5 acres of barren land were affected. The slurry discharge was brought under control in two days. It was established that the failure of the bund was due to improper drainage provision of water from the ash pond. This deficiency led to accumulation of excess water in the pond and the resulting hydrostatic pressure initiated the failure. HWB undertook failure analysis of the ash pond dyke and proposed a methodology for repair of the breached portion of the dyke. The report on the analysis and proposals for repair of the breached portion were reviewed by CESCOP and SARCOP. Based on the review, SARCOP granted clearance to undertake the repair and asked HWP to undertake a study to establish stability of the existing ash pond bunds and implement a maintenance program for the ash pond bunds. The plant was also asked to study the liquefaction potential and slope stability under seismic loading. Consequently, the ash pond bunds were strengthened and a programme for periodic maintenance and surveillance of the bunds is being followed.

KAPS-1 Incident of Regulating System Failure

On March 10, 2004, there was an incident involving failure of reactor regulating system resulting in uncontrolled increase in reactor power in KAPS-1. Prior to the event, reactor was operating at 75% FP. During the event, the power supply to all the adjuster rods of the reactor failed while preventive maintenance was being carried out on power UPS-1. Consequently, the reactor power started increasing and the reactor tripped on 'Steam Generator delta T high'. The incident did not cause any damage to the plant and there were no radiological consequence. The event was rated at level-2 as per INES. The initial investigations and analyses could not adequately explain the reasons for increase in the reactor power encountered during the incident. Noting this anomaly, AERB had asked the affected Unit to be maintained under

safe shutdown state till the underlying phenomena that resulted in this event was fully investigated and understood. Subsequently a Committee constituted by SARCOP carried out investigations and analyses on the event, which revealed certain new phenomena, which were not realised earlier.

At the time of the incident, KAPS-1 was being operated at a reduced power of 75% FP, in a peaked flux configuration, instead of normally followed flattened flux configuration. This was adopted as a policy of NPCIL at that time, in all PHWRs to maximize the utilization of the available natural uranium fuel. Due to this, there has been significant increase in the average in-core burn up of fuel, which was at 4900 MWD/T as compared to the normal value of about 3000 MWD/T, under the design intended flattened flux configuration. Analysis carried out taking account of this and the latest detailed neutronic cross section libraries, as recommended by IAEA showed that the reactivity feedback coefficients existing at the given reactor configuration differed from the ones that were considered in the design. After accounting for this, the behaviour of the reactor during the event could be explained. The review of the incident and investigations in AERB had also brought out several other shortcomings, in the form of deficiencies in areas of human performance and configuration of power supplies to reactor regulating system.

A number of corrective measures were identified to address the deficiencies observed in this event and to improve the safety culture and operating practices in NPCIL and its stations. These involved modifications in hardware, procedures, training and management systems. The specific measures taken at KAPS and other reactors included;

- Formal and elaborate retraining and re-licensing of all the frontline operating staff and the station management personnel. The training covered the safety aspects related to operation of the reactor in the peaked flux configuration, the reactor regulating system and safety culture.

- Establishment of a computerized operating experience feedback sharing system.
- Modification in the automatic liquid poison addition system to prevent manual inhibition.
- Modification in the configuration of power supplies to reactor regulating system.

AERB had stipulated that the operations of both KAPS Units could be permitted only after all the identified short-term measures were completed. As directed by AERB, KAPS Units remained shutdown till June 2004, for implementation of the identified actions. Restart of the unit was permitted in the first week of June 2004, after ascertaining the satisfactory implementation of the identified measures. Implementation of the actions arising out of the event was taken up in other units also.

Effect of Tsunami on MAPS

The Tsunami waves hit the east coast of India on the morning of December 26, 2004 and had affected the operation of MAPS Units, located at Kalpakkam. Unit-2 was operating while Unit-1 was under long shutdown for enmasse coolant channel replacement and safety upgradations, since August 2003. The water level in the seawater pump house of the plant had risen causing tripping of Condenser Cooling Water (CCW) pumps. The reactor was brought to cold shutdown state by following the emergency operating procedure. The increase in water level in pump house during tsunami made all the seawater pumps located in this area unavailable. Further, cooling of the reactor of MAPS Unit-1 and different loads were achieved by using the firewater system.

The damage caused by the tsunami was limited only to the peripheral areas, such as damage to the cement-brick wall at the plant periphery on sea side and inundation of roads on the east side of turbine building.

After a detailed review of the impact of tsunami, AERB permitted to restart the operation of MAPS Unit-2 in January 1, 2005. The Tsunami has brought out some important issues, which need detailed review and follow up in the context of safety of NPPs in the event of natural calamities. The telecommunication links to MAPS and Kalpakkam site had suffered severe degradation as the telephone exchange of Kalpakkam was damaged due to Tsunami. In the light of this experience, NPCIL had been asked to augment the communication facilities at Kalpakkam site and examine the need for providing diverse and reliable communication channels at NPP sites.

Life management of PHT feeders

Based on the reports from Canadian reactors, on the problem of thinning of PHT feeder elbows in the later half of nineties, AERB had asked NPCIL to examine the status of PHT feeders in RAPS and MAPS reactors. The inspections done in RAPS-2 which was under EMCCR showed noticeable thinning in some of the feeder elbows. Following this, a detailed exercise of assessment of residual life and repair of some of the feeders was carried out prior to restart of RAPS-2 after EMCCR in 1998. Full-scale inspection and health assessment was carried out in MAPS Unit-2 during its EMCCR, in 2003.

In the subsequent years, pursuant to the PSRs of NAPS and KAPS, SARCOP / AERB recommended instituting a programme for augmented inspections, health assessment and life management of feeders, as part of the ISI programme. The subsequent inspections and assessments indicated that the rate of thinning in some of the feeders is higher than the initially anticipated rates. The reason for the thinning appears to be flow induced erosion-corrosion of the feeder pipe. After the problem has been highlighted, NPCIL had taken a policy decision changing the material of the feeders, for better resistance to Flow Assisted Corrosion (FAC), in all new reactors. Also it was decided to use elbows of higher thickness, so as to increase the margins against FAC. NPCIL had also decided to replace the feeders

in the operating reactors, at the time of coolant channels replacement. In line with this, feeders have already been replaced in MAPS-1 and NAPS-1, during their EMCCRs. Feeder replacement is also planned for NAPS-2 and KAPS-1, which are presently undergoing EMCCR.

In RAPS-2, en-masse replacement of feeders was taken up as stipulated by SARCOP, in July 2007, after inspections and assessments indicated very low margins existing in some of the feeders.

Flow Assisted Corrosion in High Energy Piping

Following the failure of secondary feed water pipe to steam generator in KAPS-2 in February 2006, SARCOP asked NPCIL to institute a surveillance programme for monitoring the health of high-energy secondary cycle piping in all the operating reactors. Pursuant to this, a comprehensive programme was undertaken by NPCIL in all stations to monitor the vulnerable areas of high-energy piping. As per this, nearly 3000-4000 locations were identified in each NPP, where thickness gauging was undertaken, for establishing the baseline data. Programmes have also been established based on analysis of the baseline data in all plants, for future monitoring and/or replacements. Compliance to this programme at all operating NPPs is being closely followed up by OPSD.

Summing up, the safety review process of AERB had originated as part of the Nuclear Power Programme. Over the years it has been established into a matured, responsible and effective system. The regulatory system followed by AERB is unique in many respects. The safety review and regulatory mechanism as established today has the support of a large number of committees at the plant level, nearly 20 unit safety committees, more than five expert committees established as part of the multi-tiered system, under AERB and SARCOP. The presence of stakeholder representatives in the safety committees has helped in better understanding of the ground realities and

obtaining realistic commitments from the utilities. The participation of the utility representatives in decision making has been helpful in avoiding the need for coercive enforcement actions on the part of the regulator. It is often seen that having understood the concerns of the regulators, the utility voluntarily accepts the decisions taken by the safety committees and more often than not comply with the decisions in a timely manner.

The safety surveillance provided by OPSD and IPSD through its regulatory inspections and reviews has proved effective. The regulatory supervision by these divisions also ensure that the decisions taken in the safety committees are in tune with the safety goals and principles enunciated in various AERB Codes / Guides and Standards. The framework involving the Safety Committees and these Divisions of AERB has helped in evolving a decision making system which is flexible enough to adjust to the specific situations, taking into account the merit of each case, without compromising on the safety considerations.

The regulatory framework has been functioning effectively as a means of experience feed back. The system of renewal of authorizations has been effective in addressing the issues of evolving safety practices.

The safety review set up has seen a number of organizational changes, new faces came and gone, seen many developments, challenges, but evolved itself to meet all of them in a satisfactory manner. But there have been those attributes; high level of safety culture and professionalism, which remained intact all along.

Major inputs by: *S.K. Chande, N.K. Jhamb, S. Hari Kumar, P.C. Basu and R. Bhattacharya*

9

APPLICATION OF RADIATION IN MEDICINE, INDUSTRY AND RESEARCH

After Apsara and CIRUS reactors in Trombay started producing significant quantities of radioisotopes in early sixties, there was a phenomenal growth in the application of isotopes in medicine, industry and research. Soon it became apparent that the use of radiation sources in public domain warranted much greater attention than the DAE facilities which were all under the surveillance of Health Physics Division of BARC. In parallel the country was also witnessing regular induction of huge number of X-ray machines into the market virtually without any regulatory control. In fact, until the promulgation of the Atomic Energy Act in 1962, there was no agency identified with the responsibility to ensure protection from radiation generating plants such as medical X-ray units. The Section 17 of the Act specifically referred to making rules to ensure safe use of radiation generating plants and clearly it was DAE's responsibility to ensure the safety of the application of radiation sources in the public domain.

The need to educate and train the non-DAE personnel handling radiation sources and radioactive materials became imperative. It was to provide an effective radiation protection programme, Bhabha set up the Directorate of Radiation Protection (DRP) in 1963. DRP, headed by P.N. Krishnamoorthy, was under Electronics Group led by A.S. Rao as Director. P.N. Krishnamoorthy, well known for administrative acumen and organizational skill went ahead with organizing a nation wide radiological protection programme. The responsibilities of DRP included radiation surveillance in hospitals, industries and research institutions, authorization to procure sources, approval of site plan, provision of personnel monitoring services, preparation of safety standards and organization of radiation safety training programmes. In fact it was Head, DRP who was designated as competent authority under the Radiation Protection Rules, 1971.

Thus when AERB was formed in 1983, there already existed a fairly well organized safety framework in BARC in the form of DRP for the safety of radiation installations outside the Department of Atomic Energy and more importantly, P.N. Krishnamoorthy joined the Board as its Member Secretary. AERB secured several senior scientists from DRP to form a core group to jumpstart the regulatory activities in non-DAE installations. This group included I.S. Sundara Rao, K.S. Parthasarathy, D. Singh, R.N. Kulkarni, Masood Ahmad and K.R. Das.

The Board reviewed the regulatory activities carried out by DRP over the years and established a road map to streamline the activities. As per the constitution order setting up AERB, DRP/BARC was required to assist the Board in some of the essential activities. The Board noted that DRP had been playing more an advisory role than a regulatory role for the regulatory control of medical x-ray equipment and installations. AERB realized the need for establishing a firm legal basis and strong regulatory framework which included all radiation sources. This would mean promulgation of required rules, preparation of appropriate codes and guides and establishment of regulatory standards.

AERB set up an Advisory Committee on Radiological Protection in January, 1985. AERB soon issued surveillance procedures for medical application of radiation which elaborated the requirements for enforcing radiation safety stipulations in medical diagnostic and therapeutic applications of radiation. These documents were forerunners to publication of codes on teletherapy, brachytherapy and nuclear medicine.

Safety Review Committee for Applications of Radiation (SARCAR)

AERB constituted a Committee known as Licensing and Appellate Committee in October, 1987 and reconstituted it again in August 1989

with a view to streamlining the implementation of Radiation Protection Rules in all the institutions using radioisotopes and radiation sources in the country. M.V. Ramaniah (Former Chairman, DAE-SRC, BARC) was the first Chairman of the Committee.

The Committee recommended approval of Radiological Safety Officers, provided guidelines for education and training in radiation safety, reviewed and recommended "Type Approvals" of all radiation equipment as well recommended issuance of "No Objection Certificates" to such equipment imported from abroad. The committee reviewed and approved installation of plants for X-ray machines and Teletherapy units, evolved procedures for licensing of radioactive materials and registration of X-ray equipment. It reviewed and recommended applications for transport certificates for radioactive materials and reviewed the emergency preparedness plans for transport of radioactive materials. It provided norms for penal action and also to hear appeals from contending parties.

AERB classified the Radiological Safety Officers (RSOs) into three levels Level I, Level II and Level III. Among these Level III RSO is the most qualified. The Licensing and Appellate Committee reviewed the safety requirements of sources used in each application of radiation along with its hazard potential and decided the level of RSO to be designated in each category. High Intensity sources such teletheraphy units, accelerators and radiation processing units require an RSO at Level III, diagnostic nuclear medicine applications require RSO at Level II and simple diagnostic radiography unit needs to employ an RSO at Level I.

This Committee was re-constituted in September, 1991 as Safety Review Committee for Applications of Radiation (SARCAR) with A. Nagaratnam, formerly Director, Defence Laboratory, Jodhpur as Chairman. At present, A.R. Reddy, Formerly Director, Defence Laboratory, Jodhpur, is the Chairman.

SARCAR recommends granting of design/type approval of transport packages, radiation sources, radiation devices, consumer products, equipment and facilities based on safety review and assessment of applications submitted by the designers/manufactures/vendors. This Committee reviews and advises AERB on education and training programmes to meet the present and future requirements of qualified and trained manpower for radiation safety.

In addition to these functions, it reviews and recommends granting of authorizations for disposal of radioactive wastes generated in medical, industrial, agriculture and research applications under the Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987 and reviews the dosimetry in food irradiation and recommends granting of certificate of approval under the Atomic Energy (Control of Irradiation of Food) Rules, 1996. It examines the cases of safety violations and recommends corrective measures.

What is SARCOP to DAE installations is SARCAR to non-DAE installations. The only difference is that SARCOP is delegated with some powers to enforce regulatory restrictions on DAE installations. The recommendations of other committees serving the functions of Radiological Safety Division (RSD) are sent to SARCAR for review and follow up. Recommendations of SARCAR are forwarded to Chairman AERB for further regulatory action.

Medical X-Ray Installations

Regulation of medical X-ray units in the country posed an immediate challenge to AERB soon after its formation. AERB set up a seven member group in 1986 to review the existing status of radiation protection measures in medical X-ray installations. The committee evaluated the effectiveness of the existing programme by visiting a cross section of institutions. The committee observed several deficiencies such as improper layout, lack of protective accessories, inadequate training of staff, etc., prevalent in various X-ray installations.

AERB organized a national seminar in March 1986 on "Radiation Exposures in Medical X-ray Practices: Consequences and Control". The invitees included Health Secretaries, Directors of Health Services and Directors of Medical Education from State Governments, representatives from regulatory agencies, standards organizations and professional associations, eminent radiologists, X-ray equipment manufacturers, physicians, radiological safety officers, medical physicists and other professionals.

Recognizing the need to evolve a broad consensus on the regulatory steps to be enforced, A.K. De, Chairman, AERB set up a specialist committee in 1985 under the Chairmanship of Arcot Gajaraj, an eminent radiologist and the then Director of Barnard Institute of Radiology, Chennai to prepare a comprehensive report on the implementation of radiological safety requirements of medical X-ray equipment and installations. The Committee had representation from the Directorate General of Health Services, AERB and BARC. The detailed report of the committee provided practical insights into various issues and was immensely useful to AERB to draw up future course of action.

AERB decided in 1986 that certain regulatory controls were necessary to ensure safety in the design, manufacture, installation and use of medical X-ray equipment. AERB supported the Bureau of Indian Standards in the development of Indian Standards for medical X-ray equipment. The Bureau issued the following standards in 1986:

1. Standards specification for diagnostic X-ray equipment, Part 3 -Radiation safety requirements.
2. Standards specification for radiation safety of dental X-ray equipment.

The total number of X-ray installations in India was not known accurately then. A. Gopalakrishnan, then Chairman AERB secured the support of Council of Scientific and Industrial Research (CSIR) and

Defence Research and Development Organization (DRDO) through a memorandum of understanding for the registration of medical X-ray machines all over the country. Six laboratories of CSIR and 15 laboratories of DRDO participated in the programme.

AERB arranged six orientation programmes in 1994 covering various safety related aspects to train 125 inspectors from CSIR and DRDO for collecting the above data. Chairman, AERB wrote to all State Chief Secretaries and Health Secretaries requesting their support and cooperation for the registration programme. Chairman, AERB also brought to their notice the need for enforcing AERB guidelines and requirements in the medical X-ray installations in the hospitals under their control.

AERB sent the information on AERB guidelines for medical X-ray installations to all district authorities in India through the NICNET system of National Informatics Centre requesting their cooperation. The district authorities sent addresses of medical X-ray installations located in their area. This provided the initial input to the X-ray registration programme. The inspectors from CSIR and DRDO collected data on 30,583 X-ray installations. The programme did have a tremendous impact. Now in the year 2008 the number of diagnostic X-ray units registered is around 50,000. The staff of AERB made a detailed analysis of the data collected and sent letters to all the above institutions and where deficiencies were observed, directions were given to remedy the deficiencies.

In order to improve the status of radiological safety in medical X-ray installations, quality assurance test of each X-ray unit had to be carried out and the deficiencies found were to be remedied. A quality assured X-ray unit would result in optimizing the radiation dose to patients and minimizing radiation exposure to radiation workers. AERB and Radiological Physics and Advisory Division (RPAD), BARC organized a few QA workshops for the benefit of staff in radiation units of the hospitals.

Effective control on such a widely used diagnostic tool is possible only if the regulatory responsibility is decentralized. Exercising the powers conferred by the Radiation Protection Rules, 1971 Chairman, AERB authorised Director, Directorate of Radiation Safety, Government of Kerala to carry out inspection of medical diagnostic X-ray installations in Kerala. The Directorate has been functioning for the past many years and has been submitting to AERB periodic reports about its inspection activities. AERB has been urging other State Governments to start similar Directorates to enforce the mandatory requirements in their medical X-ray installations. AERB web page carries information on registration procedure and also a list of type approved X-ray machines.

Radiation Therapy and Nuclear Medicine

With the life expectancy of the population increasing steadily over the years, there is a corresponding increase in the number of cancer patients in the country. To meet the growing demands for treatment of cancer, more and more numbers of hospitals and therapy units are added, For example, in the past five years fifty more hospitals, fifty more telecobalt units, fifty more nuclear medicine centres and sixty more accelerators have been added. Also the newer machines have several novel treatment and safety features. AERB with the help of RPAD has been carrying out the safety assessment of these units.

Gamma Radiation Processing Plants

High intensity gamma irradiators are widely used in the world on industrial scale for many radiation processing applications. These include sterilization of medical products, irradiation of food materials to prevent sprouting or rotting or to delay ripening, treatment of sewage, etc. Though the first few gamma irradiator plants were designed and operated by a DAE unit, subsequently several such units operated by private companies have come up in various states in the last two decades. In view of the very large inventory

(10^{15} to 10^{17} Bq) of Co-60 sources involved and high potential for severe exposures, gamma radiation processing plants undergo a multi-tier safety review process. AERB has issued a Safety Code on Land Based Stationary Gamma Irradiators, which specifies the various regulatory requirements to achieve safety. The safety of the gamma irradiator plants are reviewed by a Safety Committee on Gamma Irradiation Processing Facilities (SCOGRAPP) chaired by A.R. Sundararajan, former Director, RSD, AERB. The recommendations of the committee are reviewed by SARCAR before authorizations are issued by Chairman, AERB.

Particle Accelerators

Accelerators used for accelerating various atomic particles like electron, protons and heavy ions are used not only for experimental studies in nuclear physics but also for several applications in medicine and industry.

DAE facilities

Department of Atomic Energy had established a Variable Energy Cyclotron Centre (VECC) at Kolkata in 1970. This Centre has a Variable Energy Cyclotron which can accelerate protons, deuterons and other heavy ions at various energies ranging from tens to hundreds of MeV. A super conducting cyclotron, set up within the VECC premises and meant to accelerate heavy ions with energies in Giga electron volt range is in its initial stage of commissioning. VECC has also proposed to install a medical cyclotron to accelerate proton ions up to 30 MeV at 500 micro amperes current for production of PET and SPECT isotopes. This facility will also have beam lines catering to the experimental requirements of BARC and IGCAR. The project is in its construction stage.

The Centre for Advanced Technology, presently known as Raja Ramanna Centre for Advanced Technology (RRCAT) was established in 1983 at Indore. The Centre now houses several accelerator facilities like microtron, linear accelerator, DC accelerator

and synchrotron facility known as INDUS-I with 450/700 MeV at 30 mA. The second synchoroton facility INDUS-2 with 2.5 GeV capacity at 300 mA is presently in commissioning stage.

The safety review of both, VECC and RRCAT facilities is carried out by VECC-RRCAT Safety Committee (VRSC) chaired by M.R. Iyer, former Head, Radiation Standards and Systems Division (RSSD), BARC.

Non-DAE Facilities

There are also many accelerators in the private sector essentially catering to industrial and medical applications. Accelerators are fast replacing radiotherapy machines using Co-60 sources. Electron beam accelerators are used for cross linking and chain scission of polymers to improve the strength of the insulators of the cable and also to enhance their water repellant properties. M/s Radiant Electron Beam Technology Centre at Hyderabad has three electron beam accelerators with energy upto 2.5 MeV and M/s NICCO Cables Pvt. Ltd. at Kolkata has one electron beam accelerator of 3.0 MeV for irradiation of electrical cables. Also a number of medical cyclotrons have been installed in the recent times for production of medical isotopes like F-18, Ga-67, Tl-201, etc. All these units have been reviewed by Safety Committee for Medical, Industrial and Research Accelerators (SCMIRA) chaired by M.R. Iyer.

