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From the Director's Desk

Main steps in the design of a nuclear power plant

Designing a nuclear power plant is a challenging multifaceted activity involving various specialisations and disciplines. While, the conceptual idea of a fast reactor may be simple, the practical implementation of the same with emphasis on technological features, safety, cost-effectiveness and quality is a complex task. Many checks and balances go into various stages of design and construction of the plant for ensuring reliable operation over the entire plant life. Successful operation of Fast Breeder Test Reactor (FBTR), beyond the design features, especially with respect to carbide fuel, sodium pumps and other important subsystems is a demonstration of some of the above criteria. We are now entering the decisive phase of the construction of Prototype Fast Breeder Reactor (PFBR), based on the good experience gained from FBTR.

The design of PFBR requires high level of competence, with inputs from various engineering and science disciplines, as well as coordination at various levels. This is particularly true for a prototype design. The important steps involved in the design are *conceptual design, detail analysis, detail engineering of components, system engineering and quality assurance. Conceptual design* involves selection of feasible options with respect to the plant, systems, components and part levels. The main considerations at this stage are the safety, reliability and economy. Inputs and feedback from operating experience must be fully considered for a successful project. In our case, the existence of large in-house research and developmental capability as well as long operating experience has been very helpful. Having selected conceptual designs, in the second stage of *detail analysis*, it should be validated with detailed analysis, and/or experiments on scaled-down models. Unlike conventional plants, nuclear plant requires more rigorous and intense design analysis, since many events and aspects during its design life need to be considered. Very highlevel of competence in analysis using sophisticated, validated computer codes is essential. In the third stage of *detail engineering phase*, every minute detail of each and every part is to be decided, checked and indicated in specifications and drawings. For this stage, engineers must be thorough in codes and standards, engineering practices, tolerance requirements, manufactur-ing and installation considerations. It is not only enough to have a perfect design for a component, but its design must be compatible with the system. Many times, it is the other components of the system that dictate the requirements of a specific part ex. the head developed by a coolant pump, assembly requirements. In the fourth stage of *system engineering*, frequent interactions and discussions among all the designers viz., civil, mechanical, electrical, instrumenta-tion & control and also with the specialists in reactor physics, chemistry and metallurgy are very vital for crosschecking various minute details. Finally, the *quality assurance* in design of the activities, in which complete checking of all documents, preferably by an independent designer, with a separate analysis to check that no detail is missed including procedures, is very crucial. Editing of all the design documents to achieve uniformity and harmonisation is also essential for both knowledge presentation and effective communication to others. Interactions with outside agencies, such as research & development units, regulatory authority, manufacturing industry and experts become essential at appropriate times of design stages. A few iterations are integral part of any nuclear plant design. High quality documentation is the final product of all the design activities. A systematic design requires not only high level of scientific and technical competence, but also human qualities to create a coordinated working atmosphere for a well focussed project work. PFBR is presently going through these final stages of design.

(S.B. Bhoje)
Director, IGCAR

BORON ENRICHMENT PLANT - A FRUITFUL EXPERIENCE

^{10}B isotope of boron has higher neutron absorption cross-section than ^{11}B. The natural abundance of ^{10}B is approximately 20%. Enriched boron compounds find many applications in control rods for reactors, neutron detectors, shielding, and also in neutron capture therapy. Among the known processes, ion exchange chromatography is an industrially viable process for the enrichment of ^{10}B.

The isotopic separations in the past were done by the diffusion and distillation methods. These methods of separation are expensive and less efficient. Separations by ion exchange chromatography and laser technique have been developed for the separation of the isotopes. Separation of isotopes by the laser technique is highly efficient but the operation is costlier. Ion exchange chromatographic method is flexible in operation and more viable industrially as any discontinuity arising out of feed flow rates/power failure etc do not affect the process. Based on this process, a plant has been designed and commissioned in April 2001 at IGCAR (refer IGC Newsletter, Vol. 48, April 2001). The operating experience of the plant is described in brief below:

Two major factors in the operation of ion exchange chromatography plant are separation factor and height equivalent to a theoretical plate (HETP). The values of separation factors can be determined experimentally whereas there is no direct procedure to determine HETP in applications involving isotope separations. However, these values can be inferred only from the data obtained from the operating plants/ pilot plants.

Initially Boron Enrichment Plant was designed to produce 5 kg of 90% enriched ^{10}B annually to meet the requirement of FBTR. The plant was designed based on literature value of HETP of 26 mm, separation factor of 1.012, band length of 26 m and band velocity of 10cm/h. The value of HETP was estimated from the first enrichment profile taken during the operation of pilot/main plant and it was estimated to be in the range of 50- 75 mm. Higher HETP can be attributed to back mixing of the liquids in the columns. Maximum enrichment obtainable from the operation of the plant is shown in Figure 1. Based on this data, it may be possible to achieve the enrichment up to 60% in ^{10}B in the present plant.

Boric acid was charged to process ion exchange columns and the displacement of borate band started in May 2001 with borate band length of 8m. The isotopic analysis of the profile samples taken after completion of 11 cycles of band displacement (in the 2nd week of March, 2002) showed a peak value of enrichment to 42.5% in ^{10}B. The quantity of boric acid enriched in ^{10}B to 40% and above was estimated to be 5 kg and that for 35% and above it was 51 kg. These samples were analyzed for $^{10}B/^{11}B$ ratio using ICP-MS available with Materials Chemistry Division (MCD).

After two more cycles of displacement, isotopic analyses of the profile samples showed a peak enrichment value of 42.9% ^{10}B. The quantity of boric acid enriched in ^{10}B to 40% and above was increased to 62 kg and that for 35% and above it was 121 kg. Though there was an increase in the quantities of the enriched product, further enrichment was observed to be very low. To overcome this problem, a detailed study was carried using a mathematical model. It was found that there are two possibilities to enhance the enrichment i.e. by decreasing HETP or by increasing average enrichment in the borate band. The second option was adopted during operation. Accordingly, it was decided to remove the depleted portion of the borate band and load fresh natural boric acid to increase the inventory of ^{10}B in the band. This operation is referred to as "cut and feed operation".

The cut and feed operation was carried out without interrupting the displacement of the borate band. The results of the profile samples taken during July/August, 2002 have shown enrichment of 52% in ^{10}B, giving an increase of nearly 10%. The quantity of boric acid enriched in ^{10}B to 50% and above was estimated to be 1 kg, 45 % above it was 32 kg and for 40% and above it was 78 kg. The latest profile samples were taken in Jan 2003 after completion of 20 cycles of displacement. The enrichment profile is shown in Fig.2. The results have shown maximum enrichment of 57%. The quantity of boric acid enriched in ^{10}B to 40 % and above was 157 kg, 45% and above was 99 kg and for 50% and above was 64 kg. As the change in enrichment after completion of last two cycles of displacement was less, cut and feed operation was carried out again in Feb 2003 to maintain a band length of 26 m without interrupting the displacement of the borate band. According to the present status of the existing plant, model calculations have shown that it would be possible to achieve 60% enrichment level, in three months. Thereafter, 14 kg of ^{10}B enriched to 60% can be produced every year. However, PFBR requirement is 100 kg annually.

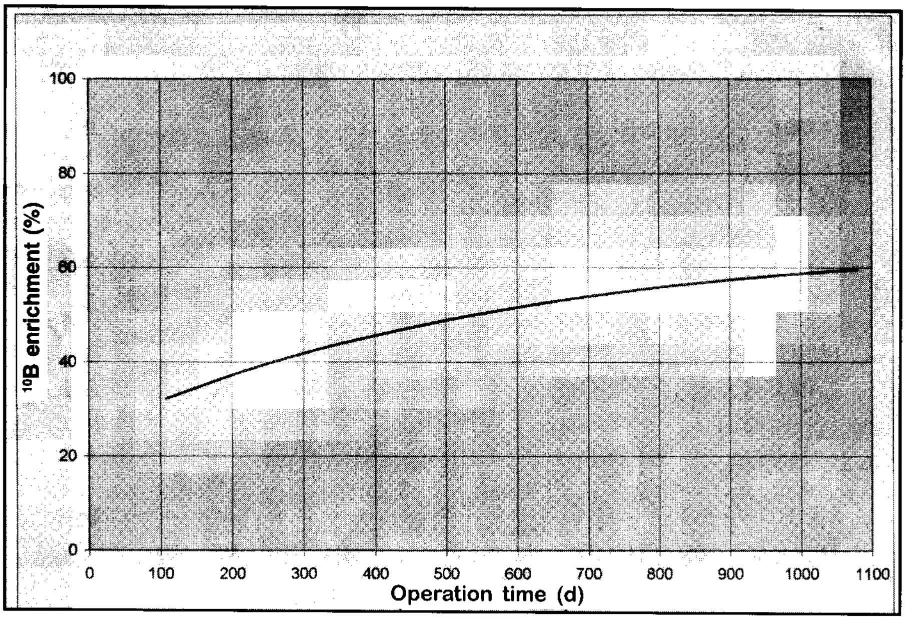


Fig. 1 : Variation in maximum enrichment obtainable with operation time.

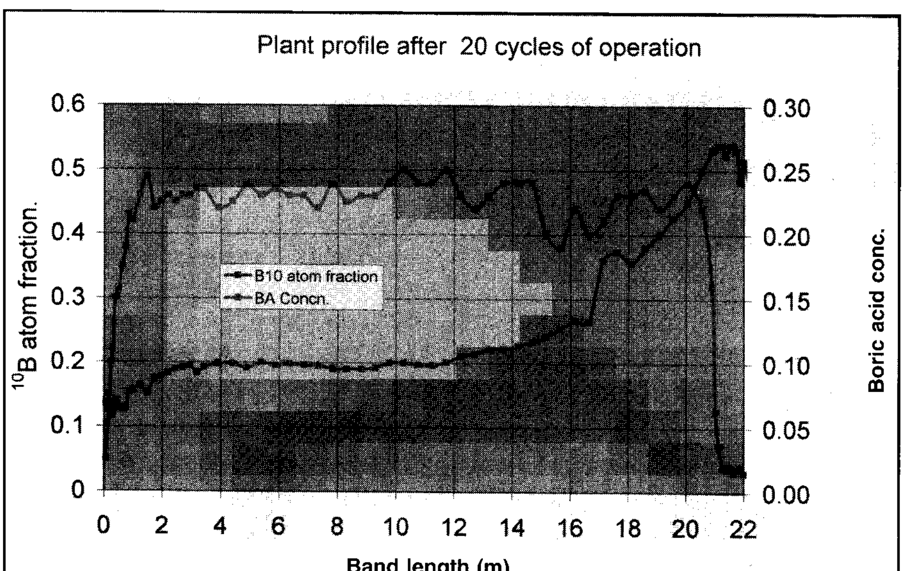


Fig. 2 : Variation in enrichment and concentration of boric acid

To meet the above requirements, it is planned to augment the existing plant. The augmented facility will have a three cascade system. The first two cascades will produce enriched boron to meet the requirements of PFBR, whereas the third cascade will meet FBTR requirements.

To increase the efficiency of the existing plant, some development works are being taken up especially to decrease the value of HETP. In this regards experiments are planned with fine particle sized resin to increase the mass transfer coefficient. The operating experience with the existing plant has been fruitful and given invaluable data and confidence to design the new augmentation facility.