Safety in Transport of Radioactive Materials

A large number of radioactive consignments, nearly 80,000 per year, containing radioactive materials in different forms, varying nature and quantities are being transported within the country for use in medicine, industry, agriculture and research, and also for nuclear fuel cycle activities. In addition, radioactive materials are also imported and exported or pass through the country in transit. Radiation Surveillance Procedures for the safe transport of radioactive materials were formulated in 1987, which stipulated the requirements for ensuring safety to persons, property and

environment associated with such transportation. Ever since, the competent authority is approving every package deployed for shipment and only the packages of approved design are being used. Designers, manufacturers, consigners and users of such packages comply with the requirements including submission of safety report on the package design, test reports. and quality assurance manual as applicable to specific packaging or shipment. Certain shipments such as those for teletherapy sources, high activity radiation sources used for certain exposure devices, high intensity irradiators, etc., cannot be carried out without prior approval from AERB.

A Committee on Safe Transport of Radioactive Material (COSTRAM) has been constituted in May 2003 by Chairman AERB to review various safety aspects of transport of radioactive material chaired by R.G. Agarwal, Head, RTD, BARC.

Regulatory Inspection of Radiation Facilities

Inspection and enforcement activities are important components of regulatory functions of AERB. The objective of the inspection is to ensure that the stipulated regulatory requirements related to handling of radiation sources are fulfilled in practice. The then Industrial and Radiation Safety Division (IRSD), under the Directorate of Regulatory Inspection and Enforcement (DRI&E) was responsible for carrying out such inspections of all the non-DAE institutions where radioactive materials and radiation generating plants were handled and used. Subsequent to the re-structuring of divisions of AERB, the Radiological Safety Division (RSD) is responsible for carrying regulatory inspections of all non-DAE radiation facilities. RSD prepares the schedule of inspections as per the category of radiation facility which depends on its potential hazard. Plants with high intensity sources like gamma radiation processing plants are inspected once a year while radiotherapy units are inspected once in three years.

In 1994, IRSD had arranged eight teams to carry out the first ever large scale surprise inspection of about 25 industrial radiography sites located in and around the cities of Surat, Bharuch, Baroda and Ahmedabad in Gujarat State to ascertain whether the radiography sources were handled in a safe manner. Since then, such surprise inspections are periodically carried out and about 100 radiography sites / institutions located all over the country are covered yearly in this surveillance programme.

The major violations observed during the inspections include source movements from one radiography site to another site without prior approval of the Competent Authority, operation of radiography exposure devices by uncertified persons (trainee radiographers), inadequate physical security to source storage rooms, improper radiation survey instruments, non-availability of emergency accessories / safety records and not using personnel monitoring badges while carrying out radiography work. These violations are categorized into four different classes from minor to extremely serious violations with a view to streamlining the enforcement actions.

Based on these inspections and the findings thereof, AERB took action against those institutions which were found to be violating the safety norms. In some instances, the radiography sources were recalled from the offending company for a minimum period of three to six months, while further investigations continued. Radiography personnel such as Site-In Charge, Radiographer etc. who failed to carry out their duties as per AERB stipulations were asked to surrender their authorization certificates. Radiography work was suspended in a few cases by sealing the radiography exposure devices at site and directing that they should not be used until further instructions.

Enforcement and Follow-up

AERB enforces regulatory actions as per the Atomic Energy (Radiation Protection) Rules (RPR), 1971 which was revised in 2004, on the basis

of assessment of radiological risk to the radiation workers and members of the public from violations observed. The show-cause notices and warning letters are issued before enforcement of any regulatory actions. The regulatory actions to be enforced are recommended by the Standing Committee for Industrial Radiography (SCIR) which was first constituted in January, 1995 chaired by G. Venkataraman. Since then, SCIR has been re-constituted twice and now renamed as the Standing Committee for Investigation of Unusual Occurrences in Radiation Facilities (SCURF) chaired by B.C. Bhatt, former Head, RPAD.

Two radiography agencies and one of the radiography personnel challenged the regulatory actions enforced by the Competent Authority in the judicial Courts. However, in all these cases the Court has upheld the actions enforced by the Competent Authority proving the necessity of enforcement of actions in the interest of public safety.

Action against Hospital in New Delhi

In view of the lack of compliance with several safety requirements, AERB had sent a directive to the Medical Superintendent of a Hospital in New Delhi and to the Health Secretary, Delhi State on April 6, 1995 to stop accepting or scheduling any new patient for radiotherapy until such time radiation protection requirements are fully complied with. The violations by the hospital included non-appointment of a Radiological Safety Officer, in spite of repeated reminders, failure to provide personnel monitoring badges and failure to calibrate therapy dosimetry units. AERB lifted the ban imposed on the Hospital with effect in January 1996 when these deficiencies were corrected. A very similar situation prevailed in yet another hospital in Delhi in October 2003 necessitating a ban on the treatment from AERB for about a month.

Recovery of Lost Radioactive Source in Coovum River

While discharging its regulatory function, AERB did encounter a

few ticklish problems to handle and which also caught the attention of the press and the public. One such case is mentioned here.

Three radioactive sources consisting of two americium-beryllium (Am-Be) neutron sources of strength 684.5 GBq and 18.5 GBq and one caesium-137 (Cs-137) source of strength 55.5 GBq were allegedly stolen from the premises of a foreign company based in India, engaged by Oil & Natural Gas Commission (ONGC) for oil well-logging operations. The authorization to import these sources was issued by BARC to ONGC in January, 1990. The first information report (FIR) regarding theft of the sources was received on September 23, 1993 by Madras Police.

Preliminary investigations indicated that the company which was expected to keep three high activity, long half-life sources in safe and secure custody had not complied with this obligation. ONGC, the party to whom import authorization was issued, had also failed to oversee the operations to ensure the security of these sources. In view of this, AERB ensured by a directive that the foreign company suspended all its well logging operations using radioactive sources in India.

Several teams of scientists were mobilized by AERB to survey all potential areas where the miscreants could have thrown or hid these sources, extensively covering in this process over 450 km of roads in the city and surroundings. Police inquiries eventually indicated that the sources were lying in a slushy area in the Coovum river bed within Madras city limits. Specialists from the Atomic Energy Regulatory Board (AERB), Bhabha Atomic Research Centre (BARC), Oil and Natural Gas Commission (ONGC), Larsen & Toubro (L&T), Madras and the Indian Institute of Technology (IIT), Madras deliberated on various options to recover the lost sources safely. The sources were finally recovered intact after erecting a coffer dam around the region in which the sources were lying, to allow local dewatering,

and after a prolonged and tedious 'fishing' operation. There were instances in India and elsewhere in which such sources were lost in an irrecoverable manner either in the oil well itself or in areas such as sea beds. There are standard practices to manage such incidents.

After this event AERB did an extensive study of the issues involved in such operations and prepared a comprehensive document on the safety requirements for well logging operations. The Board instituted additional measures to ensure safety of such sources.

Withdrawal of Radium from Indian hospitals

Radiotherapy using radium was the most widely used mode of treatment for cancer in the early days until safer substitutes arrived. Radium was also the most hazardous of all the sources used in a therapy centre.

The earliest stock of radium in India arrived at the Radium Institute, Patna, in 1930. Sixty-five hospitals had totally about 20 grams of radium contained in the form of a fine powder in hundreds of platinum-iridium tubes and needles with a wall thickness of 0.5 mm. During those early years, several sources became leaky due to uncontrolled heat sterilisation and inadvertent rough handling. Many needles got bent when physicians applied them directly by piercing tissue. There have been several instances of mishandling of radium including the release of the body of a cancer patient without removing the sources. Many hospitals had lost their sources. Some radium sources might have leaked due to gas pressure developed internally. Starting 1957, scientists from BARC visited these hospitals to separate leaky sources. They recommended once in six months leak testing of all radium sources.

The Board of Radiation and Isotope Technology (BRIT) distributed kits loaded with caesium-137 as a safe replacement for radium. In 1988, AERB directed the withdrawal of radium from hospitals and its safe disposal in the interest of overall radiation safety. BARC collected

and disposed of the sources safely. Withdrawal of radium from India was a unique project. AERB could achieve it with the support of BARC in collecting the sources and disposing them of safely. In many countries unused radium is remaining in hospitals as final disposal is expensive and no one is willing to take the responsibility to accept them for disposal.

Management of Cadavers with Residual I-131 activity

There were a few cases where the patients administered with I-131 therapeutic doses died with high residual activities in the body. Relatives of the patient always would like to have the body for cremation immediately but from radiological safety angle, the bodies with high residual activities could not be released. These cases were managed under strict radiation protection program which included wrapping of the body in double polyethylene bags, maintaining a safe distance during transportation and burial.

Radioactivity in Foodstuffs: Regulatory Steps

The accident at the Chernobyl nuclear power station occurred on April 26, 1986. Shortly thereafter, radioactive fallout had shown up in foodstuffs in various countries. Public got concerned about the health impact of these contaminated food items. Food restrictions in European countries fuelled the fears.

Many felt that contaminated food items may be sold or gifted to third world countries. As a proactive measure, the Atomic Energy Regulatory Board (AERB), the competent authority to enforce radiation protection in India, enforced regulatory measures to protect the public from undue radiation exposures.

In order to evolve a consensus opinion of a wide cross section of specialists on radiation protection policies, AERB organized in 1987 a national meeting of senior specialists from the Ministries of Agriculture, Food and Civil Supplies, Health and Family Welfare, Commerce, Environment and Forests, Bureau of Indian Standards,

Marine Products Export Development Authority, Export Inspection Council, Tea Board, Indian Dairy Corporation, National Institute of Nutrition, Consumer Guidance Society of India, Research Institutes dealing with Food Technology, Fisheries and Toxicology and Bhabha Atomic Research Centre (BARC).

The International Commission on Radiological Protection (ICRP) had stipulated dose limits for members of the public. In the absence of other precedents to go by, the specialists group in India decided that the contribution from man made radionuclides in food items should only be a small fraction of this dose limit. This led to overly conservative values of concentrations. Based on the recommendations of the specialists, AERB prescribed the permissible levels of Iodine-131, Strontium-90 and Caesium-137 in food items.

AERB recognized three BARC laboratories at Kolkata, Kalpakkam and Trombay for measuring and certifying radioactivity in the food samples sent to them. The Directorate General of Health Services instructed their offices located at ports to send samples of imported food for testing. This covered the bulk imports of food items. BARC laboratories tested thousands of samples over the past several years. On rare occasions, when they found samples containing levels above those prescribed by AERB they issued suitable instructions.

A development, which received wide media coverage, pertained to the safety of 200 Metric Ton of Irish butter imported into India in 1987. Three office bearers of the Maharashtra State Government Employees' Federation approached the High Court of Bombay for an appropriate order banning the import of any milk or milk products and in particular butter from Ireland. After reviewing the procedure followed by AERB, the High Court rejected the petition.

On the same issue there was also a special leave petition in the Supreme Court of India. After hearing the counsels for the petitioners and respondents, the Supreme Court thought it fit to appoint a

committee of three experts namely M.G.K. Menon, P.K. Iyengar and G.V.K. Rao to give its opinion on the safety of milk and dairy products and other food products containing man-made radionuclides within permissible levels prescribed by the AERB. After perusing the opinion of the committee of experts, the Supreme Court dismissed the petition.

Currently there are many laboratories, both DAE and non-DAE which have been accredited by AERB to measure low levels of radioactivity in commodities including food materials.

In line with International Regulations

AERB derives its radiological safety standards from those of International Organizations like International Atomic energy Agency (IAEA) or International Commission on radiological Protection (ICRP). When ICRP issued in 1990 its recommendations on the dose limits to radiation workers and the members of the public, AERB decided to implement them in a phased way. The Board reviewed the data on the radiation exposures to workers in different categories, held meetings with different stake holders and issued a series of Safety Directives over the next few years to implement the recommendations of ICRP. In fact, AERB is one among the handful of countries which implemented them promptly. When AERB finally implemented the recommendations, the dose limit to radiation workers prescribed by it was more conservative than that of the ICRP. Whereas ICRP recommended an annual dose limit of 50 mSv, the limit prescribed by AERB was only 30 mSv.

An important development during the nineties was the publication of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS). These standards were prepared jointly by the International Atomic Energy Agency (IAEA), the International Labour Organization (ILO), the World Health Organization (WHO), the Food and Agricultural

Organization (FAO) and Pan American Health Organization (PAHO). These standards explicitly required licensing of fuel cycle facilities, including nuclear reactors and radiation sources used in medical, industrial and research applications.

The recommendations of BSS were taken into account while framing Radiation Protection Rules, 2004. The rules specify the functions and responsibilities of the employer, the licensee, the workers and the radiological safety officers. The regulatory consenting scheme was decided on the hazard potential of the sources. The highest level of consent was called "Licence" and covered nuclear fuel cycle facilities, high intensity radiation sources such as gamma irraditors, teletherapy units accelerators, computed tomography units, interventional radiology units, etc. The other consents were authorization, registration and approval.

Current Scenario

In the last two decades the number of radiation installations and devices has registered a phenomenal increase, be it in the application in medicine or in industry. The radiation sources/installations include 300 telecobalt therapy units, 100 accelerators, over 2,000 Computed Tomography scan units, 150 nuclear medicine centres, 1400 industrial radiography cameras, 8000 nucleonic gauges and 14 gamma radiation processing plants.

AERB has put in place an elaborate scheme to ensure that in the use of all these installations and devices, both the occupational workers and members of the public do not receive undue radiation exposures. As part of this scheme, all devices including radiation generating equipment and those incorporating radioactive sources are subjected to a type approval procedure. AERB permits only type-approved devices to be marketed in India. AERB stipulated the criteria for type approval in the Standards Specifications (SS) documents for a variety of devices. These SS documents are periodically reviewed and

revised, where necessary, in order to be in tune with internationally accepted and current standards.

Yet another major initiative AERB undertook in recent times was the creation of extensive computerized data base on the entire inventory of radiation sources used in medicine, industry and research. The system allows the tracking of any radiation source from its procurement to disposal and thus ensuring its safety and security.

Major Inputs by: *K.S. Parthasarathy, A.R. Sundararajan, S.P. Agarwal and A.U. Sonawane*

10

EVOLUTION OF INDUSTRIAL SAFETY REGULATION

Early Days

The Factories Act, 1948 lays down the provisions of industrial safety requirements in factories. The responsibility for implementation of this Act lies with the State Government. However, by virtue of the Atomic Energy Act, 1962, the responsibility for administration of the Factories Act in DAE units has been vested in the Central Government. Prior to formation of AERB, industrial safety aspects of DAE facilities were looked after by Industrial Hygiene and Safety Section (IHSS) of Health Physics Division, BARC. IHSS advised various plants on industrial hygiene and safety aspects of the design and operations. It also carried out measurements of toxic pollutants and surveyed noise and illumination levels in the working environment. It investigated industrial accidents and brought out periodic reports on industrial safety aspects of DAE facilities. The Inspection Section (Factories Act) of BARC used to enforce the provisions of the Factories Act, 1948 in the units of DAE. These sections provided the inputs to the Safety Review Committee of DAE (DAE-SRC) which had the responsibility for overseeing the safety of DAE units. However, when AERB was constituted in 1983, AERB was mandated to administer the provisions of the Factories Act, 1948 in all DAE units. Atomic Energy (Factories) Rules were first published in 1984 based on the Factories Act.

Industrial Safety Regulation (1983 – 2000)

Committees to review the Industrial Safety Status

Within few years of its formation, AERB constituted a committee in 1985 for Review of Industrial Safety Status in Department of Atomic Energy Units (RISSDAEU Committee) with M.S.R. Sarma, the then Director, Nuclear and Industrial Safety Division, AERB as Chairman. The committee held meetings with DAE organizations

and visited some of them. The recommendations of the committee were categorized as 'General', which were applicable to all units and 'Specific', which related to the facility concerned. The 'General' recommendations pertained to safety management which included safety policy, safety organization, cadre of safety, awareness and understanding statutory requirements, development of safety culture, safety training requirements, emergency plans, etc. The 'Specific' recommendations related to issues specific to plants such as augmentation of ventilation (NFC & IRE), correction of certain design deficiencies (HWPK, NFC, NAPP), management of H_2S problems (HWPK), etc.

In 1988, AERB constituted another Committee to Review the Industrial Safety Status in R&D units of DAE with H.N. Kaul, the then Executive Director, HWB as Chairman. The recommendations mainly pertained to applicability and compliance with provisions of statutory acts & rules like Factories Act, 1948, Atomic Energy (Factories) Rules, 1984 to R& D units. The major recommendations were related to safety policy, safety organization, assurance of safety, emergency planning, accident investigation & analysis, occupational health, etc.

Fire Safety Study Committee

The Committee for Fire Safety Study was appointed by Chairman, AEC in February 1991 under the Chairmanship of G.R. Balasubramanian consisting of experts in this field from AERB/ DAE and non-DAE units. The committee was appointed to identify major fire hazards, requirement or availability of fire protection system and the consequences of fire in DAE installations. The committee visited all the twenty three nuclear installations and made recommendations for improvement of fire safety for each unit. This committee was later renamed and reconstituted by Chairman, AERB as Advisory Committee on Fire Safety (ACFS) with S. Sen and later N.K. Agrawal as Chairman.

Regulatory activities related to industrial safety

In June 1987, DAE-SRC was renamed as Safety Review Committee for Operating Plants (SARCOP) and AERB designated four major divisions which included Industrial Safety Division (ISD) led by D.K. Dave and was entrusted with the responsibility for ensuring industrial safety in DAE units. From 1990 this division was headed by P.K. Ghosh. Through this division AERB started issuing formal licenses to operating personnel of HWPs after reviewing their qualification, experience and training. AERB started issuing approval to Competent Persons under the Factories Act and issuing of licenses to the industrial units of DAE under the Factories Act. AERB also designated Competent Persons under the relevant sections of the Factories Act for civil construction and structural works, operation of dangerous machines, lifts and hoists, lifting machinery, lifting tackles, pressure plant, dangerous fumes, supervision of handling of hazardous substances and ventilation system.

In January 1994, ISD was reconstituted as Industrial and Radiation Safety Division (IRSD) as a part of the Directorate of Regulatory Inspection and Enforcement (DRI&E). This division now handled the operating industrial units of DAE and their projects as well as the non-DAE activities involving radioactive sources and radiation generating equipment. In 1994, the responsibility for regulatory inspection and enforcement of Factories Act and the Atomic Energy (Factories) Rules, 1984 in DAE units was also transferred from Inspection Section (Factories Act) of BARC to IRSD and subsequently this section was merged with IRSD of AERB.

Review of the Atomic Energy (Factories) Rules, 1984

Amendments were made in 1987 to the Factories Act, 1948 as a sequel to Bhopal gas disaster. AERB had also received significant feedback from the operational experience of implementation of Atomic Energy (Factories) Rules, 1984 in DAE units. In the light of these as well as recommendations made earlier by RISSDAEU Committee, it

was felt necessary to amend the existing Atomic Energy (Factories) Rules. A committee consisting of experts from BARC, DGFASLI and AERB was entrusted the responsibility to review the Atomic Energy (Factories) Rules, 1984 and propose the amendments. The amended rules after review in AERB and vetting by various ministries of Government of India were published in the Gazette of India as Atomic Energy (Factories) Rules, 1996. In 1996, Chairman AERB for the first time designated some of the senior officers of AERB as inspectors under the Factories Act, 1948.

Industrial Safety Regulation (2000 -2008)

Following an organizational restructuring in AERB in 2000, IRSD was renamed as Industrial Plants Safety Division (IPSD). The regulatory inspections for enforcement of the Atomic Energy (Factories) Rules, 1996 are now being carried out by IPSD for all nuclear fuel cycle facilities including nuclear power plants and projects and DAE accelerator facilities.

To bring industrial safety structure at par with that of nuclear and radiation safety, the Board reconstituted the ACFS as the Advisory Committee on Industrial and Fire Safety (ACIFS) in May 2005 with H. N. Mirashi, former Director, DISH, Govt. of Maharashtra as the Chairman in line with Advisory Committee on Nuclear Safety (ACNS) and Advisory Committee on Radiation Safety (ACRS). The scope of ACIFS was now extended to include the industrial safety aspects also. In September 2008, S. K. Mukherjee, Former, Executive Director (HSE), HPCL, Mumbai took over as the Chairman of the Committee. ACIFS advises AERB on generic industrial and fire safety issues, recommends measures on industrial safety aspects for prevention of accidents at all DAE installations including projects under construction, provides guidance on the overall planning for fire prevention, detection and protection at all DAE installations, conducts final review of the safety documents being developed by AERB on industrial and fire safety and advises on preparation of new documents and revision of existing ones on the subject.

The industrial safety aspects of uranium and thorium mines were being enforced by both Directorate General of Mines Safety (DGMS) and AERB. Based on a decision by DAE and AERB to remove this dual regulation, Chairman AERB issued an office order in October 2005. As per this order, Industrial Safety in mines of DAE (where Factories Act is not applicable) would be solely under the purview of DGMS under the Mines Act.

Industrial and Fire Safety Review

IPSD prepared a checklist for Fire Safety Audit and based on this checklist AERB directed all DAE units to carry out Fire Safety Audit which is a detailed study and assessment of the fire prevention programme. The audit is required to be carried out by persons independent of the plant and the review is to be focussed on site specific requirement, depending on the hazard potential of plan operation.

During life extension review of TAPS-1&2 and MAPS, AERB carried out a detailed study on the upgradation of the fire protection systems to meet the current standards. The recommendations of the study were implemented. These studies formed the basis of fire hazard analysis for all fuel cycle facilities and formed a regulatory requirement for the consenting process. Guidelines for conducting fire hazard analysis have been incorporated in the AERB Standard for Fire Protection in Nuclear Facilities. Over the years AERB has enhanced its risk assessment capability by application of the state of the art softwares like FDS, COMPBRN-IIIe etc for fire hazard analysis and PHAST, ALOHA, SAVE-II, EFFECTS etc for chemical consequence and risk analysis. IPSD carried out fire risk assessment study for Heavy Water Plants and several hazard identification studies and consequence analysis for projects and operating units with respect to hazard potential.