(B.K. Sharma, G. Mohanakrishnan and C. Anand Babu)

Nitric Acid Loop for Long Term Corrosion Evaluation of Materials used in Reprocessing Plants

Materials selection for critical components in the nuclear programme has been given due priority by the Department of Atomic Energy. The selection of materials for pressurized heavy water reactors have been based on the results of materials tested under simulated temperatures and pressures in autoclaves and loops. Similarly, for the evaluation of materials for fast breeder reactors sodium loops were established to study the materials behaviour under simulated operating conditions of temperature and other parameters like, flow, impurities, carbon content etc. in sodium. However, for the qualification of materials for the reprocessing plants ASTM A262 practice C (HUEY test) is employed which is also recommended by the United States Nuclear Regulatory Commission (USNRC). The major drawbacks of this accelerated corrosion test are that the specimens are tested in highly concentrated medium (65% HNO_3) in static condition, the total test period is shorter (240 h), and it is specific to evaluate intergranular corrosion only. The testing procedure only detects susceptibility of the materials to intergranular corrosion, and does not simulate the plant conditions. It is well known that AISI type 304L SS used in nitric acid medium undergoes several types of corrosion other than intergranular corrosion, namely, end-grain attack, tunneling corrosion, transpassive dissolution, vapour phase attack etc.. So, it is evident that complete corrosion assessment of AISI type 304L SS by ASTM A262 practice C (Huey test) is impossible, taking into consideration the ranges of concentration of nitric acid used, temperature of operation, impurities and redox chemicals present, and the metallurgical state of the materials used in the reprocessing plants. This necessitated the need for designing of a dynamic nitric acid loop which is shown in Fig.1, with flowing nitric acid at different temperatures, to evaluate the corrosion performance of materials used in reprocessing plants.

An unique dynamic nitric acid loop was conceived and designed with a 220 litres capacity at IGCAR, for evaluating the corrosion performance over a long operating period under plant simulated conditions. Fig. 1 shows the schematic flow diagram, while fig. 2 shows a photograph of the plant. The loop consists of a hot leg and a cold leg. In the hot leg the temperatures are maintained at 313, 333, 353 and 380 K with the help of specially designed and fabricated titanium-sheathed heaters. The vapour generated in boiling acid section are passed through a sample holder, and then completely condensed in a shell-and-tube type condenser. This enables to place samples in the flowing acid vapours for studying the corrosion behaviour in vapour condition. The loop also employs special type of leak detectors developed in-house by the Ultra Sensitive Devices and Techniques Section (USDTS) (working on the principle of conductivity) for detecting any acid/vapour leak in the system. Sample holders consisting of 12 specimens each are placed at different temperature zones of acid and the vapour. The sample holders are designed to achieve a maximum flow velocity of 1.55 m/s. The loop can operate with both 4 N and 6 N nitric acid as these concentrations are employed in reprocessing plants for many unit processes. The loop is provided with state-of-art instrumentation for measurement and control of operating parameters. In-service inspection of the loop components at critical weld joints and corrosive zones has been carried out using

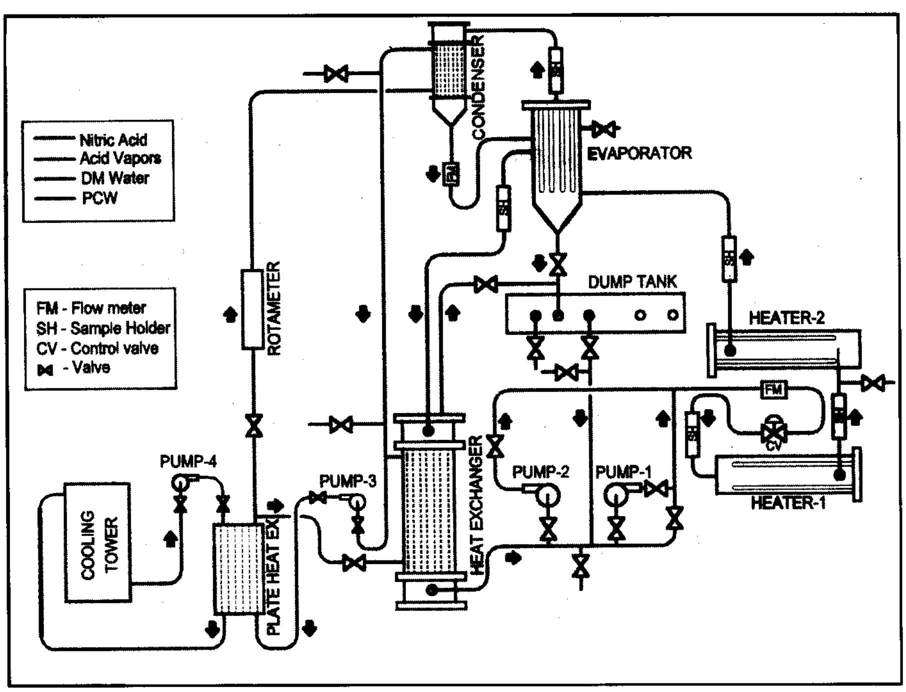


Fig. 1 : Schematic flow diagram of the nitric acid loop

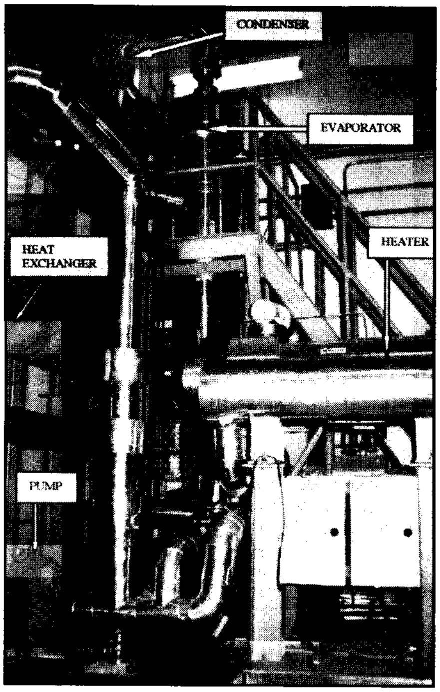


Fig. 2 : Photograph of the Nitric Acid loop

ultrasonic methods, and the ISI will be continued during maintenance shut downs to study the health of the loop components.

Corrosion resistance of materials used in reprocessing plants in different metallurgical conditions, namely, cold worked, solution annealed, sensitized, alloy composition etc. will be evaluated in this loop in flowing nitric acid at different flow velocities (up to 1.55 m/sec) and temperatures (313, 333, 353, 380 K and vapour phase). The data generated over a long period of exposure (from 100 h to 10,000 h) would be used to arrive at an acceptable corrosion rate for the materials. Samples made from AISI type 304L SS alloy used for the fabrication of evaporators of the fast reactor fuel reprocessing plant (FRFRP) at Kalpakkam, and the nitric acid grade (NAG) type 304L SS manufactured at MIDHANI, Hyderabad are currently loaded into the sample holders for evaluating the corrosion rates. Nondestructive evaluation of the samples will be carried out by using ultrasonic and eddy current testing methods apart from microstructural examinations and dimensional changes of the samples. During each exposure period, all the above examinations will be carried out on the samples in addition to the corrosion rate evaluation. The availability of such a reliable and useful data will be helpful in predicting the life of the components in nitric acid service. Further, such valuable data and information from diversified examinations will be helpful in modeling of the corrosion processes occurring at various unit operations. Currently, the loop, and is operating with 6 N nitric acid at Phase III building of the Reprocessing Group. It is proposed to examine the samples after exposure for durations of 100, 250, 500 and 1000 hours and every 1000 hours thereafter.

(V.R. Raju, R. Rajeev, U. Kamachi Mudali, R.K. Dayal, S.B. Koganti and H.S. Khatak)

Neutron Radiography of Pyro devices for Polar Satellite Launch Vehicle (PSLV)-C3, C4 and Indian National Satellite (INSAT) – 3C and 3A Using KAMINI Reactor

The main utilities of KAMINI (Kalpakkam Mini Reactor) are neutron radiography (NR) of active and inactive objects, activation analysis and shielding experiments. The beam tube at southern end is used for neutron radiography work. The neutron flux at the outer end of the beam tube is ~ 10^7 -10^8 n/cm^2/sec. The highly collimated beam (L/D ratio ≈ 200) makes it possible to obtain radiographs with very good contrast and sensitivity. The aperture size at the radiographic site is 220 mm x 70 mm.

Pyro devices for the Polar Satellite Launch Vehicle (PSLV-C3 and C4) and also for INSAT- 3C and 3A satellites received from Vikram Sarabhai Space Centre, Thiruvananthapuram were neutron radiographed at KAMINI. Pyro devices are basically mechanical devices with a certain amount of explosives. While certain pyros are used for ignition, there are other pyros, which are used for the purpose of shearing the straps and cables (cable cutters and bolt cutters). The pyros have to also deliver the correct energy for ignition and also the required thrust for cutting operations. This in turn depends on the charge density and uniformity of the loaded charge. Apart from the above, the spacing between the explosive and other assemblies is also critical since the energy has to be transferred with full impact. Hence, ensuring the reliability of the pyros is a very crucial aspect. More than 1200 pyro devices are used in any space launch vehicle. Of all the non-destructive evaluation (NDE) techniques available, the best one for pyro device is NR. It is well known

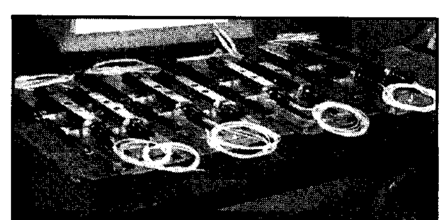


Fig. 1 : Cable cutters assembled in fixtures

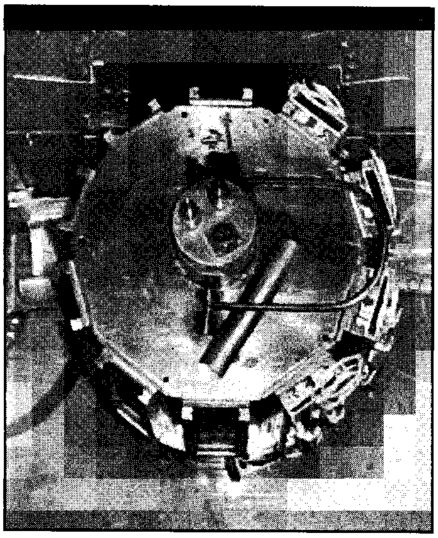


Fig. 2 : Cable cutters loaded in cassette drive mechanism

that NR is complementary to X-radiography. The ability of neutrons to get absorbed by low atomic number elements - especially organic materials makes it an ideal choice (and the only NDE technique) for the examination of the explosives present and also charge density within the pyros.