IPSD regularly reviews the tri-annual Safety, Health and Environment (SHE) reports containing information on injury statistics,

fire occurrences, environmental releases etc. Safety Related Unusual Occurrences Reports (SRUOR) related to Fire and Industrial Safety events are subjected to three-tier review, namely, the Plant Safety Committee, Unit Safety Committees and SARCOP.

Occupational Health Safety Review

AERB constituted an Advisory Committee on Occupational Health (ACOH) to advise it on occupational health aspects including implementation of statutory provisions, occupational disease etc. Usha Desai was the founder Chairman of this committee. B.J.Shankar and P.T.V.Nair, former Heads, Medical Division, BARC subsequently chaired the committee. Yearly status reports on occupational health and industrial hygiene of DAE units are reviewed by this Committee. Approval of Certifying Surgeons in the units of DAE was also started from the year 1998 as per the requirements under the Factories Act and The Atomic Energy (Factories) Rules, 1996.

Fatal Accident Assessment

AERB constituted a Fatal Accident Assessment Committee [FAAC] to assess fatal accidents in DAE units and to arrive at the root causes of accident and preventive actions to be taken to avoid recurrence. Due to concern over the increase in fatal accidents at the Construction Sites of DAE, AERB issued in July 2002 the notification on "Industrial Safety Personnel at Construction Sites" which stipulates the minimum requirement of safety personnel and their qualifications. AERB also organized a discussion meeting of the plant heads of DAE in July 2004. The meet focused on the job hazard analysis for different jobs/activities carried out at construction sites. Emphasis was given on strict usage of personal protective equipment, safety training to the workers, penalty clauses in tender documents, supervision of the workplace and empowerment of inspectors. To further strengthen the industrial safety in DAE units, AERB issued another notification in November 2004 on "Empowerment of Inspectors- Power to Stop Work" in case of unsafe conditions. The minimum safety requirements needed on site were specified along with this notification.

Despite these measures, fatal accidents recurrence continued at construction sites of DAE. In view of this AERB organized a meeting with all unit heads of DAE in August 2005 to discuss various pertinent issues like lack of supervision, inadequate job hazard analysis, violation of safety norms, faulty procedures, etc. Consequently, it was decided that special regulatory inspections of all construction units of DAE shall be carried out once in every month from September 2006 onwards with particular emphasis on works at heights. These monthly inspections have helped in improvement of safety culture at construction sites and betterment of safety record.

Safety Promotional Activities

Apart from the routing regulatory activities of review, inspection and development of safety documents, AERB also instituted various schemes to encourage and promote safety in the DAE units. As a step to appreciate the assiduous efforts put by the units to improve the safety standards, AERB introduced the Safety Awards scheme. It organizes the safety professionals meet every year at various DAE sites, which not only serves as a valuable platform for exchange of information and sharing of experiences but also helps in enhancing the role and importance of safety professionals in the organization. These meetings also provide a good feedback to the regulators.

Safety Professionals Meet

The first Meeting of the Safety Professionals was held way back in June 1982 at Kalpakkam under the leadership of G.R. Balasubramanian, the then Head, Reprocessing Programme at IGCAR. The meet was attended by 9 safety professionals. Subsequently, the next three meets were also held at Kalpakkam. In the 5th Meeting of Safety Professionals, held at Mumbai in September 1988, the then Chairman, SARCOP, M.S.R. Sarma informed about the report brought out by the RISSADEAU Committee. During the meeting two major decisions were taken (i) to hold workshop at the individual units to discuss statutory requirements and their implications and (ii) to conduct a

seminar on industrial safety. As a follow-up to the meet, a one-day workshop was organized with the top management of Department of Atomic Energy at OYC auditorium, Mumbai. The requirements like commitments to the provisions for safety in tender documents, safety organization at site and headquarters, safety supervision, safety review, responsibilities of management etc were discussed in great detail in the workshop.

During this workshop it was decided that one day seminar should be conducted during the Safety Officers meet to be held at various units and an attempt should be made to bring in the local authorities like Inspectorate of Factories, etc. for participation in the two days workshop. The 6th DAE Safety Professionals Meet was held at IGCAR, Kalpakkam. It was then decided that AERB should conduct the safety professionals meet every year at various units with the help of concerned units. The 7th meet was held at Kakrapar Atomic Power Station in August 1990 and for the first time, a theme was assigned to the meet. Since then, safety professionals meets are being held at different DAE units to discuss safety issues and to share information.

The 11th Safety Professionals Meet was held at NFC, Hyderabad in November 1994. This meet was preceded by one-day seminar on "Occupational Health". The meet was attended by safety professionals and doctors of various units of DAE. During this meet, all the Medical Officers met separately to discuss the "Occupational Health Programme of DAE". It was felt that the medical officers should also be aware of the various legislations relating to occupational health and it was then unequivocally decided that all Medical Officers/Certifying Surgeons shall meet every year during the DAE Safety Professionals Meet to discuss the various issues of occupational health. This meet became the forerunner for future safety and occupational heath professionals meet. From 15th DAE Safety and Occupational Health Professionals

meet, AERB decided to arrange endowment lecture of experts in various field for knowledge up-gradation of the safety professionals. In the 24th meet it was announced that the future endowment lectures would be named as Ramaswamy Memorial Endowment Lecture in memory of the Late Dr. S.S. Ramaswamy, Former Member, AERB Board. A monograph on construction safety was also released during the meet.

Safety Awards

The Industrial safety award scheme, started in the year 1992, promotes industrial safety among various units of DAE. The safety performance is assessed based on computed value of Safety Numbers as per a pre-defined computational methodology. The unit having highest Safety Numbers is awarded in their respective group. The unit which had any fatality in a year is debarred from participating for Industrial Safety Award. Data are collected in standard formats every year from all the units for assessment of Safety Numbers.

The Fire Safety Award scheme was started in 1993 in order to promote fire safety among various units of DAE. The safety performance is assessed based on computed value of Preventive Efforts and Fire Hazard Index (PEFHI) as per a pre-defined computational procedure. The unit having maximum PEFHI is presented the Fire Safety Award. Data are collected in standard fire safety award data format every year from all the units for assessment of PEFHI.

The Green Site Award scheme was instituted in 1993 to promote tree plantation among various units of DAE to ensure that the atmosphere around the plant is clean and better to live in. The performance is assessed based on computed value of Greenery Index as per a pre-defined computational procedure. Data are collected in standard green site award data format every year from all the units for assessment of green site award parameters

Discussion Meetings

A one day "Workshop on Safety Legislation for Heads of the DAE Units" was arranged in AERB by IPSD on October 13, 2000. The topics such as various acts and rules, disaster management and national emergency committee, international nuclear event scale and incident reporting system, role of certifying surgeon, clarification on injury on duty leave and exemption of nuclear boilers from boiler inspection were discussed during the workshop.

A workshop on "Duties and Responsibilities of Certifying Surgeon" was conducted from March 28-29, 2001 at AERB. During the workshop, the main focus was on appointment of Certifying Surgeons in DAE units and their responsibilities in the light of the provisions of the Factories Act, 1948, Atomic Energy (Factories) Rules, 1996, Radiation Protection Rules, 1971 and Atomic Energy (Working of Mines, Minerals & Handling of Prescribed Substances) Rules, 1984.

Fire Safety Professionals Meet was organized at AERB during December 23-24, 2002. The topics such as up-gradation and modification done in operating plants, latest design provisions in the plant under design / construction, management of fire services and state of the art developments in the fire safety were covered in the meet. During the meet discussion were held on the issues such as fire prevention measures, roles and responsibilities of fire protection engineers, insights / experiences in implementing the AERB Standard for Fire Protection Systems of Nuclear Facilities.

One day discussion meet on "Enhancement of Industrial Safety in DAE Units" was organized on July 15, 2004 at AERB auditorium. The purpose of the meeting was to review the basic issue pertaining to industrial safety with special emphasis on the factors which have contributed to accidents at construction sites of DAE. The topics covered were industrial safety requirement in DAE units, overview of fatalities in DAE units, safety measures at construction sites, challenges of industrial safety at construction sites and challenges

of industrial safety at an operating plant. This was followed by discussions on specific topics related to construction activities such as job hazard analysis, need for more departmental safety supervision, use of personal protective equipment, "training for contractor workers, safety culture, work at height" and empowerment of inspectors. The conclusions arrived at after the discussions were sent to all DAE units for implementation.

In order to share the rich experience gained in the field of industrial safety and health in India, AERB organized a national symposium on Industrial and Fire Safety (SIFS) co-sponsored by Directorate General Factory Advice Service & Labour Institute (DGFASLI) of Government of India, Directorate of Industrial Safety & Health (DISH) of Government of Maharashtra and National Safety Council of India (NSCI) in November, 2006. The symposium had overwhelming response and participation with around 240 delegates from DAE units and non-DAE organizations from various parts of India.

A two-day discussion meet was jointly organized by AERB and SRI, Kalpakkam on 'Fire Modeling' on 20-21 September 2007 at AERB. The objective of discussion meet was to understand the current capabilities of computational tools available for fire modeling, their application to various scenarios and their validation for postulated scenarios. Delegates from DAE and Non-DAE actively participated in this discussion meet. The discussion meet focused on the topics such as Regulatory perception/requirements for Fire Hazard Analysis (FHA) of nuclear power plant facilities, computer codes for fire modeling-present predictive capabilities, CFD modeling of fires -current trends, Benchmark data for validation of fire models, Fire-Probabilistic Safety Assessment (Fire-PSA) etc.

A seminar on 'Challenges and Innovation in Fire Safety' along with the regular fire safety award distribution ceremony was held in April, 2008. The two-day seminar had five technical sessions on varied themes such as 'Fire Technologies and Fire Testing Facilities', 'Fire

Analysis and Modeling', 'Fire Organization, Administration and Past Events', 'Fire Safety Challenges and Fire Analysis' and 'Operational Plants Fire Safety'. These sessions had invited talks of eminent experts from DRDO, HPCL, NPCIL and BARC. A monograph on fire safety was also released during the seminar.

A workshop for paramedical staff was organized in September 2008 at NFC, Hyderabad. Nearly twenty five paramedical staffs from DAE units and twenty five certifying surgeons along with ACOH members attended the workshop. There were lectures by experts from Krishna Institute of Medical Sciences, Hyderabad and St. John's Ambulance Association on acute trauma management, cardio pulmonary resuscitation with practical demonstration of resuscitation.

Workshops for competent persons were being organized earlier by NPCIL and IPSD of AERB over the years at different plant/project sites of NPCIL. The workshop for competent persons was organized for the first time by HWB at Kota in September 2008. Senior officers from AERB delivered lectures on the regulatory requirements, material handling, major hazard control in chemical industries etc.

Services rendered to other agencies

The professional expertise of IPSD in matters related to industrial and fire safety was sought time and again by various agencies other than DAE as well. For example AERB was the executing institution for IAEA Inter Agency Project on "Assessment and Management of Health and Environmental Risks from Industries in Trans Thane Creek Area" which started in 1990 in collaboration with Maharashtra Pollution Control Board, Bhabha Atomic Research Centre, Indian Institute of Technology, Mumbai and Thane Belapur Industries Association. IPSD was also involved in the IAEA Co-ordinated Research Project for comparative risk assessment for waste from different electricity generating systems.

Safety Audit, Hazard Identification and Consequence Estimation for M/s Lubrizol India Ltd was carried out in 1992-1993, Safety Audit and Consequence Analysis for the potentially hazardous industries situated in Chembur area was conducted in 1993-1994 on the request of Ministry of Environment and Forests. District wise Hazard Analysis of Major Hazardous Industries in Raigad District in Maharashtra was carried on in 1998 on the request of Ministry of Environment and Forests. IPSD carried out the review of the Safety of Underground Oil Pipelines in and around Anushaktinagar.

Bureau of Indian Standards (BIS) sought expertise of AERB for drafting of documents like the Indian Standards on "Code of Practice on Occupational Safety and Health Audit (IS 14489: 1998)", "Code of practice on Hazard Identification and Risk Analysis (IS 15656:2006), "Code of Safety for Chemical Laboratories", etc. AERB prepared 'Uniform and Harmonized Risk Assessment Standard and Guidance Manual' for the Ministry of Environment & Forests (MoEF) in 2008. Expertise of IPSD has also been sought by Government of Maharashtra for investigation of accidents in various textiles and explosive industries. IPSD, AERB has also provided necessary support to DCSEM in the formulation and review of guidelines on industrial safety in DAE township. Experts from IPSD, AERB are regularly called by DAE units, non-DAE units and other organizations like National Safety Council as invited speakers for various workshops, seminars and symposia on industrial, fire, occupational health and environmental safety.

Recent Developments

The experience and feedback gained over the years while enforcing the regulations has served as valuable inputs for further strengthening of the regulation. Based on the current amendments to the Factories Act, 1948, the review amendments to the Atomic Energy (Factories) Rules, 1996 are now being carried out. Similarly review of AERB Standard for Fire Protection Systems of Nuclear Facilities has been

undertaken to incorporate the current changes and developments in Fire Safety. Review of Safety Guide on Works Contract is being carried out in the light of the experience gained in the construction safety in various DAE units. Thus regulatory activities related to industrial and fire safety have come a long way since the inception of AERB. However, there is a constant endeavor in AERB to keep upgrading the industrial and fire safety status in DAE units.

Major Inputs by: *R. Bhattacharya, K. Ramprasad, S.R. Bhave, N.M. Chodankar, S.M. Kodolkar and S. Sinha*

11
DEVELOPMENT OF REGULATORY DOCUMENTS

AERB has been entrusted with the responsibility of laying down safety requirements in the form of regulatory documents that would serve as the basis for conducting the design and operational safety review for granting consent to the nuclear and radiation facilities in the country.

AERB has been engaged since its inception in the development of these documents in the form of safety codes and safety standards for siting, design, operation, quality assurance and radioactive waste management and related guides and manuals for nuclear and radiation facilities. In order to ensure good quality of the documents, the best expertise available nationally is made use of and each document is developed after extensive discussions and consultations. The safety standards of the IAEA and nuclear regulatory bodies of other countries are also taken into account while developing our regulatory documents.

In the early days the Health Physics Division of BARC issued a number of safety documents. In 1982 the Department of Atomic Energy Safety Review Committee (DAE-SRC) brought out a comprehensive document entitled 'Radiation Protection Manual for Nuclear Facilities' which remained for a long time a reference document for radiological safety. Soon after AERB was established in 1983, the work on development of safety documents was taken up in earnest, thanks to the initiative of A.K. De, the first Chairman of AERB. As a result we have today a large number of safety documents issued by AERB that cover all important safety aspects of nuclear power plants, the fuel cycle facilities and application of radiation in medicine, industry and research.

AERB Regulatory Documents: First Decade

The nuclear power stations at Tarapur (TAPS 1&2), Rajasthan

(RAPS 1&2) and Kalpakkam (MAPS 1) were all in operation and the design safety review of Narora Atomic Power Project (NAPP 1&2) was in progress when the Atomic Energy Regulatory Board was constituted. Advisory Committees were constituted during mid eighties for preparation of safety codes in the fields of design, operation and quality assurance. This was carried out to facilitate the safety review process of the operating plants and also for the purpose of design review of nuclear power plants. In addition to specialists from AERB, experts from various DAE research units such as BARC and IGCAR, from Nuclear Power Corporation of India Limited (NPCIL) and from research and academic institutions such as IITs, Government Departments and Undertakings and several retired experts participated in this effort.

The Advisory Committee for preparation of the Code of Practice in Design of Nuclear Power Plants was constituted under the Chairmanship of S.K. Chatterjee. In addition to the task of preparing the code, the committee was also given the responsibility to identify different disciplines for which safety guides need to be prepared to elaborate the provisions specified in the safety code and initiate action for preparation of the same. Similarly under the Chairmanship of N. Ramamurthy and V.S.G. Rao Advisory Committees were constituted for preparation of Code of Practice on Safety in Nuclear Power Plant Operation and Code of Practice on Quality Assurance for Safety in Nuclear Power Plants respectively. P.N. Armugham was Chairman of the apex Committee, the Advisory Committee on Nuclear Safety which finally reviewed these codes prior to submission to Chairman, AERB for approval and publishing. During the period when our safety codes were unavailable, the relevant safety standards of International Atomic Energy Agency (IAEA) and those of other advanced countries were used as reference material during design safety review of nuclear power project proposals.

In late 1980s when more proposals were received for nuclear power projects such as for Kaiga-1&2, RAPP-3&4, Kudankulam

NPP-1&2 and TAPP 3 &4, the need for codal requirements for safety in siting was felt. An Advisory Committee was constituted by AERB in 1988 under the Chairmanship of T. Subbaratnam for preparation of the Code of Practice on Safety for Nuclear Power Plant Siting. This safety code was published in 1990. Following the severe accidents at TMI (1979) and Chernobyl (1986) greater emphasis was placed on the emergency preparedness plans at all the Indian nuclear power plant sites and AERB brought out two safety manuals for on-site and off-site emergency preparedness.

Regulatory documents were also prepared in the area of radiological safety particularly for medical and industrial applications. Safety codes on Brachytherapy sources and Telegamma therapy equipment and installations, and also for the transport of radioactive material were issued as early as in 1986. A few safety guides and safety manuals in the field of industrial and medical applications were also issued during this period.

Thus a good beginning was made for development of regulatory documents within a few years of the establishment of AERB. In fact by the end of the first decade of its formation, AERB had issued as many as 30 safety documents.

AERB Regulatory Documents: The next 15 Years

Based on the feedback from the early experience, a well structured scheme was put in place for the development of regulatory documents. The responsibility for this important task was assigned to the Safety Analysis and Documentation Division (SADD) (erstwhile Nuclear Safety Division) of AERB. Following four broad areas cover all the documents:

(i) Regulatory process
(ii) Nuclear safety
(iii) Radiological safety
(iv) Industrial and fire safety

In line with international practice, AERB has adopted a formal hierarchical structure for the regulatory documents which comprises of three distinct categories:

(i) Safety Codes and Standards

(ii) Safety Guides and Guidelines

(iii) Safety Manuals

Safety codes and safety standards are formulated on the basis of experience and internationally accepted safety criteria for design, construction and operation of nuclear and radiation facilities and their specific equipment, structures, systems and components. The requirements specified in these documents are mandatory. Safety codes and safety standards establish the objectives and also set the requirements that shall be fulfilled to provide adequate assurance for safety in nuclear and radiation facilities. The requirements specified in codes and standards are elaborated in safety guides and methods are described in these documents to fulfill these requirements. The recommendations in safety guides are not mandatory and the applicant can choose other methods also, but the onus of demonstrating to AERB that the chosen methods meet the requirements of the code or standard lies with the applicant. Safety guidelines are documents which lay down requirements along with elaborations of how to meet them. These documents are generally developed for the facilities for which no codes are in existence.

Another category of regulatory documents called safety manuals are issued for specific activities and they elaborate on specific aspects that may contain technical information and procedures.

Process of Regulatory Document Development

A Working Group consisting of experts in the subject prepares the initial draft of a safety document and thereafter keeps track of all comments received and their disposition during revision of the draft.

An Advisory Committee consisting of experienced senior experts by the relevant field reviews the draft document. A number of such Advisory Committees have been constituted in AERB for identified areas. The Advisory Committee reviews the document from the point of view of content, clarity, consistency with other documents and completeness. The Committee also identifies organizations and the relevant experts whose comments are sought on the document. All experts' comments are tabulated by the Working Group and are reviewed by the Advisory Committees. The Advisory Committee then decides on the disposition of the comments received with reasons recorded. The document is then revised by the Working Group in light of the decisions of the Advisory Committee on comments received.

The revised draft undergoes 'technical editing' by an independent expert who is conversant with the subject but is not associated with the preparation of the document, to focus on flow and clarity of language from the point of precise and unambiguous communication of technical contents to a reader.

An apex committee comprising specialists of national standing subsequently reviews the revised draft. This committee not only oversees the draft from the point of view of technical accuracy and implementability but also takes into account generic safety issues, policies and philosophies of safety management. The Working Group then revises the document taking into account the suggestions by the apex committee.

The document then undergoes 'copy editing' for improved clarity in language and presentation. The Working Group incorporates the suggestions of the copy editor to arrive at the final version of the document.

The document thus developed is finally submitted to Chairman, AERB along with a summary note on its evolution for approval of publication. In case of safety codes, the Board of AERB issues the approval for publication.

With a view to improving the procedure for regulatory document development and the quality of the documents, a safety document development proposal (SDDP) was recently introduced. This procedure helps by way of resolving matters of fundamental nature such as the need for the document, its scope, structure, contents and reference documents to be used in the preparation process before detailed work on document preparation is taken up. The SDDP is subjected to the same review process as followed for the document itself.

Regulatory documents were developed for nuclear and radiation facilities as detailed below:

Regulatory Process

Regulation of Nuclear and Radiation Facilities

During 1995 under the guidance of S.S. Ramaswamy, who was also then a Board member of AERB, a safety code on regulation of nuclear and radiation facilities was finalized. In this document, procedures for issuance of regulatory consents, and for regulatory inspection and enforcement of safety provisions for various nuclear and radiation facilities were formulated. The code identifies various stages of regulatory consents and the procedure for safety review and assessment during the consenting process. The information to be supplied by applicant for any regulatory consent and the responsibility of the consentee are also stipulated in the document. This code also addresses the requirements for conducting various regulatory activities. A safety guide under this code identifies various downstream documents to be prepared for regulatory activities and a procedure for development of such documents.

Regulation of Radioactive Waste

Responsibility for development of regulatory documents on radioactive waste management for nuclear as well as radiation facilities is assigned to another Advisory Committee. The AERB Code on 'Management of Radioactive Waste' has been published, which

covers various safety aspects relating to management of radioactive waste arising out of all practices. Safety guides dealing with management of waste from various nuclear and radiation facilities have also been published under this code.

Nuclear Safety

Nuclear Power Plants

As described earlier, in the scenario of development of regulatory documents for nuclear facilities, the initial thrust was on the development of regulatory documents in the areas of siting, design, operation and quality assurance activities relating to nuclear power plants only. In recent years preparation of regulatory documents for facilities at the front end and back end of the fuel cycle has also been taken up.

After issuance of safety codes in the areas of siting, design, operation and quality assurance relating to nuclear power plants, the respective Advisory Committees identified the safety guides to be prepared under each safety code and these were prepared and issued. Working Groups assist each of these committees in the preparation of the first draft of the identified documents. For regulatory documents relating to nuclear power plants, the Advisory Committee on Nuclear Safety (ACNS) is the apex body for review of these documents.

The regulatory documents are also updated periodically. For example, the code of practice for operation of NPPs issued in 1989 has been revised recently along with a few of the related safety guides. The code of practice on Quality Assurance in NPP was issued in 1988 and is being revised presently.

Nuclear Fuel Cycle Facilities

Preparation of regulatory documents for nuclear facilities other than nuclear power plants has been initiated in recent years only.

Because of the diverse nature of the facilities, which are quite different from nuclear power plants, a different Advisory Committee has been constituted for preparation and review of these documents. A number of safety guides have been identified for preparation relating to various activities in fuel reprocessing plant such as design, operation, commissioning, quality assurance, decommissioning, physical protection, emergency preparedness, etc. on similar lines as for nuclear power plants. Action has also been initiated for preparation of regulatory documents for other facilities such as uranium mining and milling, fuel fabrication, heavy water plants, etc. These documents are reviewed by the Advisory Committee for Safety Documents relating to Fuel Cycle Facilities other than Nuclear Power Plants (ACSD-FCF) before submission to the Board for approval.

Civil Engineering

A need for regulatory documents in the field of civil engineering was felt and accordingly an advisory committee was constituted for identification and preparation of regulatory documents on civil engineering structures important to safety of nuclear facilities. The Committee has prepared five safety standards which have been reviewed by ACNS before publication. Except the safety standard on Design of Nuclear Power Plant Containment Structure, all other standards are applicable to NPP as well as other nuclear facilities.

Radiological Saftey

Radiation Facilities and Transport of Radioactive Material

Radiation facilities cover a wide spectrum of radiation sources, equipment and installations. Wide ranging activities in the field of medical, industrial, agricultural, research applications, etc. are to be covered while preparing regulatory documents on radiation facilities. Efforts made during the early days of AERB resulted in publication of safety codes on some medical installations such as Teletherapy facilities, Brachytherapy facilities and Nuclear medicine facilities.

Safety codes on Industrial Radiography and Transport of Radioactive sources and safety standards on other industrial applications such as ionizing radiation gauges, consumer products and gamma irradiators were prepared in the later years. In addition to the safety codes and safety standards, a number of safety guides have been prepared covering various areas of applications and also for transport of radioactive materials.

A number of these regulatory documents require updating in view of developments which have taken place over the years. For this purpose and considering the ever changing scenario, a Standing Committee for Review and Revision of AERB's Radiation Safety Documents (SCRSD), currently chaired by A.R. Reddy, has been constituted. A number of regulatory documents in areas such as food processing, particle accelerators, research, education, security of radioactive sources, etc. have been identified for preparation. The regulatory documents, after review by this committee, are forwarded to the Advisory Committee on Radiological Safety, which is the apex body for the purpose currently chaired by U.C. Mishra.

Industrial And Fire Safety

The area of industrial safety covers regulatory requirements and guidance on fire safety, personnel safety and safety management, and the Advisory Committee on Industrial and Fire Safety (ACI&FS) is overseeing the development of the regulatory documents in this area. In addition to the safety standard on Fire Protection Systems of Nuclear Facilities, a few safety guides and safety manuals are already available for areas such as personal protective equipment, works contract, safety report format, pre-employment medical examination, etc.

Summing Up

Development and periodic revision of safety documents is a

continuous process due to the evolution of technology and availability of new information from research and experience, and AERB is alive to this situation. In the past twenty five years a total of 127 regulatory documents have been published by AERB comprising of 25 safety codes and standards, 86 safety guides and guidelines and 16 safety manuals and technical documents. While the availability of regulatory guidance is good with respect to PHWR type nuclear power plants, sustained efforts are now being put in to cover other reactor designs as also fuel cycle facilities, and emerging technological advances in the medical and industrial applications of radiation.

Major inputs by: *G.K. De, S.K. Gupta and K. Srivasista*

12
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.

Major Inputs by: *S.E. Kannan, A.R. Sundararajan, O.P. Singh and A. Ramakrishna*

13

INTERNATIONAL CO-OPERATION

AERB places high importance on interaction with IAEA and regulatory bodies of other countries as this helps in better understanding of the issues important to safety and the measures for their resolution. Towards this AERB has formed co-operation arrangements with the regulatory bodies of USA, France and Russian Federation. AERB is also member of CANDU Senior Regulators Group (Canada, Republic of Korea, Romania, Argentina, Pakistan and China) and VVER Regulators Group (Russia, Ukraine, China, Czech Republic, Slovakia, Finland, Iran, Bulgaria, Armenia and Lithuania). AERB also participates in various activities of IAEA. Additionally, India ratified the Convention on Nuclear Safety (CNS) in 2005 and participated in the 3rd and 4th review meetings of CNS in 2005 and 2008 respectively.

International Atomic Energy Agency (IAEA)

The staff of AERB participate in various Technical and Consultants meetings organized by IAEA on a range of topics: nuclear power plants and fuel cycle activities, emergency preparedness, radiation facilities and transportation of radioactive materials. AERB staff have been participating in IAEA Coordinated Research Programme (IAEA-CRP) on topics like Methodologies for Event Analysis and Safety Significance of Near field earthquakes.

S.D.Soman, one of the past chairmen of AERB and S.K.Sharma, the current AERB Chairman have served as members of the International Nuclear Safety Group (INSAG). INSAG is a group of international experts, constituted by the Director General of IAEA, with high professional competence in the field of nuclear safety, working in regulatory organizations, research and academic institutions and the nuclear industry. INSAG provides recommendations and opinions on current and emerging nuclear safety issues to IAEA, the nuclear community and the public. AERB hosted one of the meetings that

was held during 12-16 March 2007 in Mumbai. On this occasion, a seminar was held wherein seven of the INSAG members from OECD/ NEA, Finland, Hungary, Korea, South Africa, Russian Federation and Canada presented technical talks on a variety of current topics of interest. The INSAG meeting provided a good opportunity to Indian Nuclear Scientists and engineers to interact with this group of international experts.

AERB is the national coordinator for IAEA -International Nuclear Event Scale (INES) based reporting of events and IAEA/NEA – Incident Reporting System (IRS). The INES is a means for promptly communicating to the public in consistent terms the safety significance of events reported at nuclear installations. The scale was designed by an international group of experts in 1989 and is being followed by all the countries. The scale is applied to classify events at nuclear power plants and other nuclear facilities and has now been extended also to radiation sources and transport events involving radioactive materials. India adopted INES scale since its inception and has been participating in all INES activities including further development of INES. AERB being the national coordinator participates in biennial meeting of the INES national coordinators. S. K. Sharma, the present AERB Chairman is a member of the INES Advisory Committee.

The IRS is an international reporting system jointly operated by IAEA and NEA. The objective of the system is to improve the safety of commercial nuclear power plants worldwide by providing timely and detailed information on both technical and human factors related to events of safety significance. The system was started in 1980. India has been reporting events of major safety significance at Indian NPPs since inception of the system. India also receives information on the events in other countries through this system. AERB being the national coordinator participates in annual meeting of the IRS national coordinators and S. K. Chande, the present Vice Chairman of AERB is a member of the IRS Advisory Committee. AERB has also conducted topical studies under IRS on violations of operating limits

and conditions, closing the feedback loop from events to definite elimination of the causes and fuel handling events, which led to publication of Topical Reports on these subjects.

CANDU Senior Regulators Group

AERB is a member of the forum for the CANDU Senior Regulators for exchange of information on issues related to safety of PHWRs. Besides India the other countries participating in this forum are Argentina, Canada, China, Pakistan, Romania and South Korea. The CANDU Senior Regulators meeting is held once in a year. India hosted CANDU Senior Regulators meet in November 2005.

The participation in this forum helps AERB in better understanding of events and generic safety issues in CANDU reactors world over, and for arriving at the corrective actions to be taken in Indian NPPs.

VVER Regulators Forum

AERB has become a member of VVER regulators forum as two VVERs (2x1000 MWe) reactors are being constructed at Kudankulam. The other countries participating in this forum are Russia, Ukraine, China, Czech Republic, Slovakia, Finland, Iran, Bulgaria, Armenia and Lithuania. The participation in this forum helps us in understanding the various regulatory approaches for this type of reactors and the design and operational safety issues in VVER reactors.

Nuclear Regulatory Commission of USA (USNRC)

The US-India dialogue for co-operation in nuclear safety regulation began in July 1994 with the visit of an American delegation led by former U.S. Energy Secretary Hazel O'Leary and a former Commissioner of USNRC, E. Gail de Planque. The officials of the two countries decided to open a nuclear safety dialogue between AERB and NRC. The topics of development of symptom-based emergency procedures, technical exchanges on design issues, fire

safety in Nuclear Power Plants, materials Aging and In-service Inspections were identified for the co-operation. In October 1994, A. Gopalakrishnan, Chairman, AERB along with a team of engineers visited NRC and various nuclear facilities in the US. In February 1995, Ivan Selin, Chairman, NRC and his team visited India.

In March 1998, P. Rama Rao, Chairman, AERB and S.V. Kumar, Vice Chairman, AERB visited NRC headquarters. They held discussions with NRC officials on developing and implementing three NRC-AERB nuclear safety projects (i) back-fits and design modifications to existing nuclear power plants (ii) historical information on fire incidents and use of good fire protection engineering practices; and (iii) symptom-based emergency procedures.

A USNRC team led by Shirley Ann Jackson, Chairman of the NRC visited AERB in April 1998 when she addressed "Fire Safety 1998", a conference on fire-safety related topics. She summarized the history of fire protection in nuclear power plants, the associated regulatory frame work and the NRC deliberations for possible improvement.

The nuclear safety co-operation dialogue between AERB and USNRC restarted in February 2003 when Richard A. Meserve, Chairman, USNRC accompanied by a 15-member team visited AERB on invitation from S.P. Sukhtame, Chairman, AERB. Meserve delivered a lecture titled "Advancing nuclear safety through international cooperation" at BARC; he described the key attributes to regulatory effectiveness and how NRC faces the challenges and achieves these attributes.

Between 2003 and now, nine meetings have been held between AERB and USNRC with the meeting venues alternating between India and USA. Some important topics discussed during these meetings include Probabilistic Risk Assessment Technology, License renewal of old reactors, emergency operating procedures, passive systems reliability evaluations and severe accident analysis. It is worth

mentioning that Commissioner Jeffery. S. Merrifield accompanied the USNRC team in 2005 while Commissioner Peter. B. Lyons accompanied the USNRC team in 2006. From USNRC Ashok Thadani and later James Lyons led the technical discussions. S.K. Sharma and S.K. Chande led the Indian expert teams during the meetings. The objective of these meetings continues to be furthering the dialogue regarding nuclear safety between AERB and USNRC. In addition to discussions on technical topics, the visiting teams have also visited some nuclear power plants and other related facilities.

Two young AERB officers were deputed to USNRC for a period of one year for familiarisation with the NRC approaches on risk informed decision making and its applications.

Collaborative work related to joint exercises of benchmarking Computer Codes through analysis of Standard Problems has also been initiated since the beginning of 2007 and work on two such exercises is in progress.

Nuclear Safety Authority (ASN) France

A formal cooperation agreement between AERB and ASN, France, was signed in 1999 for Exchange of Information and Co-operation in the Regulation of Nuclear Safety and Radiation Protection, for a period of five years. This agreement was extended for a further period of five years in 2005. The arrangement now covers cooperation in the fields of radiation protection and safety of transport of radioactive sources and materials in addition to the previously covered areas.

AERB team visited France to witness Emergency Preparedness Exercise in Flamanville in October 1999. In May 2000, S.P.Sukhatme, Chairman, AERB visited Emergency Control Centre at IPSN and St. Laurent NPP. AERB team again visited France to exchange experience on transport of radioactive materials, civil engineering aspects, seismic issues and fire safety in December 2000. The team also

visited Cruas-Meysee NPP and Aube radioactive waste repository. In February 2001, AERB team visited Transportation Cask Test Facility at Cesta.

In 2001 A. C. Lacoste, Director General, ASN and his team visited AERB for discussions and exchange of ideas on licensing of NPPs, periodic safety review and life cycle management of nuclear facilities. In October 2005, French Delegation lead by A.C.Lacoste discussed issues related to flooding and tsunami, safety of pre-stressed concrete containment and safety in transport of radioactive materials.

A five-member ASN delegation led by Olivier Gupta, Head of the Direction of Nuclear Power Plants of ASN visited AERB in 2007 when a seminar on 'Pressurized Water Reactors' was organized. The seminar resulted in better appreciation of Regulatory practices and safety review approach followed in the two regulatory bodies, safety objectives and approaches for new reactors and design assessment of reactors with evolutionary new features. In 2008, AERB received Computer Code ASTEC (Accident Source Term Evaluation Code) from France.

In May 2008, ASN team led by Guillaumme Wack, Head of the Nuclear Power Plants Department visited AERB for a seminar on reactor safety which included presentations on concrete containment, reactor pressure vessels and periodic safety review of NPPs.

Federal Nuclear and Radiation Safety Authority of Russia

AERB and ROSTEKHNADZOR, the Federal Nuclear and Radiation Safety Authority of Russia entered into an agreement in February 2003 for cooperation in the field of safety regulation in the process of use of nuclear energy for peaceful purposes. The first workshop between AERB and ROSTEKHNADZOR was held in February 2005 to discuss regulatory practices for ensuring safety of the plant personnel, public and the environment, regulatory experience and current safety norms.

The second workshop on Information Exchange on Nuclear Safety between AERB and ROSTEKHNADZOR, was held during March 25-27, 2008 at Mumbai. A three member delegation from the Russian Federation, led by Vladislav Manakov, Deputy Department Head of the ROSTEKHNADZOR participated in this Workshop.

Technical presentations were made by the members of Russian delegation and the Indian team on the topics of regulatory and licensing process, aspects related to construction experience, severe accident analysis, and on the experience on safety review of control and instrumentation, pre-stressing system for primary containment and reactor pressure vessel of the Kudankulam VVER type reactors.

Convention on Nuclear Safety

The Convention on Nuclear Safety (CNS) was adopted in Vienna on 17 June 1994 by a Diplomatic Conference convened at the International Atomic Energy Agency, Vienna. Its aim is to legally commit participating States operating land-based nuclear power plants to maintain a high level of safety. The Convention obliges Contracting Parties to submit national reports on the implementation of their obligations (Legislative and regulatory framework, regulatory body, siting, design, construction, operation, availability of adequate financial and human resources, the assessment and verification of safety, quality assurance and emergency preparedness) in the country for "peer review" at meetings of the contracting parties. The Convention entered into force on 24 October 1996. All countries with operating nuclear power plants are now parties to the Convention. India ratified the Convention on March 31, 2005 and attended the 3rd Review Meeting of the convention as observer. For the 4th Review Meeting, the first National Report on India was submitted for review by the Contracting Parties to the Convention on 24th September 2007. A total of 143 questions were raised on India's report that were answered in writing prior to the 4th meeting. The preparatory committee for India's participation in fourth Review Meeting was

headed by S.K. Sharma, Chairman, AERB. National reports of 12 countries (Argentina, Canada, China, Czech Republic, France, Finland, Japan, Korea, Pakistan, Romania, Russia, and USA) were reviewed by experts in AERB, NPCIL and BARC and sixty questions were raised. The Fourth Review Meeting of the Convention was held at IAEA headquarters, Vienna, Austria from April 14-25, 2008. An 18 member Indian delegation led by S.K. Sharma, Chairman, AERB and comprising of experts from AERB, NPCIL and BARC attended the meeting. The interactions with other contracting parties during the review meeting were extremely useful for India and AERB. The Indian report and its oral presentation at the review meeting was highly appreciated by the participants and a number of good practices followed in India were included in the meeting report.

Major Inputs by: *D. Ojha, A. Prabhakaran and K.S. Parthasarathy*

14

INFRASTRUCTURE AND HUMAN RESOURCE DEVELOPMENT

Initial Years

A.K. De on his appointment as first Chairman of AERB in 1984 was given office in Old Yacht Club (OYC) building while the office of P.N.Krishnamoorthy, Member Secretary was located in the Annexe Building of Central Complex, Bhabha Atomic Research Centre. By the end of 1984, the total staff of AERB was nearly twenty-five with ten scientific, four technical, nine administrative and two auxiliary staff. The 2nd floor in OYC building was converted as the first formal office of AERB occupying an area of about 340 square metres. One side of the wing was made into cabins for the officers and the other side was made into cubicles to be allotted to the other administrative and technical staff. Soon, a library was also added to acquire technical books and journals. In 1986 AERB got its very first mini computer SN-23 to be followed by two more desktop computers. These computers were essentially used for analytical work related to reactor safety and data processing.

With the construction of Vikram Sarabhai Bhavan at Anushaktinagar in 1988, AERB secured part of its North Wing in the 4th Floor to meet the requirements of its expanding strength. S.D.Soman, who took over from A.K.De as Chairman AERB in 1990, moved to his office in this wing. AERB grew at a very rapid rate from 1992 to 1996 reaching a total staff strength of 113 by 1996 with 70 Scientific Officers and 17 Technical, 19 Administration and 7 Auxiliary staffs.

Niyamak Bhavan

During the tenure of S.D. Soman, action was initiated for construction of a new AERB Building at Anushaktinagar which had

an area of 4500 square metre. Later A. Gopalakrishnan, who was the Chairman AERB following S.D. Soman along with S.V. Kumar, guided the establishment of necessary infrastructure in the new building. The AERB Building named as Niyamak Bhavan was inaugurated by R. Chidambaram, the then Chairman, Atomic Energy Commission on August 2, 1996 when S.V. Kumar was the officiating Chairman of AERB.

In keeping pace with the fast expansion of DAE programme, AERB had to augment its manpower. There was also shortage of meeting rooms in the Niyamak Bhavan. Therefore an additional building was constructed near the existing Niyamak Bhavan building. The new building was inaugurated by A. K. De in November 2007 to mark the commencement of AERB silver jubilee year. Both the buildings are identical in external appearance and have similar floor areas. The old building was renamed as Niyamak Bhavan-A and the new building was named as Niyamak Bhavan-B.

The library at Niyamak Bhavan today has nearly 8000 books in its hold and subscribes to 25 national and international journals. It uses the library management software (Libsys-4) and is a part of the DAE internet library network. The buildings are equipped with state-of-art internet and intranet facility. In addition to the Board room, there is one auditorium, one lecture hall, one conference room and eight meeting rooms in the building complex.

Safety Research Institute

AERB established its Safety Research Institute (SRI) in 1999 at Kalpakkam in the IGCAR complex. It moved to its own building in 2003 which has an office area of 2300 square metres. SRI also has a guest house in Anupuram which can host 60 guests. A seminar hall is also a part of the guest house which is frequently used for organization of scientific meetings, seminars, workshops, etc.

Regional Centres of AERB

Action has been initiated under the XIth plan to establish two regional centres of AERB, one in Kolkata and another at Anupuram near SRI to cater to the need for conducting regulatory work in the eastern and southern regions of the country in a more efficient and expeditious manner.

Development of Human Resource

There has been considerable amount of emphasis on the Human Resource Development (HRD) in AERB right from its inception. The main emphasis has been on maintaining adequate and competent manpower. Appropriate recruitment policy to induct talented manpower, organization of appropriate training of staff and knowledge management towards maintaining competence and efficiency in the organization have been the main feature of HRD in AERB.

Manpower Induction

A mixed approach of induction of manpower depending on the need and expertise required in AERB, is being followed by AERB. The fresh graduates (scientists and engineers) are taken from the Training Schools of Human Resource Development Division (HRDD), Bhabha Atomic Research Centre (BARC) Mumbai and its affiliated training schools at Indira Gandhi Centre for Atomic Research (IGCAR) Kalpakkam, Nuclear Fuel Complex (NFC) Hyderabad and Nuclear Power Corporation of India Limited (NPCIL) Mumbai. These scientists and engineers join AERB after undergoing the Orientation Course for Engineering graduates and Science postgraduates (OCES). The direct recruitments are done from nuclear and other industries through the normal process of advertising the posts in national newspapers and on AERB website, shortlisting the candidates by screening and then conducting the personal interviews. The post graduate engineers/ scientists and the ones with experience in relevant industries and/or in research organizations are selected for induction at lower middle

level. Students with B. Tech. degree are sponsored for M. Tech. in I.I.T Bombay at Mumbai and I.I.T Madras at Chennai. These students join AERB after completing their post graduation. In addition, personnel from DRP and Health Physics training courses are also inducted in AERB. Certain posts, particularly at higher levels, are filled by transfer of competent staff with required expertise from various DAE organizations like BARC, IGCAR, NPCIL and IREL. AERB presently has 171 scientific and secretarial staff and another 40 staff in administration and accounts. A total of 101 scientific staff were inducted in AERB during the last 12 years through various induction modes described above.