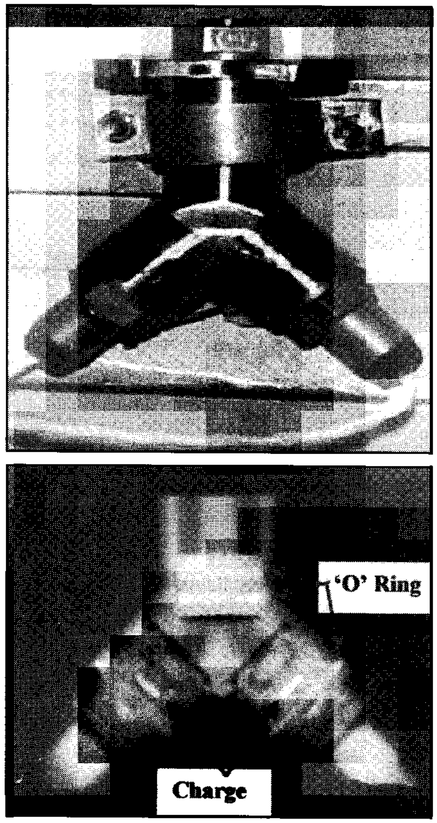


Fig. 3 : Photograph of a typical pin pusher along with the neutron radiograph showing details of the internals

Neutron radiography was carried out using the south end beam tube with the reactor operating at 15-20 kW. Typical devices radiographed include cable cutters, bolt cutters, explosive manifolds, through bulk head initiators, detonating catridges, explosive nuts, pin pushers and pyro thrusters. Special fixtures were made for holding the pyro devices. The cassette drive mechanism used for irradiated fuel pin neutron radiography was retrofitted with these fixtures facilitating multi exposures in a single run. Figure 1 shows the cable cutters assembled in the fixture. Figure 2 shows the cassette drive mechanism loaded with the assemblies of cable cutters and suitably positioned in front of the south end beam tube at KAMINI. Dysprosium converter screen with multi film technique was adopted. Figure 3 shows the photograph of a typical pin pusher and its neutron radiograph showing the details of the internals. The presence of the charge and 'O' rings is revealed. Excellent radiographic contrast and sensitivity was achieved throughout the campaigns. A total of 793 devices were examined in three campaigns

(R.R. Ramanarayanan, B.Venkataraman, N.Raghu and T. Johny)

A Pulsed Laser Deposition (PLD) facility for making thin film sensors

Chemical sensors find many applications in nuclear industry. Sensors are used for monitoring for oxygen, hydrogen and carbon in sodium coolant. Monitoring for hydrogen in argon cover gas in a fast reactor is helpful in detecting steam generator leaks. Monitoring the reactor ambient for sodium aerosol can help detect sodium leaks. For some of these applications, sensors are being developed at IGCAR. Sensors for NO_2, ammonia and hydrogen sulphide are also under development for use in reprocessing plant and heavy water plant. These sensors use oxide semiconductors, whose electrical conductivity changes on exposure to a given analyte gas. They are highly suitable for inclusion in hybrid micro circuits (HMC), as they are in film form and can operate at moderate temperatures. Their sensitivity and selectivity can be improved by using them in thin film form, where the chemical and physical means of enhancing the probability of the analyte reacting with the sensor material is greater. The most suitable technique for preparing these films is the Laser ablation technique, where a laser pulse is used to ablate the sensor material and deposit it on a substrate. A Pulsed Laser Deposition (PLD) system for this purpose has been designed and constructed at Materials Chemistry Division (MCD).

In PLD, a laser pulse, focused to an appropriate energy density impinges on a target material and vaporizes a few hundred angstrom layers of the surface material in the form of neutral/ionic or clusters (known as plume) having kinetic energies of few electron volts. The plume, (Fig.1) is then allowed to deposit over a substrate, which is heated to an appropriate temperature. As implied by the name of the process, PLD

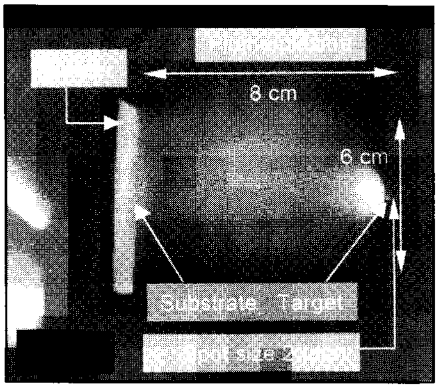


Fig. 1 : Plasma during film deposition

consists of periodic bursts of several such plumes followed by relatively long periods of uninterrupted surface relaxation. The two most important features of PLD are: (a) the extremely short pulses (of about 30 n) with a peak power of greater than 10^8 W cause congruent evaporation and (b) the capability exists to operate under high pressures of reactive gases like oxygen since ion or evaporation sources having hot filaments (requiring operation under vacuum) are not employed.

Figure 2 shows the Pulsed Laser Deposition system commissioned in MCD. This facility consists of an excimer laser, high vacuum deposition chamber, pumping system, beam delivery system, multi-target carrousel system and substrate heater assembly. The excimer laser has a pulse width of about 30 ns delivering the pulses at repetition rate of 20 Hz with a peak power density of ~ 10^8 W. The laser is capable of operating at multiple UV wavelengths, namely 192 nm, 248 nm and 356 nm. A high vacuum deposition chamber (~ 20 l capacity) is capable of giving an ultimate vacuum of 10^{-7} torr and has adequate number of ports to accommodate pumping system, multitarget carrousel and heater assembly. A turbomolecular pump of adequate capacity having built-in safety interlocks is integrated with the chamber. The multitarget carrousel assembly is capable of handling six targets based on planetary gear and rastering mechanisms and is automated for multilayer deposition under in-situ conditions. The substrate heater is provided with x-y-z translation facility and is capable of heating the substrates to 900°C under high vacuum conditions. The design of chamber takes care of the requirements with respect to incident angle of the laser beam with the target and the position of the substrate heater. The as-fabricated muti-target assembly, heater flange assembly, etc were tested under a vacuum of ~10^{-7} torr. The beam delivery system with positional and focusing adjustments has been fabricated and integrated with the facility.

Using this facility, thin films of various sensor materials have been deposited and tested for their sensing characteristics towards trace level constituents in gas ambients. Sensor grade thin films made by

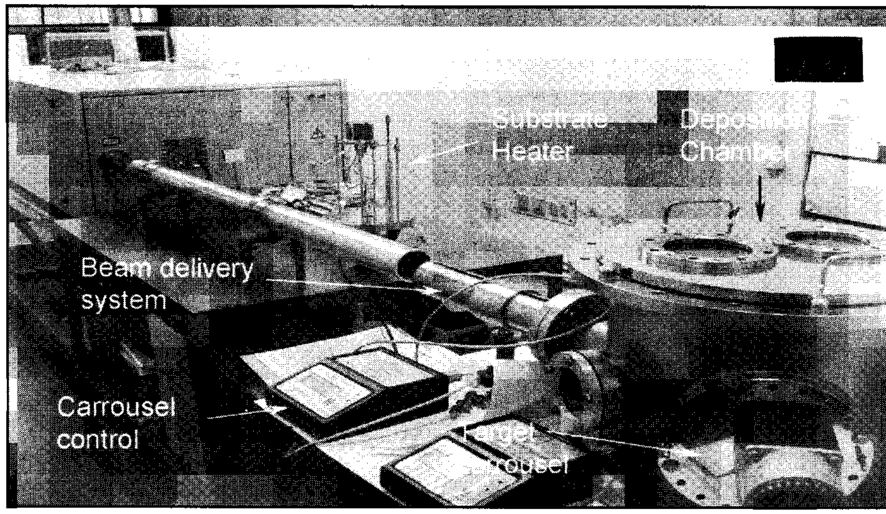


Fig. 2 : Pulsed Laser deposition Facility

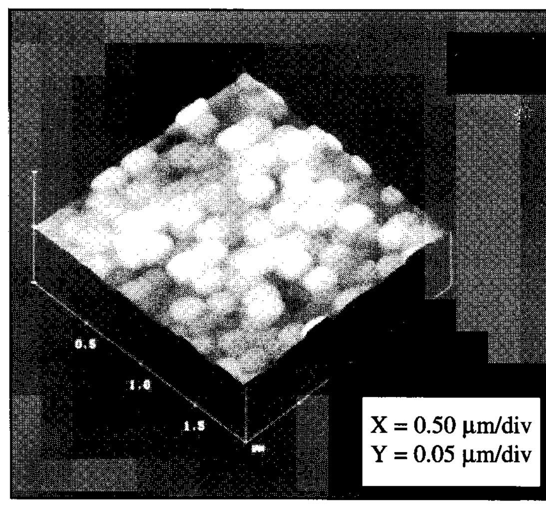


Fig. 3 : AFM micrograph of $FeNbO_4$ film

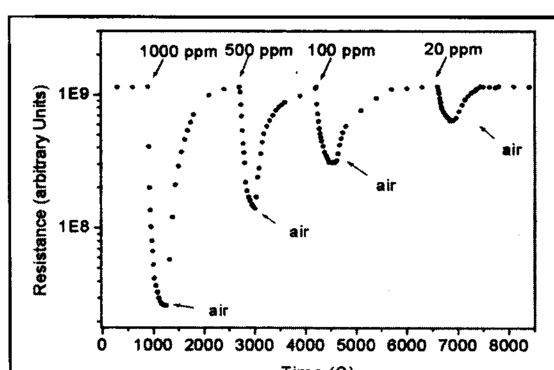


Fig. 4 : Response characteristics of $FeNbO_4$ for different concentrations of H_2

this facility include (a) SnO_2 for measuring trace levels of H_2, NO_x etc. in air and inert gas streams, (b) $FeNbO_4$ for measuring trace levels of H_2 in gas streams (c) MoO_3, $Ag_6Mo_{10}O_{33}$ and $Cr_{1.8}Ti_{0.2}O_3$ for measuring trace levels of NH_3 in air and (d) $SrFeO_3$ for measuring percentage levels of O_2 in gas streams. As a typical example, the morphological characteristics of thin film of $FeNbO_4$ deposited at 700°C as examined by atomic force microscope (AFM) are shown in Fig. 3. The AFM micrograph shows that the film is granular with an average grain size of about 150 nm. The response pattern of the film for different concentrations of H_2 is shown in Fig. 4. Its response characteristics have demonstrated the feasibility of using this film at hydrogen concentrations below 20 ppm also. The response time of the sensor is about 30 s and the retrace time is about 10 min at an operating temperature of 330°C [Fig 4]. The development of various sensors integrated with support electronics is in progress.

(G. Periaswami, T. Gnanasekaran, K.I. Gnanasekar, E. Prabhu and V. Jayaraman)

HIGHLIGHTS OF SYMPOSIA/SEMINAR/CONFERENCES

IAEA Technical Meeting on Primary Coolant Pipe Rupture Event in Liquid Metal Cooled Reactors January 13-17, 2003 Kalpakkam

In pool type liquid Metal Cooled Fast Reactors (LMFR), the primary coolant pipes (PCP) connect the primary coolant pumps to the grid plate. A rupture, even in one of these pipes, could cause significant loss of coolant flow to the core which may lead to severe consequences. In loop type reactors, all primary pipelines are provided with double envelopes and inter-space coolant leak monitoring systems that permit leak detection before break. Thus, the PCP rupture event can be placed in the beyond design basis event (BDBE) category. Such an approach is difficult to incorporate for pool type reactors and hence the PCP rupture event is analysed in detail treating it as a category-4 design basis event. Primary coolant pipes are made of very ductile austenitic stainless steel material and operate at temperatures of the cold pool under which the creep effects are insignificant. The operating pressure is low which induces insignificant stress. The sodium corrosion and embrittlement effects are negligible. Hence, it is worth to consider the double ended guillotine rupture (DEGR) of PCP as a BDBE category.

In order to enable the international specialists to discuss on the various issues related to pipe rupture event, IAEA organized a Technical Meeting at IGCAR during January 13 - 17 2003. The scope of the meeting was to provide a global forum for information exchange on the philosophy applied in the various participating Member States and the analyses performed for different LMFRs with regard to the primary coolant pipe rupture event. Totally, twenty five participants including one each from China, France, Japan and Korea and the Scientific Secretary from IAEA attended the meeting. Discussions were held on four main themes, viz. safety philosophy, structural integrity assessment, thermal hydraulics and new concepts. There were nine presentations on these topics. Besides, each country presented the status of FBR programme in their country. The meeting was chaired by Director, IGCAR.