Training

AERB organizes In-house Orientation Training Programs for newly inducted staff. This program covers the entire knowledge canvas of AERB such as the legislative (Acts), legal (Rules) and regulatory (codes, guides and manuals) framework, functioning of AERB, regulatory processes followed and basic aspects of nuclear, radiation and industrial safety in nuclear and radiation facilities. Those who join AERB after completing the AERB sponsored M. Tech. program, undergo Orientation Course for DAE Graduate Fellowship Scheme (DGFS) of BARC Training school. In addition, the staff undergoes On the Job Training (OJT) at Nuclear Training Centers of NPCIL and at other nuclear facilities. Regular staff are also deputed to the Continued Education Program of BARC training school. Refresher courses are conducted in-house on various topics of regulatory and safety aspects. AERB colloquia are organised frequently on topics of current interests and on new developments in various fields. The staff is provided opportunity to participate in Conferences, Seminars and Workshops in India as well as abroad to keep them abreast of the new developments in the areas of relevance. In addition, seminars/ talks are arranged by the respective divisions to encourage more and more interaction with the members of other divisions. The staff are encouraged to improve their educational qualifications and

those with Ph.D. degrees are encouraged to do post-doctoral work in reputed Universities/ Institutes with renowned professors in advanced countries. In the recent past, AERB has also deputed some of its employees to reputed institutes abroad for advanced training. Senior staff are encouraged to teach in training schools of different units in DAE and educational institutes like universities and IITs.

Knowledge Management

AERB library subscribes to different types of journals, books, reports, etc. After the advent of Information Technology, the journals and other information sources are stored in the electronic form. The international collaborative efforts have also been very useful in knowledge capture and in gaining insights into the regulatory process of other countries and emerging methods of regulatory decision making.

Important documents of AERB related to legislative, legal and regulatory framework, regulatory and safety documents, inspection and enforcement reports, minutes of safety committee meetings are preserved in hard copy form as also in electronic forms in library and in individual divisions. A Knowledge Portal has been opened in the LAN of AERB to make the documents easily accessible and retrievable. The tacit knowledge of individuals is best utilized through participation in the meetings, seminars and workshops. AERB extensively uses retired experts in its regulatory review and regulatory documents development process to benefit from their long experience and wisdom.

Public Information

One of the important functions of AERB is to "take such steps as necessary to keep the public informed on major issues of radiological safety significance." Right from its inception, AERB took many steps to carry out this function. Since 1985, AERB has been bringing

out periodically newsletters covering national and international news related to safety regulation. . Annual Reports of AERB brings out details of the work carried out in various divisions, reports on unusual occurrences in nuclear and radiation facilities, international cooperation, etc. The newsletter and the annual reports are widely circulated to all the units of public sector undertaking under DAE, Regulatory Bodies of other countries, IAEA, premier educational and research institutes in India, Radiological Safety Officers of various hospitals and nuclear installations and news agencies in India.

AERB has often used electronic and print media to keep the public informed about important regulatory activity. In addition AERB maintains a website which is a reliable source of information for the licensees and the public.

ISO Certification

AERB places high emphasis on quality in its regulatory and safety enforcement functions. Towards this end necessary systems have been put in place and AERB obtained ISO 9001:2000 certification for its Quality Management Systems related to the processes for consenting, regulatory inspections and development of regulatory documents in November 2006. AERB is the first technical regulatory body in the country to have received ISO certification.

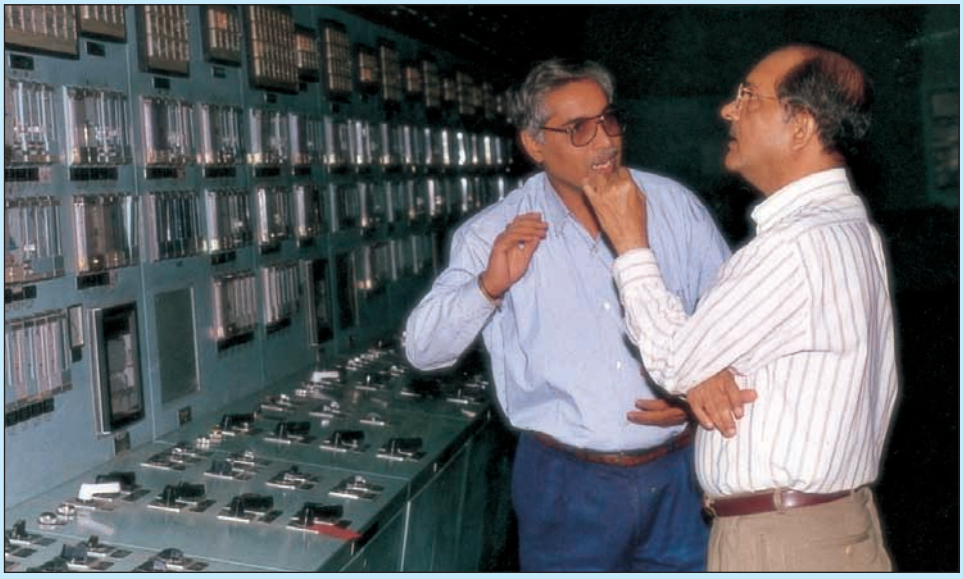
Major inputs by: *O.P. Singh, P.C. Basu, S.E. Kannan, P. Shylamoni, R.J. Palamattam, C. Senthilkumar, E.R. Titto and Kavi Upreti*

AERB Board Meeting at Niyamak Bhavan

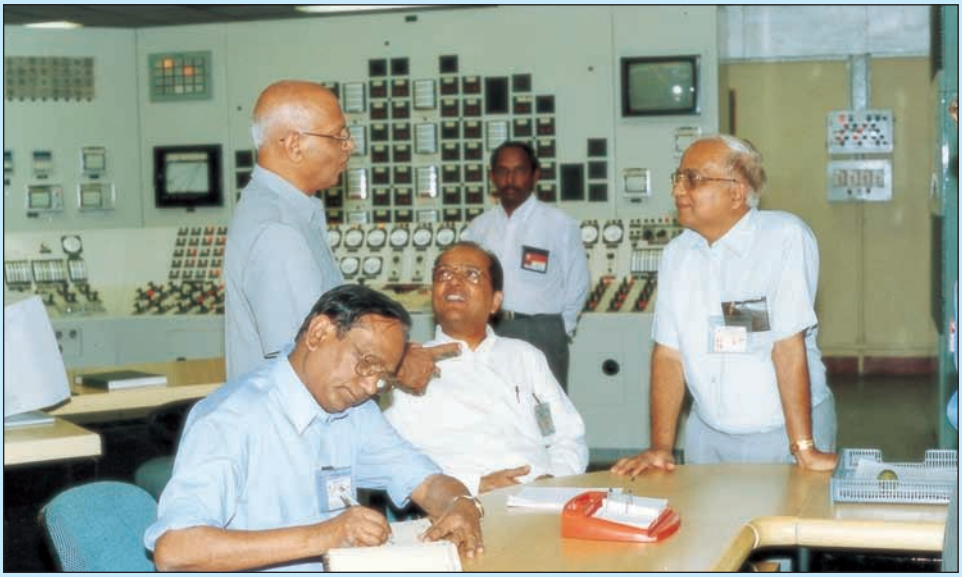
SARCOP meeting at Niyamak Bhavan

SARCAR meeting at Niyamak Bhavan

AERB Board members at control room of NUOFP, NFC in December 2000



Prof. Sukhatme in discussion with C. Seshasai at HWP, Manuguru in January, 2002



AERB Board members at control room of TAPS-1&2 (February 2002)

Shri R.P. Kapoor, Prof. S.P. Sukhatme, Shri S.A. Bhardwaj and Dr. S.K. Jain at IGCAR in February, 2002

Visit of SARCOP members to Jaduguda mine in December 2002

Joint Meeting of ACPSR-PHWR and SARCOP in Progress at Tarapur in May 2006

Board Members visiting Kaiga Generating Station (KGS) in October 2007

Board members visit PFBR in May 2008

Prof. S.P. Sukhatme greeting Mr. A.C. Lacoste,
Director General, ASN in October 2001

Prof S.P. Sukhatme and Mr. Yuri G.Vishnevsky, Chairman,
GAN signing the agreement in January, 2003.

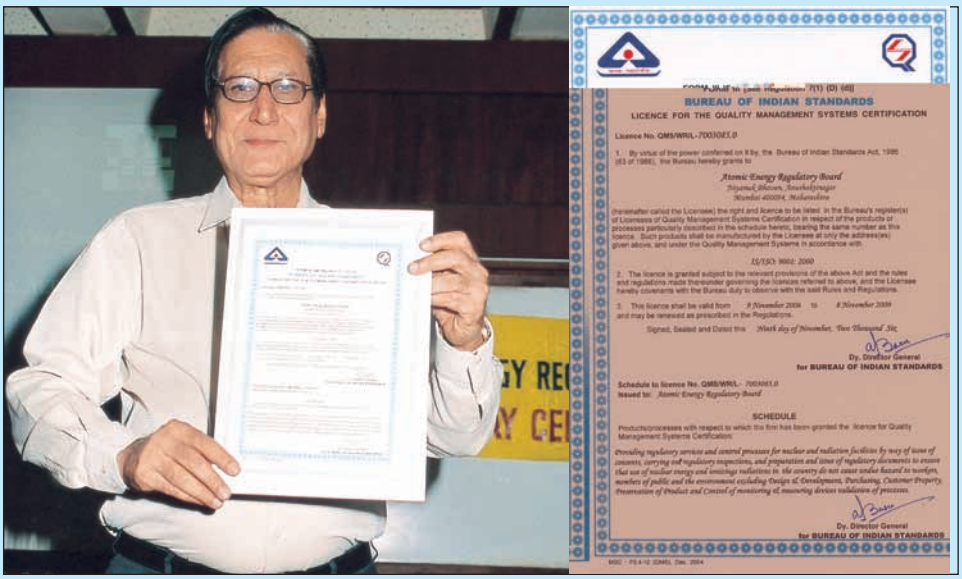
USNRC team at AERB in February 2003

Prof. S.P. Sukhatme and Dr. Richard A. Meserve,
Chairman USNRC in February, 2004

Delegation of the French Nuclear Body, ASN with Senior Officials of AERB in the Technical Meeting at AERB in May 2007

Discussion Meeting between AERB and USNRC during February 2008

Shri S.K. Sharma greets Mr. Vladislaw Mankov, deputy Department Head, ROSTECHNADZOR during the Workshop on Information exchange on Nuclear Safety held at AERB in March 2008



Shri S.K. Sharma displaying the ISO certificate received from BIS on November 2006

AERB Safety Documents

Release of monograph on 'construction safety' during the 24th DAE Safety and Occupational Health Professionals Meet at RAPP Site in December 2007

Prof. J.B. Joshi: AERB Silver Jubilee Colloquium in September, 2008

Dr. (Smt.) K.A. Dinshaw : AERB Silver Jubilee Colloquium in October 2008

Shri S.K. Chande, Shri G.R. Srinivasan, Shri S.D. Soman,
Prof. P. Rama Rao, Prof. S.P. Sukhatme, Prof. A.K. De, Dr. Anil Kakodkar,
Shri S.K. Sharma and Shri S.V. Kumar during the inauguration of
Niyamak Bhavan-B on November 23, 2007

Niyamak Bhavan-B

Appendix

Excerpts of speeches and messages

Dr. Anil Kakodkar
Chairman, AEC

I think it is a great day and I want to begin by expressing gratitude to all the stalwarts who are sitting on the dais and in the audience for shaping this great organization and taking it to the present strength. My compliments and greetings to you all.

On this day, I distinctly remember (not that I was directly involved in it but have witnessed it on the sidelines) about the fair bit of debate, the brainstorming that was taking place in those days. I know Mr. Soman was in the thick of it. But, it was Dr. Ganguly, who was the anchor and who all along emphasized the scientific and technical orientation to safety regulation and laid a firm philosophical base in this regard while piloting the transformation to an independent regulator through an informed debate. I must salute to all those people who were involved in those brainstorming and facilitated the transition from the "internal safety committee structure to a fully independent Atomic Energy Regulatory Board".

I want to share a happening (where I was involved in) just to highlight the importance of the presence of wise men in a regulatory system. I think this is the main distinction between Atomic Energy Regulatory Board as a regulator and the very large number of other regulatory agencies that we have in the country. I also remember that recently at a very high level discussion, some of those regulatory systems have in fact been characterized rather sarcastically as dispute resolution mechanisms. I also remember that AERB has been a model which people have been quoting for emulation whenever there has been a thought of establishing a good regulator. Report of Professor Swaminathan is a case in point. AERB has lived up to what Dr. Bhabha used to say (in the context of radiation protection) that in whatever we do, we must do in a manner that the whole country may want to emulate. You can't have a better example than AERB coming of age. So, I think it's a moment that all of

us feel very proud and I want to compliment every member of Atomic energy Regulatory Board on this occasion.

Coming back to the spirit of wise men, I want to tell you an episode which I was myself a witness with Dr. Ganguly. And this was at the time when the concepts of Dhruva were being hotly debated. There were huge arguments with groups taking sides on whether it should be full tank concept or a partial tank concept. I was still an outsider and when I was asked to join the Dhruva project, it looked to me that BARC was vertically divided because of this controversy. The question was how to convince people that whatever is being proposed is right. It was Shri Seshadri's idea, to go to Dr. A.K. Ganguly. We took an appointment. There were only three of us in the room. Seshadri told Dr. Ganguly "I want to apprise you with what we are wanting to propose". Dr. Ganguly replied back "you want to brainwash me". Seshadri said "no, we can't brain wash you, we just want to tell you our view point" to which Dr. Ganguly said "ok, you can tell but that does not mean that I will side with you". He gave a patient hearing which lasted a couple of hours. Sheshadri did his part and then I did my part. And at the end of it, Dr. Ganguly said "ok, you told me so many things, I have heard them all but I want to forget all that". He then looked at Seshadri and asked "how confident are you?" Seshadri said "hundred percent". He looked at me and asked "how confident are you?" and I said "hundred percent". Finally, he asked us to leave. And of course the discussions in safety committees and all other parts of the process did take place, and proper decisions followed. I am not saying that you regulate by looking at people and asking their confidence but I am only wanting to refer to the insights of wise men. AERB has been particularly fortunate that we have wise men conducting the affairs of AERB and so we are in this stage.

I think the point made by Prof. Sukhatme and many others in the context of knowledge base and human resource base are very crucial. Wisdom comes a little after we acquire knowledge. You can't be wise unless you have knowledge. Strong knowledge base on part of people who are involved in regulation is a fundamental prerequisite. Otherwise you end up in what happens in many other regulatory systems. You first

have an Act of the Government, you set up certain rules under the Act which are placed in the Parliament. And then any clerk can put a finger on the rule and say that this can be allowed or not allowed. And that unfortunately happens in many places. It is the higher level understanding and enlightened way of dealing with things, of course consistent with rules, is what's important. Rules are a must and conformance with the rules also is a must but then you can't become slave to the rules. The importance of greater inhouse competence, knowledge driven ambience cannot be under emphasized. It is also important because it's only this knowledge base which will allow you to make sure that you are no longer close to the cliff edge. I think this is extremely important in safety regulation. There are many instances where you can meet all rules, all requirements and yet could be very close to the cliff edge and the slightest departure from normal can be a catastrophe. And this is where existence of research insights and holistic understanding of the system is important.

All of us are aware that we are now at a turning point. The turning point where we expect the rate of growth to be much higher than what it has been before. The rate of growth will be higher not in terms of just megawatts but also in terms of the range of technologies that we need to handle. I think this is a major challenge before us. When we talk the technology which has been already practiced somewhere else, then obviously you also have some information and background about the technology, the knowledge base for the technology and also the regulatory view about the technology. But I think we are fast entering a new situation where we are talking of fast reactors. Not many countries have fast reactors. Very soon we will talk about fast reactors of a very different kind. We have our own interest in thorium. We are talking about systems which will be coupled accelerators and reactors and so on and so forth. And I think all these things will happen surely within the next decade. We will be faced with the challenge of regulating systems which do not exist anywhere. The challenge before us now is how to ensure safety in the context of such evolutions. And mind you, this is not unique to India. Even abroad, there are major initiatives in terms of generation IV reactors. These are different concepts, which are being worked out

and obviously the safety of all these concepts have to be understood world over. But, we would be talking of the concepts which are not quite the same as those developed else where. One of the principal tenants of safety regulation is so called 'proven on experience'. If you have prior experience, we obviously have greater confidence in terms of safety assurance. Now we have to evolve new innovative systems, because we can't remain with just 10,000 MWe. that we want to reach with PHWRs. 10,000 MWe will be reached inspite of the uranium shortages. But we cannot restrict ourselves to just 10,000 MWe because if the goal of atomic energy is just 10,000 MWe, then I think atomic energy may not even have existed. 10,000 MWe is too small as far as the requirements of this country are concerned. And so I think that it is absolutely inevitable that we now move on a path where we might not have the benefit of learning from experience of others. However, we have to make sure that there is absolutely no compromise as far as safety regulation is concerned. And I think that again underscores the spirit of those pioneers like Dr. Ganguly. I think we are likely to go through a second revolution in terms of safety regulation because of these changes. It is important that AERB within its silver jubilee year does get into a lot of discussion on how to organize ourselves for meeting this new challenge.

I must tell you at this stage that AERB commands a huge respect outside. Some years ago in Vienna, we had a meeting with the US. In that meeting, Chairman of USNRC was talking about the AERB-NRC co-operation which has been ongoing and the very positive impression he has had on the development that has taken place as the part of the cooperation and the respect the USNRC has for the Atomic Energy Regulatory Board. In fact, he went on to say that there were elements in Indian Programme from which they thought they could learn. This is a major statement and he did say that in a formal meting. So, I think we have every reason to be proud of. AERB has shaped itself to come to present stage. It can certainly shape itself into being a vibrant regulatory organization to take on the new challenges of regulating the new technology developments. After all when the fission reactor started, this is the way it had gone on in many other countries. And so I have no doubt that given the strong capability and the will we would also be in

a position to do so.

Now that brings me to yet another way of looking at this matter. We of course have to have the codes, standards, we have to have requisite procedures for reviewing safety. Now the question is when it comes to details, it has to be specific. And so PHWR regulation and fast reactor regulation for example, have to have their own specific special elements. But then in terms of assuring safety, there are some fundamentals and whichever technology one is talking about, we still respect those fundamentals. I think at the top level this is something which is very clearly being done. But I think time has come when one should also address this issue of being able to regulate in a technology independent manner. I know there are practical difficulties when it comes to details. But surely there must be a way of spelling out the safety requirements in a manner which are technologically independent. It may seem little difficult to begin with, but if you don't do that then we may face a situation of wheels within wheels where we are handling several technologies simultaneously. Today we are doing regulation with a few licensees and they are inhouse organizations like NPC, BHAVINI and other units. But tomorrow when it comes to private entities, they will surely put finger on the written rules. At that point of time, one way would be to have detailed standards laid down for all technologies well before we get their regulation or other way is to be able to do it in a manner which is technologically independent but still be able to carry out the detailed process, meeting all the requirements. I know it is very easy to say all this than actually do it. But it looks to me that this is bound to be of significant importance sooner than later.

There is another area which I think I must highlight and may be this could become an agenda for brainstorming during the silver jubilee year of AERB. It relates to the standards. There are, of course, safety standards and AERB has done wonderful work in that field. But there are also the industry standards. It is important that there is a strong indigenous standardization process as far as industry standard is concerned. I am a firm believer of the fact that industry standards are better done by the professional societies rather than by the Government or by the regulatory

body. It is necessary to launch that activity with all seriousness. There are some industry standards which are available. ASME codes for example which are undisputed. There may be others which can be adopted as has been already done. But I think if you want to really pilot an Indian Nuclear Industry where we promote maximization of value addition within our country then we need to have a much broader framework of industry standards and we need to mobilize the professional societies; of course the Indian Nuclear Society certainly can be one important platform but there could be others. Otherwise you would get into the confusion of overlapping responsibilities. I thought I will just leave this thought for your consideration as an agenda for the silver jubilee year brainstorming.

And the last point is, of course, on the regulatory ethics and I wholeheartedly complement AERB for bringing out this document. I think just as when we say, charity begins at home, the culture begins at home, so also ethics begin at home. And I think it's a great job that all of you have done. I think when it comes to ethics, it is also important that we are aware that the ethics are the part of the way the society evolves. We can interpret that in our own context. Traditions are very important. Somehow I feel that there is strong relationship between good traditions and good ethics. I think while we must evolve, and must adapt to the changing circumstances, there is some value about the good traditions that we have and there is a lot of importance to building on the foundations of those good traditions as a society and as an organization. And it is only then we can really put good ethics into practice. Otherwise ethics will remain in the booklet for the purpose of showing it to others.

I must conclude now. I think it's a great day. I once again congratulate all of you and let me reemphasize my gratitude to all the wise men who are sitting here for showing us this day and we look forward to another twenty five years of glorious achievements, lets say that in advance. Thank you.

Prof. A. K. De,
Former Chairman, AERB

AERB was constituted in November 1983. One day Dr. Raja Ramanna, the then Chairman, AEC called me up sometime in the middle of December. He was then Chairman, Board of Governors, IIT Bombay and so he knew me well and my capabilities. He invited me to become Chairman of the newly created AERB.

I did not know much about AERB. I was with IIT, so I knew about teaching; I was in research institutes, so I knew about research activities. I was in industry also before I joined IIT Bombay, so I knew how to run an industry, but I had no experience in regulatory practices. But he (Dr. Raja Ramanna) told me to join saying "you have all the experiences and people over here will assist you, don't worry". He was IIT Chairman, so how can I say no to him.

When I joined AERB in January 1984, there were only two people: Mr P.N. Krishnamoorthy, the member-secretary and myself. We had our office in Anushakti Bhavan for sometime. Then we moved to the Old Yacht Club (OYC) building. Subsequently, we went to Vikram Sarabhai Bhavan and now AERB has its own independent building.

Only after joining AERB, I came to know about the existence of DAE Safety Review Committee (DAE-SRC) and functioning under Chairman, AEC and this continued even after the creation of AERB. In that case what are we supposed to do? Initially there was much confusion, many anxious moments and much of suspense. Dr. Ramanna's simple logic was that "DAE-SRC is doing a fine job. Let it continue its work. AERB should concentrate on radiation safety issues connected with medical and industrial applications". Frankly speaking, it gave me a rude shock.