There was consensus on many issues. It is adequate to assume only single pipe rupture, which itself is considered to be pessimistic. A reliable SCRAM parameter is power to flow ratio. This requires a sodium flow meter in the circuit, which will truly represent the core flow. All the participants were unanimous on the choice of a core by-pass flow meter at the pump discharge, as in EFR. Analysis of the event has to be carried out for the rupture occurring at various locations of the pipe, and the worst location including the grid plate – pipe junction, should be identified for DEGR analysis. One dimensional analysis to obtain the consequences of the event was agreed to be good enough. However, flow redistribution amongst various SA in core should be assessed separately. For this, three-dimensional hydraulic analysis or experiments as performed by India are required. Considering the complexity involved in analytical simulation of the entire phenomenon, it is desirable to quantify the approximations involved in 1-dimensional simulation with data obtained from experiments of increasing complexity. This becomes more important for larger cores.

There are certain open issues on categorization of DEGR, time for pipe rupture, temperature limits, demonstration of leak before break (LBB) and improved design concepts. There was a consensus among participants that the structural reliability of the primary pipe is so high that DEGR should be BDBA. The time for rupture highly influences the evolutions of temperatures of fuel, clad and coolant following the event. For the highly ductile material, the assumption that crack propagation from critical length to DEGR should take a finite time. Except France which considers this period to be 1 s others assume an instantaneous rupture. Therefore, a comprehensive study in fixing this value is recommended. Regarding temperature limits, China and Korea follow a very conservative approach by restricting temperatures to avoid local boiling. However, France and India restrict the temperatures so as to avoid bulk sodium boiling and maintain the coolable geometry in the fuel SA. A better resolution on this issue is required. For loop type reactor, LBB demonstration has been applied and thereby DEGR is eliminated. There is general agreement on the fracture mechanics methodology to be adopted for this purpose. LBB justification is not possible for primary pipe in pool type reactors, because of requirement of on-line leak detection. If this problem can be adequately resolved thorough improved design concepts, LBB methodology can then be adopted to eliminate DEGR as a DBE. Improved design concepts which can facilitate leak detection, ISI, and reduce the reduction of core flow in the event of DEGR need to be studied.

Finally, in the meeting, it was proposed to initiate another Collaborative Research Programme to study analytical benchmark exercises focusing on the validation of computer codes used to assess the consequences of a pipe rupture. The benchmark model should be a reference pool type FBR design. The objective includes studying the sensitivity of certain input parameters. Further, it was proposed to conduct a Technical Meeting on ISI and leak detection of reactor internals of pool type LMFBR. A need for bringing out IAEA guideline for safety analysis of primary pipe rupture event in a pool type FBR was emphasised.

(P. Chellapandi)

Symposium on "Advances in Metal Forming"

January 20-21, 2003

A symposium on advances in metal forming (SAMF) was organised at Kalpakkam during January 20-21, 2003 by Indian Institute of Metals, Kalpakkam Chapter, Metal Sciences Division, Indian Institute of Metals and Indira Gandhi Centre for Atomic Research. Dr. S.L. Mannan, Chairman, SAMF welcomed the delegates to the symposium. The inaugural address was delivered by Shri. S.B. Bhoje, Director, IGCAR who emphasized the role of metal forming in fabrication of large components for Prototype Fast Breeder Reactor (PFBR) and the importance of near net shape forming. In the presidential address, Dr. Baldev Raj, Director, MCRG, mentioned various advances in metal forming that included microstructural evolution during forming, microstructural simulation, finite element methods and intelligent processing of materials. The keynote address was given by Shri. M. Namasivayam, General Manager (Nuclear), Bharat Heavy Electricals Limited, Tiruchirapalli. He highlighted the latest trends in metal forming and discussed BHEL achievements in fabrication of large components for PFBR. There were eleven invited talks in total. Prof. Y.V.R.K. Prasad explained the materials modeling approach to design a metal forming process, while Prof. P. Venugopal discussed the role of metal forming machinery to design the processing schedule. Shri A. Selvaraj highlighted the role and challenges for metal forming engineers in PFBR project. The various metal forming processes were covered in a special session, consisting of explosive forming, hot forging and flow forming. In another special session, the basics of finite element method (FEM) and its applications in metal forming were discussed. The advances in hot extrusion techniques at Nuclear Fuel Complex were presented. The experience in the fabrication and inspection of formed parts to the code requirements and the monitoring of metal forming processes were also covered.

Forty contributed papers covered a wide range of topics in metal forming. They included papers on application of FEM method, such as for disc forging, cold forging, forming limit diagrams, hot extrusion, dead metal zone formation and design of stream lined dies. Papers related to fabrication of components for PFBR were presented in a session that included prediction of spring back, hot extrusion, BHEL experience in fabrication large components and indigenous development of steels for PFBR. The papers on various metal forming techniques were presented in a session that included bending, stretch forming, extrusion, indirect extrusion, superplastic forming and optimization techniques for thermo-mechanical processing. There were papers on processing of sintered P/M performs. The participants were from industry such as BHEL, SAIL, Metallic Bellows, Fomas, Modern

Engineers and Prosim and academic institutions such as IISc, IITs, REC, Trichy, PSG college of Technology, Annamalai University, SRM engineering college, and Government laboratories such as DMRL, Hyderabad, RRL, Bhopal, VEC, Kolakata and IGCAR, Kalpakkam. In the concluding session Dr. S.K. Ray summed up the papers presented in the symposium and discussed the future directions.

(S. Venugopal)

26th IARP Conference National Conference on Radiation Exposure Control at Nuclear Fuel Cycle Facilities and Radiation Installations

March 5-7, 2003

The 26th National conference organized by IARP (Indian Association for Radiation Protection) was held at IGCAR, Kalpakkam during March 5-7, 2003. The conference was inaugurated by Shri B. Bhattacharjee, Director, BARC Shri S.B. Bhoje, Director, IGCAR extended a hearty welcome to the participants of the seminar. During the inaugural session, the Dr. A.K. Ganguly and Dr. K.G. Vohra Memorial Awards were presented respectively to Dr. M.C. Abani and Dr. B.C. Bhatt both from BARC.

The conference has generated unprecedented response in terms of the number of participants (nearly 250) and a large number of contributed papers in almost all topics related with radiation protection. There were ten oral presentation sessions and five poster sessions. The Proceedings of the conference have already appeared in two volumes of the journal *Radiation Protection and Environment* (vol. 26, No. 1-2, 2003) published by IARP. The proceedings feature in all 103 contributed papers, selected after peer review and eleven invited talks.

Efforts in terms of material selection, improvement in the reactor components and modification in layout, made to bring down the collective dose levels from Indian PHWR were highlighted. The 'GRAB' sampling for quick and easy air borne Tritium measurement (> 0.2 DAC) was discussed. Various efforts (eg., water filled canisters at north end shield) made to control occupational radiation exposure at RAPS was brought out in an interesting talk. The problem of internal exposure due to tritium in the reactor environs due to increased frequency of heavy water escape and spills with the aging of the plant and measures to minimize it was presented.

The paper on radiation exposure control during En masse Coolant Replacement in PHWRs was informative. The presentation by Shri Jawahar and Shri Singha Roy on the EMCCR operation at MAPS earned the best oral paper award instituted by Indian Nuclear Society. The results on the series of chemical decontamination campaigns carried out at MAPS for reducing personnel radiation exposures were presented.

The method of removing ^{137}Cs and ^{90}Sr from radioactive liquid wastes generated at MAPS using zeolite molecular sieves and $MgCO_3$ sorbent was discuused. The polymer coagulation process for the uranium recovery and safe disposal of waste was highlighted.

Various design options chosen to minimize the radiation exposures to personnel from fast reactors was presented. The results on detailed shielding mock-up experiments at Apsara reactor for PFBR and a comparison with that obtained from transport calculations was also discussed. Details on how ^{134}Cs and ^{137}Cs released during the failure of fuel pins could be removed from the primary sodium coolant by carbonaceous materials was presented in separate talk. Sodium leak incident and decontamination operation at FBTR was presented.

A TLD badge with machine readable ID, the performance of different personnel monitoring units and development of high sensitive $CaSO_4$:Dy sintered pellets were highlighted. Various monitoring techniques for the impact assessment during nuclear emergencies were also discussed.

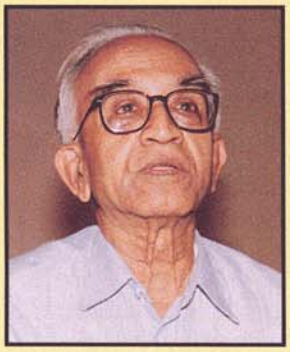
The radiation safety aspects in nuclear medicine and the assessment of radioactive body burdens by whole body counting techniques and on the low ecological half-life of ^{137}Cs in clay soil were also covered. The use of plastic scintillator as a limb monitor to check unauthorized movement of radioactive materials presented by Shri A.K. Verma et al. won the best poster presentation.

(A.R. Lakshmanan)

"Parlimentary Standing Committee on Energy" visited Kalpakkam on December 29th 2002. Shri S.B. Bhoje, Director, IGCAR welcomed the honourable Members of the Parliament and made a brief presentation highlighting the mission of the centre, R&D facilities, the performance of FBTR, status of PFBR project. The committee appreciated the presentation and assured its full support to FBR programme. The honourable members also visited FBTR.

Awards / Honours

On behalf of the centre, Editorial committee congratulates Shri N. Srinivasan, and Shri S. B. Bhoje, for being decorated with prestigious "Padma" Awards for the year 2003.



Shri N. Srinivasan, founder Director, IGCAR has been conferred with "Padma Bhushan" award for his contributions in the field of Science & Technology.

President Dr. A.P. J. Abdul Kalam decorating Shri S.B. Bhoje, Director, IGCAR with "PADMASHRI" title on April 3, 2003 at Rashtrapathi Bhavan, New Delhi for his contributions in the field of Science & Technology.

Shri D. Ganesan, DPEND has been conferred with the Award of "Shram Shri" for the year 2002 by Government of India.

Shri P. Kalyanasundaram, Head, DPEND has been presented with Gold Medal of Acoustic Emission Working Group (I) at the National Seminar of NDT held in Chennai during December 5-7, 2002.

Shri R. Bhaskaran, Dr. K. Gireesan, and Shri R. Nagendran of Materials Science Division (MSD) have been awarded S. N. Seshadri Memorial Instrumentation Award in Physical Sciences-2001 by Indian Physics Assoication (IPA), Mumbai for their development of SQUID sensors and SQUID based measuring systems.

The paper entitled "Modeling and prediction of ferrite number in stainless steel welds using Bayesian Neural network analysis and comparison with other prediction methods" by Shri M. Vasudevan, Dr. A.K. Bhaduri, Dr. Baldev Raj and Shri K. Prasad Rao received the D & H Secheron Award and also the I.T. Mirchandani Memorial Award for the best research paper during National Welding Seminar (NWS) -2001 held at Chennai during January 7-9, 2002.

Dr. Baldev Raj, Director, MCRpG has edited the Special issue of "*Insight*", the Journal of the British Institute of Non-destructive Testing, featuring the "NDT in India", which contains ten review articles from various reputed NDT groups.