Matters however, needed to be sorted out and functions well-defined. We started working for the preparation of Safety Codes, Guides and

Standards. It took sometime to re-organise ourselves. I was told much later by Dr. K. S. Parthasarthy, the then Secretary, AERB that this was not very unusual and even when USNRC was first formed, there were similar problems. When you have power in your hand, you don't want to give it up easily and lose control over it. I imagined time will take care of it and all such inconsistencies will be removed soon.

Ultimately, SRC which was acting as an independent unit, came under AERB and DAE-SRC was disbanded. AERB started with six scientific personnel. We had to search for experienced people specially in the field of civil engineering design and construction. I was lucky to recruit Dr. P.C. Basu, a proficient Civil Engineer from the open market. I am glad to see that Dr. Basu and his group are playing an important role in AERB.

AERB selected people mostly from BARC and NPC. But we tried to re-orient them and develop a new mindset in them for the safety mission. We explained to them that regulation is different from operation and they will have to give special emphasis on public safety. Public should have confidence and trust in them. I am happy to see the huge expansion that has taken place in AERB in terms of both scientific personnel and also the number of activities.

India today is on the fast track of economic growth (9% GDP) and development. I think our electrical energy demand should grow at least by 10-12% every year for the next few decades. Today the effect of green house gases on global warming and climate change has captured the attention of all countries in the world. Nuclear energy does not emit any green house gases and has an edge over other alternative source of energy.

In 1985, I visited a nuclear power plant in France near Paris. At that time there was a dispute going on at TAPS regarding the safe distance of its outer boundary. When I visited this plant in France, I noticed a fine cluster of houses (almost a small township) well within the outer boundary of 1.6 km. I was asking how that

was possible. The French official explained to me "today we are having about 75% of electrical energy from nuclear sources and this has become possible because both the government as well as the people have accepted this as a primary source of energy. People feel safe with nuclear energy" France does not possess oil, coal or even uranium fuel. Nuclear energy, therefore, suits the country best.

In such matters, transparency is very important in our thoughts and actions. In India we at times want to keep things under a veil of secrecy. I was prevented in 1984 to take part in a discussion over nuclear issues. I could not call press people and talk to them. However, things changed slowly. I could do that in 1987 when I was appointed for the second time as Chairman. I met the press people and told them what we are and what we are doing at AERB.

One very important practice that the French Government was following was through a procedure called "Public Hearing". Many doubts about safety issues were removed through such dialogues. The public in France has full trust and confidence in government dealings with nuclear energy. I feel we will have to create such public confidence in our people about nuclear energy; we will have to ponder over it very seriously.

Nuclear energy, no doubt deals with dangerous and radioactive materials. Some radioactive fallout/radioactive leakages may take place but that should not go into the public domain. During my Chairmanship many professional people often asked me "Do you think, we are safe with nuclear energy?". AERB conducted an opinion poll-survey in 1987 about the common man's perception about nuclear energy through a questionnaire amongst the students, staff and faculty at TISS. Many of them had vague ideas about nuclear energy, its potentials and other effects.

It seems to me that we should go out and tell the people as the French Government is doing or even the Japanese Government is doing now.

Japan today has 30% of its energy share from nuclear sources and they are planning to reach 60% during the next few decades (a country that was ravaged by the nuclear holocaust). The Regulatory Body is not a promoter for nuclear energy. A utility would build nuclear plants but a regulator would approve its operation subject to regulatory procedures keeping public safety as its primary focus.

At one time we were proud to say that our control room operators are all graduate engineers whereas the USA employs mostly class twelve year school pass-outs. It is very important that people must be well trained but integrity should be one of the important characteristics of people. When one looks at AERB logo, probably notices that people here are attempting to protect people from dangers of radiation damage. When people have complete confidence in you, then there is nothing wrong in going for nuclear energy.

The country is producing at present only about 3% of the total electrical energy from nuclear sources. Many other countries have gone far ahead of us. We have enough of intelligent and competent people in the country to shoulder the complicated problems of nuclear reactor design, construction, operation and also of regulation.

In 1988, I led a team of nuclear experts to the then Soviet Union to understand and discuss the various safety issues of a new reactor design fitted with some novel safety features. The new reactor was proposed to be set up at Kudankulam. Dr. Kakodkar (present Chairman, AEC) was also a member of the team. We had very detailed discussions and with many probing questions from the Indian side. At the end of the meeting one member from the Soviet side remarked thus: "We have many visitors from abroad and discussing with us on our nuclear plants but this is the first time ever we have come across a team of experts from India who have asked so many searching questions on the safety issues of our reactor".

International Atomic Energy Agency has predicted that India would

need about 40GW of electrical energy by 2030. DAE, I understand, has a plan for nuclear energy to reach from the present 4,000 MWe to 40,000 MWe, by that time. This would, no doubt, be a very big jump. What is needed is a strong political will and a drive to garner all the resources at our command to achieve the goal. AERB has to play a very important role in this expansion programme, as it is the ultimate lynch pin on all safety issues.

I wish Mr Sharma, Chairman, AERB and his Scientific and Technical Staff all success in their endeavor; a glorious and bright future is awaiting you.

Shri. S. D. Soman
Former Chairman, AERB

I am glad to hear about the current activities and the future plans and also that good amount of effort is being put in for human resource development. One thing I would suggest that the training programmes have to be lot more broad based because regulatory body has to regulate from mine upto waste disposal. All these activities have to be covered in a program at appropriate level. In fact I had a benefit as Head HPD, BARC as I was associated with all these things activities since the health physics units were located at all these places. I had to go and see their safety things, so I didn't have any problem. But with the newer people coming, I think this is one thing which AERB should keep in mind in its training programmes.

Transparency, is again very much necessary. One of the things which I had started was every year I used to have a press conference when the annual reports came up. Give it to the press people, let them ask questions while all the members of the Board should be on the dais and they should be answerable to the questions. So programmes about the involvement of the people and the agency, which reflects the voice of the people, should be carried out. I note that in recent years this has sort of diminished.

Another challenge that AERB will face in the coming years is the participation of the private industry as the civilian nuclear cooperation programme is coming up. So far only government (public sector) agencies were involved in the nuclear power development but with the private people coming in, I think the regulatory activity will have to be much sharper and time bound to meet the private utilities' need. I am sure this can be done and it will have to be done if we have to take advantage of the activities, which are envisaged as a part of this civilian nuclear cooperation programme.

It is very important to remember that the operator and the designer

of the facility are much more knowledgeable than the regulator and the regulatory people must give enough weightage to it and also should benefit from it. That's how, infact I was able to pick up people (like Shri S.V.Kumar, former Vice Chairman, AERB) and bring them to AERB. These people knew the things and at the same time have the safety culture and will be free to criticize their own facility from safety point of view. So this is again important. Regulatory body is like an external auditor but the people who are managing are those who were in the operation of the plant, designing of the plant etc. They knew much better than the regulatory people. As regulator, we can only do the spot checks.

I'm glad that the Regulatory Board has brought out number of documents which sort of make out the framework within which the operator or the licensee has to function; it could be design, it could be operation, it could be any other thing. AERB has very much benefited from the activities of IAEA. In fact we have a programme which is similar to IAEA programme on codes and guides. One thing, at least in my time, which I had a difficulty was just as IAEA had codes and guides for governmental organization, what could be the parallel of that in AERB's codes and guides. But I am glad that AERB has come out with that and brought some guides and codes in that area also.

One of the things to which probably more importance should be given is emergency preparedness. Now fortunately incidents or events etc are very few and minor. But that should not slacken the operator or the regulatory people on how one can handle actual emergency situations. This was one of the important things that was taken up by the government after the Chernobyl incident and in fact no new power stations were approved till government was satisfied with the emergency preparedness documents, drills which were being carried out and the whole mechanism. We should not allow it to slacken.

Well I wish Regulatory Board more and more successes and heights to attain in the coming years. When I took over, AERB was 6-7 years old child and it's nice to see now that it has grown to 25 years. Wish you all greater successes in the future.

Prof. P. Rama Rao
Former Chairman, AERB

My greetings to all of you and many happy returns of the day. Anniversaries are very happy occasions. They are also occasions when one is tempted to revisit the past nostalgically. But then memories always tend to fade, more so when one is ageing as I am. Still let me try and recall a few events. Some of these are personal to me and I crave your indulgence.

I was winding down at the Department of Science & Technology, New Delhi and I did not wish to continue in an administrative position. So I returned to DRDO and I was placed in Sena Bhavan, New Delhi. It was at this time that I received a phone call from Dr Raja Ramanna. In his capacity as Chairman of the Search and Selection Committee, he wanted me to take over as Chairman, AERB. I was not inclined to moving into another desk job. Moreover I was not sure what the assignment called for. So I pleaded with Dr Ramanna to excuse me. Not willing to take a 'no' from me, he shot back, "you can't say no to me over the phone; at least say that you will come and talk to me". I agreed to see him and ended up at AERB.

I had then a fair acquaintance of the DAE activities. I had some friends in metallurgy. My first encounter with the department goes back to the late fifties. I was at the Indian Institute of Science, Bangalore as a research scholar and I was carrying out research on X-ray diffuse scattering. At OYC, Dr Brahm Prakash, Head Metallurgy Programme and his group had acquired an X-ray diffractometer which I was permitted to use for my studies. During that period I got to know more about the metallurgy program and also made new friends. Dr. R. Chidambaram and I were long-standing friends. Because of him and Shri C.V. Sundaram and their colleagues, I subsequently used to visit the department to participate in the selection and promotion committees. Beyond these, I cannot say that I knew much about DAE or for that matter AERB. However, when

I entered the portals of this then new, elegant building, I felt instantly comfortable and the credit for this feeling entirely belongs to the staff and scientists at AERB. Once I settled down here, experts, who were members of the safety committees, dropped in to talk to me about technical matters and it was a pleasure as well as was educative. With a scholar like S.V. Kumar around, the learning experience became even more pleasant.

One visitor to my office, who made an indelible impression on me was Dr Ramanaiah. He telephoned me first and then came over to my office. He was immaculately dressed. He spent more than an hour with me and enlightened me on my role as a regulatory authority in a strategic department such as DAE. Little did I know that he was gravely ill. A few days later, it was heartrending to learn that he had passed away. This meeting, more than anything else, made me appreciate how uniquely fortunate the department was in the way it perennially commanded loyalty from its employees.

I also vividly recall my first tutorial on the operation of a power reactor during the train journey to Rawatbhatta. The reactor had some difficulty with the over pressure relief device, OPRD. I had requested Ch Surendar to accompany me. During the journey, he explained quite a lot about the reactor and the problem with the OPRD. The kind of professional in-depth knowledge he had of the design, the technology and the materials was astounding. This was also true of Sanath Kumar who had designed and built the fuelling machine. I can mention more names but we do not have the time to do so on this occasion.

When a person like me who has moved around in this country in various fields comes here, he can make certain observations of his own. Let me point out to two of these.

The DAE is exceptional in having built a multi-disciplinary development programme covering a vast spectrum of difficult areas all the way from exploration of minerals to operating commercial power

reactors. I do not have to tell this audience what challenges figure in between these end points. Besides, areas of societal need have received attention. It was heartening to see this feature evident recently at Hyderabad when the Indian Nuclear Society felicitated Shri Gupta of Uranium Corporation of India Ltd and Dr. Dinshaw of Tata Memorial Hospital. It is indeed to this spectrum that I got exposed when I was associated with AERB.

The second point pertains to technology transfer. There are any number of specialists who point out that technology transfer is best accomplished on the plane of the personnel. I saw it most effectively achieved in this Dept. Heavy water industry was built by scientists and engineers who had developed the technology themselves. This is typical of what is happening all the time in the unique environment of the programmes here. Right now the Prototype Fast Breeder Rreactor is being erected at Kalpakkam by the very people who developed the technology in the first place. At least I have not witnessed this aspect taking place anywhere else in the country in the same technical depth. The DAE community deserves to be complimented to have mastered technology transfer almost as if it is its cultural characteristic.

There were many occasions when the over-all technical strength and the world class professional approach of the department came to surface. Among those I have seen first hand, I would like to highlight the restoration of the dome of the Kaiga reactor inner containment. The delamination that had occurred while its pre-stressing cables were being tensioned posed a major challenge. How the problem was investigated, the dome reengineered and a new dome constructed to exacting standards is a true testimony to the professional calibre of the DAE community. I must not fail to mention the crucial role played by AERB in resolving this important issue.

Yet another gratifying aspect of my tenure was that we could set up the Safety Research Institute (SRI) at Kalpakkam to carry out R&D in areas of interest to AERB. As you may know, our proposal for the project

was sanctioned within one month; my friend Placid Rodriguez, Director IGCAR readily gave the land and infrastructure support that helped impart a jump start to the Institute. Some months ago, I received an e-mail from Sunil Sunny stating that he had been awarded his Ph.D for his work in SRI; that was truly a moment of great joy for me.

My days at AERB have always been very vibrant and enjoyable and I cherish very much all those rewarding memories. Today I find that AERB has grown in strength, in activities, in infrastructure and so on. It is my great honour to have been given the opportunity to be amidst you all on this historic occasion; and it is my great pleasure to wish AERB many more years of outstanding professional accomplishment.

Prof. S. P. Sukhatme,
Former Chairman, AERB

Let me at the outset say that I am very happy to be present on this occasion during the silver jubilee year of AERB when we are adding a new building to the existing Niyamak Bhavan. The process of construction was initiated when I was Chairman and I am happy to see that it has been completed. I am also happy to note that a formal 'AERB Code of Ethics' has been prepared and is being released today.

The previous Chairmen have taken a look at the past. How AERB began its work in 1983 and how it has grown. How it started functioning initially in the Old Yacht Club, moved on to Vikram Sarabhai Bhavan and then to the present location. The past is obviously important and is always with us. Remembering it yields important lessons and the reviews by the previous speakers gave valuable perspectives.

However, in the short time available to me, I propose to go in another direction. I shall look to the future and highlight some issues and challenges which lie ahead for AERB. I shall also lay down a guiding principle for decision making.

The challenges are obviously many and I will focus only on two. Both issues are important and for that reason, too much should not be read into the order in which I take them up or to the fact that I will not be mentioning other issues. My comments will be general in nature and I will be speaking in an overall sense.

Perhaps the biggest challenge which AERB faces in the future is the challenge of attracting talented human resources into its fold and of retaining these personnel through well-designed human resource development programmes. This is a challenge particularly for those in charge of AERB. You may have buildings, you may have equipment, you may have computers, you may have all the material resource necessary.

However, you will go nowhere without the right kind of people. The success of an organization depends upon its human resources. I would like all those who are in AERB to ponder over this fact and always keep it at the back of their minds.

Needless to say, a lot has been done in this regard within AERB and within DAE, the BARC Training School being an outstanding example. It required vision to set up such a school in 1957 and it is because of this vision that leadership has been provided for carrying forward the country's programme in atomic energy. But human resource development does not end with having a training school, the development of people has to continue right through their careers. To my mind, that is the real challenge. You have to take young people who are well educated and qualified, orient them with appropriate training at the beginning and ensure that their education continues during their tenure in AERB. The process of learning and the desire to acquire knowledge must never end. Only then will AERB be a vibrant organization, which discharges its role efficiently.

The second challenge which I foresee is the need for more transparency. It is two years since I left AERB and I see this issue as a challenge even more clearly now. I am convinced that AERB needs to make more of its actions, decision making process and decisions known in the public domain. Again, I don't want to give the impression that nothing has been done or is being done. AERB has a good website, press releases are issued from time to time, and interactions take place regularly with the public. So AERB has a good track record. Also, I am not saying that transparency means telling everything and talking about everything. Transparency obviously has its limitations. However, in today's world with media closely watching all developments, AERB as a regulator has to do more in this regard.

Amidst these issues and challenges, what should be the guiding principle is for the staff of AERB when it comes to taking decisions. I believe that all times, the guiding principle has to be 'Is what I am

doing fair?' As a regulator, sometimes you have to be hard as a diamond and sometimes soft as a flower. However, all the time whether one is hard or soft, one's actions have to be guided by a sense of fairness and correctness. In this context, it is very appropriate that AERB is releasing a Code of Ethics today, a set of rules for behaviour and for taking action.

When faced with an issue requiring decision, what does a person as a regulator do? He reads and understands the papers on the subject, has discussions and meetings with the appropriate people, talks to the persons directly concerned and then finally comes to a decision. In this process, the individual who takes the decision, whether he be Chairman AERB, Chairman SARCOP or Chairman of some other Committee, has to ask himself the question –"Is my decision a fair one? Is what I am doing beneficial to the needs of my country and of society?"

AERB has done well in its first twenty-five years. It has grown in size and stature. I am sure it will improve on this record in the next twenty-five years. My best wishes for its continued growth and success.

S. K. Sharma,
Chairman, AERB

Friends, we are here to celebrate the start of the Silver Jubilee year of AERB. In November 1983, AERB started with an humble beginning with a handful of people at Old Yacht Club. Later it moved to Vikram Sarabhai Bhavan and further to Niyamak Bhavan. Now we have about 200 employees and one more office building, Niyamak Bhavan-B is going to be inaugurated today. In between AERB also took a southward turn, thanks to Prof. Rama Rao, and it established the Safety Research Institute (SRI) at Kalpakkam. Prof. P. Rama Rao told us that regulators should also be in the thick of scientific research: research which is of value to safety and regulation, and that is how SRI got started. I am happy to inform you that SRI is flourishing day by day and is doing very good and useful work for us.

During all these years there has been a strong emphasis on development of in-house competence and today we have a fair amount of expertise available in several specialized fields like reactor physics, thermal hydraulics, probabilistic safety assessment, seismic engineering, concrete technology, risk assessment of chemical process plants and so forth. Several of our experts are there in the committees of Bureau of Indian Standards for development of national standards. We also have won some research contracts from the Ministry of Environment and Forests for specific jobs like developing risk assessment standards for the chemical industries.

The main thrust of work in AERB is the design and operational safety review of nuclear and radiation facilities, enforcement of industrial safety in DAE units and development of safety documents. In doing this work, we had several challenges and difficulties which we faced during the last twenty four plus years. Some of them were the turbine hall fire in Narora, Kaiga inner dome delamination, safety of coolant channels in pressurized heavy water reactors, the problem of feeder pipes thinning, flow assisted corrosion of the secondary system piping, damage to the

moderator inlet manifold in the calandria of MAPS units, cracking of endshield in RAPS, unintended power rise in Kakrapar, ash pond breach and ropeway failure in the Heavy Water Plant, Manuguru, and the most recent being the flooding of the PFBR pit during the Tsunami of December 2004. We were able to tackle all these problems reasonably well and this was due to very hard work put in not only by the staff of AERB but also by several of our technical support personnel like BARC specialists, IGCAR specialists and the very special manpower resource that we have in the form of our retired colleagues. I must take this opportunity to profusely thank them all for all the help extended and I am sure that this will continue.

Another hallmark of AERB is that it does not hesitate to take help in safety evaluation from the experts of its licensees organisations and this arrangement has been working very well. When these experts sit on our side of the table, they wear a different hat and many times we have seen that they are stricter than AERB staff in enforcing safety. This I think is a very important aspect of safety regulation in this country.

Atomic Energy Regulatory Board is a unique type of regulatory body as it has to deal with not only a large number but also a large variety of designs of nuclear power plants and also fuel cycle facilities. Look at the type of nuclear power plants we have: we have boiling water reactors at Tarapur 1&2; we have 220 MWe and 540 Me Pressurized Heavy Water Reactors and recently we have been asked to examine the safety of 700MWe PHWRs. We then have the 1000MWe Pressurised Water Reactor being built at Kudankulam, Proto Type Fast Breeder Reactor and the Advanced Heavy Water Reactor. In addition to the nuclear power plants, we have several fuel cycle facilities like the fast reactor fuel cycle facility at Kalpakkam, UCIL facilities with several new mines coming up at Banduhurang, Mohuldih, Gogi and Tummalapalle, the NFC units at Hyderabad and the new Zirconium Sponge Plant at Pazhyakayal. There are beach sand minerals industries and recently several private entrepreneurs have entered into this business. We have industrial gamma irradiators, industrial radiography facilities and a large number of nuclear medicine and radiotherapy facilities. In addition we

have the heavy water plants and also the diversified projects of Heavy Water Board for development of solvents, enrichment of boron, recovery of uranium from secondary sources etc.

We have been also engaged in recent times in safety review of old plants like RAPS 1&2, MAPS 1&2, Tarapur 1&2, IREL Thorium Plant at Trombay and some of the facilities at Nuclear Fuel Complex, Hyderabad. We have conducted these safety reviews in a very extensive manner. I am happy to inform you that the work done by AERB has won appreciation not only from people here but also from several foreign regulatory body personnel. Towards formal validation of our quality management systems, we obtained the ISO 9001 : 2000 certification from the Bureau of Indian Standards in September 2006.

We have our share of problems as well. We have the problem of denial of shipment of radioactive material, problem of low level radioactive contamination in steel products in export consignments and loss or theft of radiation sources which are used in industrial radiography. And for these we have to deal with several agencies, not only the facility owner but also various government authorities, the police and even the lawyers.

Another area of our work is laying down safety regulations in the form of safety documents. This work was started right in the beginning as soon as Prof. De took over as the first Chairman of AERB. I remember that even in early 1984 when this work started, I was myself a member of the committee for developing the safety code for operation of nuclear power plant. As of now we have over 120 safety documents published and another 20 or so for which work is in progress. Even though we do not regulate the BARC facilities, we took it upon ourselves to develop the safety documents for radioactive waste management and for spent fuel reprocessing. I am happy to inform you that this work is progressing very well.

Even though AERB is a regulatory body, we consider it our duty

not only to just carry out the safety reviews and enforcement actions but also to proactively involve ourselves in bringing about initiatives for safety enhancement. And in this direction we conduct training courses, workshops, discussion meetings and even awareness programmes. AERB has instituted industrial safety, fire safety and green-site awards that are given every year to the best performing DAE units in the respective areas. I think this has stood us in good stead as several problems can get solved when we have a organized and structured discussion between the regulators and the regulated.

We are also quite deeply involved in several activities of the IAEA. We have representation in INSAG, Commission on Safety Standards, Transport Safety Committee, the Incident Reporting System of IAEA/ NEA, International Nuclear Event Scale based reporting, the illicit trafficking database of IAEA and we also participate in some IAEA coordinated research programmes and various technical meetings and seminars.

We have bilateral co-operation with USNRC for the last four years in which we already had eight discussion meetings. Similarly we have bilateral co-operation with the French Nuclear regulatory Body, ASN, and with the Russian Nuclear Regulatory Body, ROSTEKHNADZOR. We are also in the CANDU senior regulators group and recently have joined the VVER senior regulators forum. We have been able to get some of our younger colleagues trained abroad. Two of them were trained in Sweden under Prof. Balraj Sehgal and I must thank Shri S. K. Mehta for initiating that. One officer was trained in Italy on uncertainty analysis and two of our colleagues were recently trained in USNRC in the area of risk informed inspection. One officer has been sent for post doctoral studies in Japan under the JSPS scheme.

Well, this is what we have been doing in the past. And now we are in the silver jubilee year and we have drawn an outline of the activities to be conducted in the year-long celebrations. Of course the first one is this function wherein we will have the new building inaugurated by Prof. De. We also have brought out a code of ethics for AERB which will be

released by Chairman AEC today. We also plan to bring out monographs on some topics of interest and one such monograph on probabilistic safety assessment has been prepared and will be released by Chairman AEC here. Another monograph on construction safety is getting ready and we plan to get it released during the DAE Safety Professionals Meet in December this year at Rawatbhata. And then we have a plan to conduct a workshop on safety regulation of nuclear and radiation facilities in India for our media friends. We have talked to a few of them and they seem to be quite excited about it. In addition we have planned a number of seminars on technical topics and invited talks from eminent speakers including our Board members. Towards the end of the silver jubilee year we are going to have an IAEA International Conference on Topical Issues in Nuclear Safety during November 2008.

Sometime back India ratified the convention on nuclear safety and the 4th review meeting under this convention is going to take place in April 2008. Our national report has already been prepared and submitted and in this work there has been substantial involvement of the AERB staff. The nuclear and radiation facilities in our country are expanding at a very rapid pace. They are also getting spread all over the country. So in the eleventh plan, apart from augmenting our manpower resource, we are also planning to open two regional centres of AERB. One will be located in the eastern region in the Rajarhat complex of VECC & SINP, Kolkata and the second one we will locate near the guest house of our Safety Research Institute at Kalpakkam. With that we hope to be able to carry out our regulatory activities in a more expeditious and efficient manner in these two regions. For the western region, we will continue to work from Mumbai but for the northern region, may be subsequently we will think of opening another office.

Friends I once again welcome each and every one of you to this function that marks the start of the silver jubilee year of AERB. Thank you.

Shri. S. Vasant Kumar, Former Vice Chairman, AERB

I am indeed very happy that AERB is celebrating 25 years today. It's a long journey and we have reached certain maturity. I am so glad about it. We have passed through many milestones and achieved many important things. I had the good fortune of being associated with the DAE-SRC. I have very pleasant memories of those days and after SARCOP was formed, I was a member of SARCOP. Mr. M.S.R Sarma was the first Chairman of SARCOP. After SARCOP and AERB came into existence, there was a change in the approach: there was more professionalism in all the deliberations in SARCOP and in the activities of AERB. As the famous Sanskrit saying goes "Vajradapi Katorani Mriduni Kusumadapi, Lakottaranam Chetamsi Kohi Vijyatum Arhasi", a regulator has to be tough like a diamond and soft even like a flower. So a regulator will have to react to situations in different ways. I think in many cases we have adopted both these methods. During my tenure as a member of SARCOP and subsequently as Chairman SARCOP and in other activities of AERB, I had many occasions where we applied these two principles appropriately. That is the main principle on which a regulator has to work. When an important issue is involved which requires a hard decision, one should not hesitate to take such a decision. But we should also keep in mind the overall progress, the overall interest of the organization.

In all these 25 years, we earlier depended very much on the expertise available in BARC and other organizations to help us. I am very glad to know that now AERB has reached a certain maturity and there are good number of youngsters who have joined AERB and will be able to discharge these functions.

Well I encountered many challenges during my tenure. I can recall some of them here. My first challenge was to prepare the technical specifications for a reprocessing plant. This was a spin off from the reactor system and reprocessing plants did not have any technical

specifications. The main problem we had was what the reactor wants to achieve, reprocessing plant doesn't want to achieve. Namely the main aim in a reactor system is to make it critical and in a reprocessing plant one has to prevent any criticality. We did not know how to match these things. Mr. Soman helped us a lot in understanding what a technical specification was. It was necessary to understand the purpose of a Technical Specification and write them to meet the safety requirements. I am very glad to say that over these years we have had the technical specifications prepared for all the non-reactor facilities in DAE and it's really an achievement. It may not be exhaustive, it may require corrections, but a document is available and people in the non-reactor areas know the importance of technical specifications and the need to follow it for safe operation.

We had many more challenges like the fire at Narora Atomic Power Station. It was a very good team effort by both the people at Narora and the regulatory body coordinating effectively. We could arrive at very solid conclusions and it actually got us recognition internationally. In fact when I went to the IRS (Incident Reporting System) meeting of the IAEA, the way we have tackled the incident at Narora was well appreciated. They were wondering how we could handle the emergency situation so effectively. It emphasized the training that we give to all our personnel who were manning the plant. A delegation from USNRC came to find out what sort of training we impart to our shift engineers and other engineers. It is a matter of pride that we could get an international acclaim and that shows the quality of people that are available in this organization.

Subsequently we also had the problems with the bent sub assembly of FBTR. The French people refused to help us in that but we could arrive at our own methodology and retrieve the bent tube. The SARCOP deliberations we had on this topic were really memorable.

The reactor safety and radiation safety were getting sufficient importance but industrial safety is another wing, which is equally

important. We initiated efforts to focus attention on Industrial Safety. The safety officer in any unit did not have sufficient importance in the entire setup. So to give him that sort of an importance we organized annual meetings of the safety professionals. We had every year a theme topic where we would invite experts from outside to come and deliver lectures and it had been a great success. Then we had fire safety and occupational health also associated with that. We initiated giving awards on safety day. These are all the promotional activities that AERB did and I am glad these are continuing. I was happy that all the heads of units including Chairman AEC have been encouraging this activity.

These are some of the initiatives we have taken over these 25 years. I am sure with the bright people and the experienced people, AERB will go from strength to strength and will be a model for regulation and continue to flourish.

Shri. G. R. Srinivasan
(Former Vice Chairman, AERB)

I have observed the growth of AERB from 1983 to now. I am able to recall how it was built brick by brick to the present status of being able to fulfill satisfactorily all its obligations. I would like to appreciate the efforts of all the previous and present Chairmen, Vice Chairmen and entire staff who have preceded me and were after me.

There were times when there was tremendous stress for the Board as well as AEC on regulation. It was extremely important to match growth in production with being able to carry out its mandate of ensuring public, environmental and occupational safety. However, as it happened in many other countries, the growth of Regulatory Body matched the growth of the nuclear activities in India.

I had a chance to study closely the regulatory processes in US, Russia, France, Canada, Korea, Finland and many other countries and I find that the regulatory system in India, under AERB, is comparable. But this should not stop us from marching towards excellence in regulation. Marching towards excellence is a continuous journey, not a destination.

One piece of advice is that we must continue the dynamic rhythm with which we had commenced and conducted training for competency development in AERB. We had employed the SAT (Systematic Approach to Training) process for training of AERB staff. In my opinion the independence of any Regulatory Body stems as much from the esteem with which the licensee holds the licensor because of their competence, of their maturity, balanceness and because of the way they achieve adequacy in dealing with safety issues. The training course covers all the aspects which I have mentioned above and include even such characteristics of the unenvying job of a regulator, negotiating technique etc. Needless to say, in addition to the above, independence needs to be established by legal and regulatory framework.

It is difficult to dissociate oneself from the global renaissance which is taking place in nuclear power. This renaissance is public driven, user driven and not industry driven as they were earlier. Hence, it is going to be sustained and irreversible and will stay. There is bound to be shortage of the three resources: men, material (raw and manufactured) and money. India can see these as opportunities. I will not be surprised if in 15 years from now, Indian nuclear industry, like IT now, puts India in a position of global supplier of all three resources i.e. manpower, material and even funding. Specifically, the shortage of manpower will have an impact both the licensee and the licensor. One has to really develop and plan human resource because you can't produce competent people overnight.

Activities of both licensee and licensor, especially to ensure safety, are knowledge driven. We must remember nuclear industry is an unforgiving one.

I would also like to support the methodology being adopted for regulation in India, i.e. inclined towards the informal method. This is somewhat similar to the French methodology. There is tremendous brainstorming on all issues between experts from all agencies both within and outside DAE and including from licensee organizations.

The objective is common between all these experts i.e. to achieve production consistent with safety, safety having an overriding importance. In fact our observation is when the licensee wears the cap of a regulator, he becomes harder than the regulator.

The regulatory burden is inversely proportional to the pro-activeness of the licensee. It is also observed that inherent safety is always stronger than an induced one. I would request for a good safety culture and pro-activeness in their (licensee) organization, not that it is not there now, but we always aim at excellence.

I am sure that the next ten years, we would see more activities than

what we have seen in the last 25 years. I am confident that AERB will gear up for it, continue to carry out its mandate and be one of the globally leading regulators.

Message from M. S. R. Sarma, Former Chairman SARCOP

The safety practices are governed by the directive given by Bhabha in the early days which reads "Radioactive material and sources of radiation should be handled in Atomic Energy Establishment, in a manner, which not only ensures that no harm can come to workers in the Establishment or any one else, but also in an exemplary manner so as to set a standard which other organizations in the country be asked to emulate." This directive was when we had not even started handling radioactive materials. He wanted DAE to be a role model and to a large extent it had been; particularly in the areas, of course, of safety, quality control, multi-disciplinary training, multi-disciplinary activities, merit promotions etc.

In the initial days of Apsara, there was no specific committee as such to review the commissioning / operations. However, all those who matter including Bhabha, used to be present, more or less on every occasion in the initial days of Apsara operations. Dr. Bhabha also directed that when the reactor is shutdown overnight, one fuel element from the core be removed and put aside in the pool as abundant caution. This is how the safety culture in the department had started.

When it came to CIRUS, a committee was constituted, headed by A.S.Rao to authorize the commissioning operations and also review "Hazards Evaluation Report". Ironically, nuclear industry, the world over has been its own "Devil's Advocate" using terminology such as Hazards Evaluation Report, maximum credible accident, maximum permissible concentration, criticality etc. and these phrases certainly caused alarm in the minds of the common man.

Tarapur units-1&2 were licensed for operation in US by USNRC. Hence no review of the safety was done but a committee designated as Start-up Committee was constituted to review and authorize various start-up tests

/ operations in the initial days. When it came to RAPS, a safety committee was constituted, headed by S.L.Kati to recommend to Chairman, AEC for permission during various stages of commissioning. Subsequently the DAE Safety Review Committee (DAE-SRC) was constituted, headed by A.K.Ganguly. The DAE-SRC was mandated to supervise the safety in all the activities of the department including industrial safety. While this was in vogue, the Atomic Energy Regulatory Board (AERB) was constituted in 1983 with a mandate to oversee radiation safety in the entire country including DAE installations as well as industrial safety in all the units of the department.

During the initial stages after the constitution of AERB there was a tremendous communication gap between DAE-SRC and AERB. Prof. De, the first Chairman of AERB, took this very patiently in his stride. This situation of course got corrected when SRC was re-designated as SARCOP and merged with AERB. I am one of those privileged to have joined the AERB in the initial stages and my experience in the utility had strengthened my conviction with regard to decisions involving safety. The first job assigned to me was to head a committee to review the industrial safety status of DAE units. This committee made recommendations with reference to industrial units under construction as well as in operation. Specifically another committee was constituted to review the industrial safety status of R&D units. That committee also came up with recommendations for a structured organization. This has been a very important contribution towards promoting industrial safety as well as giving some sense of status to Safety Officers.

The concept of technical specification was taken from Tarapur. This was the practice laid down by USNRC. Canadian practice was to have operating policies and principles (OPPs). We started with OPPs for RAPS and subsequently adopted the Technical Specifications. This concept was carried forward to all the power plants. Further, it was applied to the other units of the department i.e. Heavy Water plants, Reprocessing plants, Nuclear Fuel Complex, IRE etc. This has become a guiding principle to be complied with by the utility. Any violation was

to be reported to AERB. Consent to restart the utility had to be obtained from AERB.

People often question the independence of the regulatory authority because it is part of the department in their view. In lighter vein I used to say that we need two Prime Ministers, one for the executive and the other for the safety. In my tenure as mentioned earlier, I have been on both sides, operations and regulations and at no time was the safety body over ruled by the powers that be. I give a few instances to illustrate the above:

1. When I was with the utility, I had approached Chairman, AEC on two or three occasions pleading with him about the decision of SRC and I had submitted a note in writing, justifying my plea. As could be expected, nothing came out and I stopped complaining subsequently.
2. There was a proposal to reduce the exclusion distance to 1 KM which was not agreed to by DAE-SRC. When the matter went up to Chairman, AEC, it was returned with a note that "both of you should agree on a figure and come to me for approval". Hence 1.5 KM exclusion distance stands even today.
3. A hold was put on restart of HWP(Kota) after H2S leak occurred in the plant coming out into the environment. There was organizational deficiency and AERB insisted that they should have a protocol for No. 2 & 3 in the organization and also an order directing that at least one of these should be present at station all the time. This was appealed to Chairman, AEC and, of course, he did not overrule AERB's decision.
4. On another occasion FBTR tripped on over power and we asked them to investigate before the restart and this was appealed to Chairman, AEC and he said; "either you convince AERB or comply – don't come to me for arbitration".
5. On one occasion, one of the units had exceeded the agreed to annual manrem in the first half of the year and hence a hold was put on the unit to restart and the unit was asked only to

do emergency maintenance so that the manrem consumption got normalized. On this issue Chairman, AEC made a visit to the unit and advised them in strong terms to adhere to the limits agreed to on consensus.

6. During the initial stages of Dhruva operation the fuel elements used to get dis-assembled due to flow induced vibration. The design was modified to correct the situation and reactor started operation. After some period of operation the safety committee wanted one fuel element to be taken out for inspection. The BARC authorities were not readily agreeable but we had to convince them about the necessity for this inspection to ensure trouble free operation in future. Dhruva authorities complied.

At the time of criticality of FBTR there was a lot of publicity given about the ensuing event and the regulatory board was meeting on that day to consider permission for criticality. One of the members was sore about the meeting. In his words "are we a rubber stamp". My colleague and I had inspected FBTR to assess their readiness and made a recommendation to the Board to consider the FBTR application for criticality. Hence, I butted in and said that in the view of FBTR they have complied with all the pre-conditions and were awaiting only the formal approval from the Board. To that he questioned "if we don't approve what will they do"? I immediately said they will wind up and go home and will not move one step forward without formal approval from the Board. This has been the tradition in the department all along. Of course finally the Board approved and gave its consent for criticality of FBTR.

While people with operating experience were initially preferred subsequently it was felt that their knowledge in other areas need to be updated with respect to prevailing codes, guides and standards. Hence, a complete training programme was started in AERB for those who were already there as well as those who were joining afresh. This is very important since the regulator must be able to discuss with the operator on equal footing on the knowledge base.

In my own experience I have avoided being present on the first

approach to criticality during my tenure with the regulatory body. Basically being an operator I was afraid that I might give in to the plea from the utility for some concession in the process of approach to criticality.

A practice of visiting the units at least once in a year was started with SARCOP and this certainly has brought benefit to both sides i.e. the regulator as well as the operator.

With respect to Industrial Safety an annual meet of the Safety Professionals was initiated by G.R.Balasubramaniam and when I took over SARCOP it was handed over to me to carry the mantle. This has been going on successfully with the Safety Officers highlighting their difficulties and problems in their units which SARCOP used to take up with the Heads of units for redress. Subsequently this was joined by occupational health professionals and that also has been bringing good interaction between the units and sharing of experience among them.

When BARC was taken out of AERB's purview there was a furore and coincidentally at that time INS Annual Conference was being held and Dr. Chidambaram was invited to inaugurate the same. After the function when the press questioned him about the implication of this move he looked at me and said to the press "He has been with the department since inception. He was part of BARC initially, then joined power projects and finally ended up with the regulatory board. He is also the President of INS at present, hence you can take his views." I had to tell them that we started our career with BARC where respect for safety and practice of safety culture were imbibed from the beginning. We had carried forward the same into other units wherever we had gone. The present change does not warrant any concern since BARC will also have safety committees to enforce safety in their operations and also the present separation is in line with the international practice.

Although it is alleged that AERB is part of the Department of Atomic Energy, AERB never hesitated to put its foot down when it was necessary.

Hence independence of the board was never in question in the day to day functioning of the departmental activities. In several committees people from all units of the department were co-opted. It goes to their credit that whenever they become part of the safety committee their allegiance has been towards safety even at the cost of their parent unit.

The order constituting AERB stated that the mandates laid down by the Board shall be complied with and any objections shall be appealed to the commission subsequently. Of course there was no occasion in all these years when an appeal had to be preferred.

AERB does not have the practice of stationing inspectors at utility site. During important / crucial operations observers are sent to make their observations and report to the Board after discussing with the utility. Essentially this has been the process of self regulation where the utility reports the violations and seeks consent for re-start depending on the severity. This has been working very well and is certainly a reflection on the maturity of both the operator as well as the regulator.

Profiles

Prof. A.K. De

Chairman, AERB (02.01.1984 - 19.03.1990)

Prof. Arun K. De, born in 1925 is a graduate of mechanical engineering from Jadavpur University (1947) and a Ph.D from Moscow (1965). After he had his industrial training and experience both in India and abroad, he switched over to teaching at Indian Institute of Technology (IIT), Bombay in 1958 as faculty member. He then joined Central Mechanical Engineering Research Institute (CMERI), Durgapur as Director in 1969, returned to IIT, Bombay as Director in 1974, went on deputation to Defence Research and Development Organization (DRDO), Ministry of Defence, New Delhi and finally became the first Chairman of Atomic Energy Regulatory Board (AERB) in 1984, the position he occupied till 1990. He is a Fellow, Indian National Academy of Engineering (INAE) and Fellow, Institution of Engineers, IE (Ind).

Prof. De is an outstanding professional engineer, a researcher, an educationist and an administrator of distinction all rolled into one. He has to his credit the autobiographical book 'Meandering Streams' published in the year 2008.

Shri S. D. Soman

Chairman, AERB (30.04.1990 - 26.04.1993)

Shri S.D.Soman, former Chairman, AERB was born in June 1931. After obtaining M.Sc. (Physics) from Nagpur University in 1953 he joined the Tata Institute of Fundamental Research and later the Atomic Energy Establishment Trombay in 1955. He has been a Member of the Safety Review Committee of the Department of Atomic Energy (DAE-SRC) till June 1987. He became the Director Health, Safety Group from June 1987, looking after the scientific work of Health Physics Division, Division of Radiological Protection and Inspection Section (Factories Act) of BARC. He took over as Chairman AERB in April 1990.

In 1975 Shri Soman was honoured with the title of "Padma Shri" by the Government of India. He received the "Environmentalist of the Year" award for the year 1985-86 from CHEMTECH Foundation. He was Scientific Secretary for the Third International Conference on Peaceful Uses of Atomic Energy held at Geneva (1964).

He was deputed as a Technical Expert to the Government of Chile for six months in 1970. He was elected Member of the Executive Council of International Radiation Protection Association (IRPA) for 1977-84. He received the outstanding service award from IRPA. He was a Member of Committee-4 of the International Commission on Radiological Protection (ICRP) during 1979-88. He participated in Many Advisory/Consultants meetings at the International Atomic Energy Agency, Vienna dealing with radiation protection in nuclear fuel cycles and siting of nuclear power plants. He was a Member of IAEA-INSAG.

He has wide ranging interests in Radiological Protection and Environmental Sciences. He has to his credit large number of publications in international journals and presentations in national and international conferences.

Dr. A. Gopalakrishnan
Chairman, AERB (17.06.1993 - 16.06.1996)

Dr. A. Gopalakrishnan was born in 1937. After graduating from the University of Kerala in Electrical Engineering he successfully completed the training course at BARC in 1959. He took Ph.D. in 1969 in nuclear engineering from the University of California, USA. He worked as scientific officer in Reactor Physics Group, BARC (1959-61); Project Manager and Research Associate in US Atomic Energy Commission/University of California (1961-66); Senior Research Engineer, CETEC Corporation, California Project Manager, US Naval Radiological Laboratory Project at University of California (1968-69); Associate Nuclear Engineer, Argonne National Laboratory, (1969-73); Programme Manager and Acting Assistant Director, Electrical Power Research Institute, California (1973-76).

He worked on planning and execution of major nuclear reactor safety projects in collaboration with US Nuclear Regulatory Commission. From 1976 to 1986 he served Bharat Heavy Electricals as Deputy General Manager, General Manager and Executive Director. After a brief assignment in Defence Research and Development Organization (DRDO) as Project Director, he joined the Central Mechanical Engineering Research Institute, Durgapur as its Director. In 1990, he became a member of the AERB Board. He took over as Chairman AERB in June 1993. His area of expertise includes nuclear reactor safety analysis, heat transfer, reliability and failure analysis, energy systems and planning and execution of remote operation and robotic systems.

He took over as the Chair Professor in Public Policy, Administrative Staff College of India (ASCI), Hyderabad in 1996 and then as Director, Engineering Staff College of India, Hyderabad in 1998. During 2000 to 2003, he served as a visiting faculty and senior research fellow at Belfer Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University, USA. From 2003 onwards, he is serving as the Honorary Professor (Energy & Security) at ASCI, Hyderabad. He also became the Honorary Advisor (Science, Technology, and Environment) to the Chief Minister, Government of Kerala in 2007.

Prof. P. Rama Rao
Chairman, AERB (22.11.1996 – 22.11.1999)

Prof. Rama Rao was born in June 1937. He did his B.Sc Hons. in 1956 and MA in 1957 from Madras University, M.Sc in 1957 from Andhra University and Ph.D from Banaras Hindu University in 1964. He worked as Senior Research Assistant in IISC, Bangalore, Dept. of Metallurgy during 1960-62. He joined Banaras Hindu University, Dept. of Metallurgical Engineering as Lecturer in 1962 and subsequently became Reader in 1967 and Professor in 1975. He was the Director of Defence Metallurgical Research Laboratory, Hyderabad during 1982-91. He served as the Secretary to Dept. of Science and Technology, Govt. of India, during 1991-1995. Additionally, in 1992 he also held the charge as Secretary to Department of Ocean Development, Govt. of India before taking over as Chairman AERB in 1996. Since 1998, he is chairing the Board of Research in Nuclear Sciences of DAE. During 1999-2002, he served as the Vice – Chancellor of University of Hyderabad. From 2002-2007 he held the post of Dr. Brahm Prakash Distinguished Professor at ISRO. He is a member of the Atomic Energy Commission since 2005.

He is a Fellow of INSA, National Academy of Science, Indian National Academy of Engineering, Andhra Pradesh Academy of Sciences. He was also the President of Indian Institute of Metals, Materials Research Society of India.

Prof. Rama Rao has made outstanding contributions in the areas of mechanical behaviour of materials, alloy development and X-ray diffraction from structural imperfections. He contributed to the setting up of Heavy Alloy Penetrator Plant, Tiruchirapally, International Advance Research Centre for Powder Metallurgy and New Materials at Hyderabad and National Institute of Ocean Technology at Chennai. He was instrumental in setting up the Safety Research Institute of AERB at Kalpakkam.

He is the winner of Bhatnagar Prize in 1979, Homi Bhabha Award in 1985, Vasvik Award in 1986, INSA Materials Science Prize in 1989. He was awarded the title of "Padma Shri" by the Government of India in 1989. He also won the IISc Distinguished Alumnus Award in 1990, Tata Gold Medal in 1992, IIM Platinum Medal in 1994. In the year 2001 he was awarded "Padma Bhushan". In 2004, he has been awarded "General Medal: The Meghnad Saha Medal 2004" by the American Society of Metals (International).

Prof. S. P. Sukhatme

Chairman, AERB (05.01.2000 – 14.01.2005)

Born on November 5, 1938, Professor Sukhatme obtained his Bachelor's degree in Mechanical Engineering from Banaras Hindu University in 1958. Subsequently he obtained the degrees of Master of Science, Mechanical Engineer and Doctor of Science from MIT in USA. He joined the Department of Mechanical Engineering, Indian Institute of Technology, Bombay in 1965 as an Assistant Professor and became Professor in 1970. He served as the Head of the Department from 1973 to 1975. In 1982-83, he was a Visiting Professor at the Department of Mechanical Engineering, lowa State University, USA. Professor Sukhatme worked as Deputy Director from December 1983 to December 1985 and as the Director of IIT, Bombay from January 1995 to January 2000. In 1995, he became the member of AERB Board. He took over as Chairman AERB in 2000.

Professor Sukhatme is known for his outstanding contributions in teaching and research in the areas of Heat Transfer and Energy. He guided nineteen students for their Ph.D. degree and published nearly 70 papers. He is also the author of two widely known text books in Heat Transfer and Solar Energy.

Prof. Sukhatme is the recipient of many honours and awards. He received the Prince of Wales Gold Medal for standing first class first in Banaras Hindu University. He was awarded the Shanti Swarup Bhatnagar Prize for Science and Technology in 1993. He was elected as a Fellow of the Indian Academy of Sciences in 1966, a Fellow of the Indian National Academy of Engineering in 1987, a Fellow of the Indian National Science Academy in 1995 and a Fellow of National Academy of Sciences in 1999. He was awarded the title of Padma Shri by the Government of India in 2001 and was the first recipient of the Lifetime Achievement Award of the Indian Institute of Technology, Bombay. He also received the Om Prakash Bhasin Foundation Award for Engineering and was conferred the title of Doctor of Science (honoris causa) by the Banaras Hindu University in 2001. At present he is serving as Professor Emeritus at Indian Institute of Technology, Bombay.

Shri S.K. Sharma
Chairman, AERB (14.01.2005 - till date)
Chairman, SARCOP & Vice Chairman, AERB
(01.01.2003 – 31.07.2004)

Shri S.K.Sharma was born in July 1942. A Graduate in Chemical Engineering from the Banaras Hindu University, he was associated with the research reactors at the Bhabha Atomic Research Centre, Trombay in various capacities since the year 1963 and was the Director of Reactor Group of BARC from 1997 to 2002. As Director, Reactor Group, he had the responsibility for operation and facilitating utilization of the three research reactors APSARA, CIRUS and DHRUVA at Trombay. He played a key role in the commissioning of the totally indigenous 100 MWt Dhruva reactor and in solving the complex problem of excessive flow induced vibration of fuel encountered during initial operation of this facility. He was responsible for successfully carrying out extensive refurbishing of CIRUS reactor. After refurbishing, CIRUS was brought back into operation at its rated capacity. He has been deeply involved in developing the design of an advanced 10 MWt high neutron flux pool type research reactor employing annular heavy water reflector around the reactor core. He served as Vice Chairman, AERB and Chairman of Safety Review Committee for Operating Plants (SARCOP) of AERB from January 2003 to July 2004 before taking over as Chairman AERB in January 2005.

Shri S.K. Sharma has carried out several assignments of the International Atomic Energy Agency (IAEA) by way of participating in expert missions and co-ordinated research programmes, developing safety documents for research reactors and nuclear power plants and as lecturer in IAEA training courses. Presently, he is a member of the IAEA's Commission on Safety Standards (CSS), International Nuclear Event Scale (INES) Advisory Committee and the prestigious International Nuclear Safety Group (INSAG). In 2002, he has received the prestigious INS award for his outstanding achievements in the field of Nuclear Fuel Cycle Technologies including radiation safety and environmental protection.

Shri M.S.R. Sarma

Chairman, SARCOP (03.06.1988 – 31.08.1991)

Shri M.S.R. Sarma was born in August 1931. He did his M.Sc. (Tech) in Chemical Engineering in 1953 from Osmania University. After spending a couple of years with the Birla organization he joined the Department of Atomic Energy in 1956 and was deputed for training at Chalk River Nuclear Laboratories in Canada for the operation and maintenance of NRX reactor for a period of one and a half years. On his return, he was a member of the team of engineers that was responsible for erection, commissioning and operation of CIRUS reactor.

He joined RAPS group in 1964 and was deputed to Canada stations for a period of three years. After returning from Canada he was appointed as the Station Superintendent for RAPS and continued to hold that position till 1984. He was transferred to the Bombay office of the then Power Projects Engineering Division as Director (Operations) and was responsible for the operation of the two power stations, namely TAPS and RAPS. He held charge as Director, Long Range Planning for a brief period before joining the Atomic Energy Regulatory Board in 1985 as Director, Nuclear and Industrial Safety Division. From June 1988 till his retirement in August 1991, Shri Sarma was holding the post of Executive Director, Operating Plants Safety Division and Chairman, Safety Review Committee for Operating Plants.

He represented India in various International Committees, conferences and symposia. He is a life fellow of the Institution of Engineers (FIE), Member of the Indian Institute of Chemical Engineers (MIIChE), Life Member and past President of Indian Association for Radiation Protection (IARP) and life member and past President of Indian Nuclear Society (INS), Life member of Indian Society for Radiation Physics (ISRP), life member of Indian Association of Nuclear Chemists and Allied Scientists (IANCAS) etc.

Shri S. Vasant Kumar

Chairman, SARCOP (01.09.1991 – 31.10.1998)

Vice-Chairman, AERB (1997-1998)

Shri S. V. Kumar was born in October 1937. After graduating in Chemical Engineering from Indian Institute of Science, Bangalore, he joined the second batch of training school at the Atomic Energy Establishment, Trombay in 1958.

He has wide experience in the field of spent fuel reprocessing and has made significant contribution in the areas of Process Engineering and Instrumentation Design and Development. He has actively participated in the design, installation, commissioning and operation of the first reprocessing plant at Trombay and subsequently in the design of the Power Reactor Fuel Reprocessing (PREFRE) Plant, Tarapur and KARP at Kalpakkam. He also developed a versatile package for the Computer Aided Design (CAD) for the complex piping in the process cells of reprocessing plants. He was responsible for introducing the Computerised Data Acquisition Systems in the Plants at Trombay and Tarapur. He joined AERB in the year 1991 and served as Executive Director of OPSD and Chairman of SARCOP. He was also the officiating Chairman of AERB during the period June1996- November 1996. In 1997, he became Vice Chairman AERB.

He has participated in many national and international conferences and has to credit more than fifty publications. He was a member of several technical committees of IAEA like INES, IRS, NUSSAG and International Working Group on Reprocessing Plant Safeguards. Presently, he is serving as the Chairman of the Advisory Committee for Safety Documents for Fuel Cycle facilities (ACSD-FCF) of AERB.

Shri G. R. Srinivasan
Chairman SARCOP & Vice Chairman, AERB
(28.12.1998 – 31.12.2002)

Shri G. R. Srinivasan, born in December 1942, obtained his B.E. (Mechanical) from M.S.University of Baroda in 1960. He then joined the 4th batch of Training School of AEET and worked in CIRUS reactor till 1964. During the period 1964-1967, he was in Canada under training and participation in the commissioning of Douglas Point Nuclear Power Station. He served in various capacities including Chief Superintendent at Rajasthan Atomic Power Station from 1967-1991. Thereafter he became the Director, Health Safety, Environment and Public Awareness (1993-1997) and Director, Quality Assurance (1995-1996) at Nuclear Power Corporation of India Ltd. Later as Director (Projects), he was in-charge of all the projects being built by NPCIL. He then served as the Executive Director of Operating Plants Safety Division of Atomic Energy Regulatory Board before taking over as Chairman SARCOP and Vice Chairman of AERB in 1998.

He was a member of Expert and Advisory Committees both nationally and internationally to prepare several important documents. He is the author of more than 100 papers published in national / international conferences/ seminars and in reputed journals mainly on nuclear power including safety.

He is a Fellow of Institute of Engineers and was Chairman of the Institute of Engineer, Kota, Local Centre in Rajasthan in 1989. He was associated with several technical activities of IAEA and also of International Organizations like WANO and CANDU groups. Presently he is chairing several important advisory committees of AERB such as ACNS, ACCGORN and ACPSR-PHWR/FBR.

Shri S. K. Chande
Chairman SARCOP & Vice Chairman, AERB
(01.08.2004-till date)

S.K. Chande, born in July 1948, has a B.E. (Hons.) degree in Mechanical Engineering from University of Jabalpur. After graduating from the 12th Batch of BARC Training School in 1969, he started his career in the Fast Reactor Section of Reactor Engineering Division, BARC. He had extensive training in plant operation in CIRUS research reactor and at Rajasthan Atomic Power Station before being deputed to France for a period of one year training at RAPSODIE Fast Reactor in Cadarache.

He worked in Indira Gandhi Centre for Atomic Research, Kalpakkam for a period of 22 years in Commissioning, Operation & Maintenance of Fast Breeder Test Reactor (FBTR). He held the post of Commissioning Superintendent of FBTR. In 1993 he joined Atomic Energy Regulatory Board and was working in the area of Safety Review of Operating Plants. He held the posts of member-secretary, Safety Review Committee of Operating Plants (SARCOP) and Director, OPSD before taking over as Chairman SARCOP and Vice-Chairman of AERB in August 2004. He was also the Director of Safety Research Institute of AERB at Kalpakkam from 2003-2005. His field of specialization is Commissioning and Operation of Nuclear Power Plants, Nuclear Safety & Training of Personnel. He is a Fellow of the Institute of Engineers (India).

He has participated in many national and international conferences and is involved in several technical activities of IAEA. He has also led AERB delegation during bilateral technical interactions with Regulatory Bodies of USA, France and Russian Federation. He was awarded the prestigious Indian Nuclear Society (INS) High Technology Award for the year 2006.

BOARD MEMBERS

1983 (October)

1.	Prof. A.K. De (Director, IIT Bombay)	Chairman
2.	Dr. E.C. Subba Rao (Director, Tata Research Development and Design Centre, Pune)	Member
3.	Dr. B.D. Gupta (Professor & Chairman Department of Radiotherapy, Post Graduate Institute of Medical and Education and Research, Chandigarh)	Member
4.	Shri V.N. Meckoni (Chairman, DAE Safety Review Committee, BARC)	Member
5.	Shri P.N. Krishnamoorthy, AERB	Member-Secretary

1986 (July)

1.	Prof. A. K. De	Chairman
2.	Dr. E. C. Subba Rao	Member
3.	Dr. B. D. Gupta	Member
4.	Shri P. R. Dastidar (Chairman, DAE-SRC, BARC)	Member
5.	Shri P. N. Krishnamoorthy. AERB	Member-Secretary

1987 (April)

1.	Prof. A.K. De	Chairman
2.	Shri J.C. Shah (Chairman, Atomic Power Authority, Mumbai)	Member
3.	Prof. K. Sri Ram (Head - Nuclear Engg. & Technology Programme, IIT Kanpur.	Member
4.	Dr. P.B. Desai (Director, Tata Memorial Centre, Mumbai)	Member

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6.	Shri P.N. Krishnamoorthy, AERB	Member-Secretary

1987 (August)

1.	Prof. A.K. De	Chairman
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3.	Shri M.S.R. Sarma (Chairman, DAE-SRC, AERB)	Member
4.	Dr. P.B. Desai	Member
5.	Shri J.C. Shah	Member
6.	Dr. K.S. Parthasarathy, AERB	Secretary

1990 (July)

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2.	Dr. A. Gopalakrishnan (Director, Central Mechanical Engineering Research Institute, Durgapur)	Member
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4.	Dr. S.S. Ramaswamy (Director General, DGFASLI, Mumbai)	Member
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6.	Dr. K.S. Parthasarathy, AERB	Secretary

1991 (September)

1.	Shri S.D. Soman	Chairman
2.	Dr. A. Gopalakrishnan	Member
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4.	Dr. R.D. Lele	Member
5.	Shri S. Vasant Kumar (Chairman, SARCOP, AERB)	Ex-officio Member
6.	Dr. K.S. Parthasarathy, AERB	Secretary

1993 (May)

1. Shri S.V. Kumar (Chairman, SARCOP, AERB)	Chairman (Officiating)
2. Dr. R.D. Lele	Member
3. Dr. A. Gopalakrishnan	Member
4. Dr. S.S. Ramaswamy	Member
5. Dr. K.S. Parthasarathy, AERB	Secretary

1993 (July)

1. Dr. A. Gopalakrishnan (Director, CMERI, Durgapur)	Chairman
2. Dr. S.S. Ramaswamy	Member
3. Dr. R.D. Lele	Member
4. Shri S.V. Kumar	Ex-officio Member
5. Dr. K.S. Parthasarathy, AERB	Secretary

1995 (October)

1. Dr. A. Gopalakrishnan	Chairman
2. Dr. S.S. Ramaswamy	Member
3. Dr. R.D. Lele	Member
4. Prof. S.P. Sukhatme (Director, IIT, Bombay)	Member
5. Shri S.V. Kumar	Ex-officio Member
6. Dr. K.S. Parthasarathy, AERB	Secretary

1996 (June)

1. Shri S.V. Kumar (Chairman, SARCOP)	Chairman (Officiating)
2. Dr. S.S. Ramaswamy	Member
3. Dr. R.D. Lele	Member
4. Prof. S.P. Sukhatme	Member
5. Dr. K.S. Parthasarathy, AERB	Secretary

1997 (January)

1. Prof. P. Rama Rao (Distinguished Scientist, DRDO)	Chairman
2. Dr. S.S. Ramaswamy	Member
3. Dr. R.D. Lele	Member
4. Prof. S.P. Sukhatme	Member
5. Shri S.V. Kumar	Ex-Officio Member
6. Dr. K.S. Parthasarathy, AERB	Secretary

1999 (January)

1. Prof. P. Rama Rao	Chairman
2. Shri G.R. Srinivasan (Chairman, SARCOP)	Ex-officio Member
3. Dr. R.D. Lele	Member
4. Dr. S.S. Ramaswamy	Member
5. Prof. S.P. Sukhatme	Member
6. Dr. K.S. Parthasarathy, AERB	Secretary

2000 (January)

1. Prof. S.P. Sukhatme (Director, IIT, Bombay)	Chairman
2. Shri G.R. Srinivasan	Ex-officio Member
3. Dr. S.S. Ramaswamy	Member
4. Dr. R.D. Lele	Member
5. Dr. K.S. Parthasarathy, AERB	Secretary

2001 (October)

1. Prof. S.P. Sukhatme	Chairman
2. Shri G.R. Srinivasan	Ex-officio Member
3. Dr. M.V.S. Valiathan (Honorary Advisor, Manipal Academy of Higher Education, Manipal)	Member

4.	Dr. K.V. Raghavan (Director, Indian Institute of Chemical Technology, Hyderabad)	Member
5.	Dr. K.S. Parthasarathy, AERB	Secretary

2003 (February)

1.	Prof. S.P. Sukhatme	Chairman
2.	Shri S.K. Sharma (Chairman, SARCOP)	Ex-officio Member
3.	Dr. K.V. Raghavan	Member
4.	Dr. M.V.S. Valiathan	Member
5.	Prof. J.B. Joshi (Director, University Institute of Chemical Technology, Mumbai)	Member
6.	Dr. K.S. Parthasarathy, AERB	Secretary

2004 (August)

1.	Prof. S.P. Sukhatme	Chairman
2.	Shri S.K. Chande (Chairman, SARCOP)	Ex-officio Member
3.	Dr. M.V.S. Valiathan	Member
4.	Dr. K.V. Raghavan	Member
5.	Prof. J.B. Joshi	Member
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2004 (October)

1.	Prof. S.P. Sukhatme	Chairman
2.	Shri S.K. Chande	Member
3.	Dr. M.V.S. Valiathan	Member
4.	Dr. K.V. Raghavan	Member
5.	Prof. J.B. Joshi	Member
6.	Dr. Om Pal Singh, AERB	Secretary

2005 (January)

1.	Shri S.K. Sharma, AERB	Chairman
2.	Shri S.K. Chande	Ex-officio Member
3.	Dr. M.V.S. Valiathan	Member
4.	Dr. K.V. Raghavan	Member
5.	Prof. J.B. Joshi	Member
6.	Dr. Om Pal Singh, AERB	Secretary

2005 (October) -present

1.	Shri S.K. Sharma, AERB	Chairman
2.	Shri S.K. Chande	Ex-officio Member
3.	Dr. K.V. Raghavan	Member
4.	Prof. J.B. Joshi	Member
5.	Dr. (Ms.) K.A. Dinshaw (Director, Tata Memorial Centre (TMC), Mumbai)	Member
6.	Dr. Om Pal Singh, AERB	Secretary

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ABOUT THE EDITORS

A. R. Sundararajan

A.R. Sundararajan, after graduating from 8th batch of BARC Training School joined as Health Physicist in Plutonium Plant at Trombay. Later he moved to IGCAR, Kalpakkam where as Head, Health and Safety Division was responsible for organizing radiation protection surveillance for the research centre. He was instrumental in starting a strong research group on internal dosimetry, atmospheric studies and aerosol research. He was Associate Director of Safety Research and Health Physics Group, IGCAR during 1997-98. Later he moved to AERB as Head Radiological Safety Division (RSD). He was associated with more than 20 AERB Safety Review Committees. He was entrusted with the responsibility of setting up Safety Research Institute (SRI) at Kalpakkam. After his retirement in 2003 as Director RSD and Director SRI, he continues to serve in many of the committees of AERB. His areas of special interests include Safety of Fuel Reprocessing, Fast Reactor Safety and Environmental Safety of Nuclear Facilities.

K. S. Parthasarathy

K.S.Parthasarathy joined the erstwhile Directorate of Radiation Protection (DRP), Atomic Energy Establishment Trombay (AEET) in 1964 after graduating from the 7th Batch of AEET Training School. He obtained his Ph.D in medical physics from the University of Leeds, UK. He served the Division of Radiological Protection, BARC in various capacities before joining the Atomic Energy Regulatory Board (AERB) in 1984. He was Secretary of AERB from 1987-2004 and Director, Information and Technical Services Division. He played a major role in setting up the Directorate of Radiation Safety in Kerala, the first effort to decentralize regulatory control of medical x-ray installations. He assisted AERB in formulating its polices for funding safety research projects and in drafting safety directives to enforce dose limits to workers. His efforts helped the removal of potentially hazardous radium from Indian hospitals. He edited the AERB newsletter from 1985-2000. His articles on safety-related topics appeared in over 180 publications including the Hindu, the Tribune, and the PTI Feature. He is currently Raja Ramanna Fellow in the Department of Atomic Energy.

S. Sinha

S. Sinha, after completing one year orientation course in Radiation Protection and Environmental Sciences from the 47th batch of BARC Training School, joined AERB in the year 2004. Initially he was involved with the review of operational health physics, waste management and emergency preparedness of operating nuclear power plants. From 2005 onwards in IPSD, he is participating in the safety review with respect to radiological safety, waste management and environmental safety of front end fuel cycle facilities namely uranium mining and processing facilities, thorium mining and processing facilities and fuel fabrication facilities, beach sand minerals facilities and DAE accelerators facilities at VECC and RRCAT. He is the member-secretary of VECC-RRCAT Safety Committee and is associated with the Beach Sand Minerals Safety Committee. In addition, he is involved in the regulatory review of NORM industries such as rock phosphate processing fertilizer plants and commercial applications of phosphogypsum. He is a member of AERB Newsletter editorial committee.

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