NEWSLETTER

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INSIDE THE NEWSLETTER

From the Director's Desk

50 YEARS OF DEPARTMENT OF ATOMIC ENERGY

The Department of Atomic Energy is celebrating its Golden Jubilee year from August 2003 to August 2004. Incidentally, this coincides with the 50 years of declaration of the "atoms for peace" in the United Nations. Dr. Homi Bhabha envisaged the use of nuclear energy for peaceful applications much before this declaration was made. In his letter to Sir Dorab Tata Trust, he wrote in 1944 *when nuclear energy has been successfully applied for power production in say, a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand.* The nuclear energy programme in India has grown with many constraints viz., lack of adequate infrastructure for mega science and hitech projects, lack of indigenous availability of special materials, inadequacy of Indian industries to manufacture nuclear components to stringent specifications, government procedures for contracting and manpower management, isolation from the rest of the world on political grounds, small size of reactors, unreliable electrical grids and low grade limited uranium reserves. Even proper roads were not existing at that time for transporting the large and heavy components. The power programme started with the three imported reactors – two BWR and one PHWR. The fourth half-constructed reactor had been completed indigenously with some delays. Inadequate production of heavy water was also an important reason for the initial delays. The capacity factors were initially low. Lack of adequate funds and embargo on the import of equipment also resulted in lower growth of power programme. India has crossed all the above barriers one by one.

Behind these successes, there were problems of cost and time overrun. The performance of the Nuclear Power Corporation of India Limited in operating the reactors during the last 5 to 6 years is excellent. They are on the top of many countries. This success is the joint effort of the R&D units, NPC, Heavy Water Board, NFC, UCIL and most importantly the Indian industries. It is a matter of pride that India is operating successfully fourteen reactors at present at high capacity factors. Construction of nine reactors is in progress, the highest number of reactors being built today by any country in the world. This goes to show the maturity of the Indian nuclear power programme. This is coinciding with acknowledgement of importance of nuclear energy in the country's energy fabric. At present, there is not only good support within the country but the expectations are also rising.

The second stage of the nuclear power programme i.e. using plutonium and uranium in fast breeder reactors has started in a big way, with the financial approval of the 500 MWe Prototype Fast Breeder Reactor accorded in September 2003. Prior to this, fifteen years of successful operating experience has been gained on FBTR, using sodium as coolant and an unique carbide fuel. The experience is very encouraging.

The fuel cycle facilities need to improve their performances and also should be augmented, in order to meet the requirement of nuclear power programme. This is a very important technology. India has long experience in reprocessing, starting with the plutonium plant, commissioned in 1965. The growth of the nuclear power will depend on the front end and back end of the fuel cycle. Reprocessing of the irradiated fuels and radioactive waste management are the keys to the success of the nuclear power programme in India.

S. B. Bhoje
(Director)

Press Releases

Dr. Baldev Raj assumes responsibilities as Director, Indira Gandhi Centre for Atomic Research, Kalpakkam, when the country is launching a large energy programme based on Fast Breeder Reactors. The Centre is the second largest R&D Centre of the Department of Atomic Energy with a mission programme to develop a robust science-based technology for Fast Breeder Reactors and the associated reprocessing technology. The Centre pursues basic research in a few select areas with the objective of leadership and excellence.

Dr. Baldev Raj is well known for his contributions to nondestructive evaluation, materials development and performance, reactor technology and associated fuel cycle technologies. He joined the Department in 1969 in the Training School of Bhabha Atomic Research Centre and moved to Kalpakkam, the then Reactor Research Centre in June 1974. He is a graduate of Ravishankar University, Raipur and did his Ph.D in interdisciplinary area of Materials Science & Aerospace Engineering from Indian Institute of Science, Bangalore. Dr. Baldev Raj is a prolific researcher, who has 550 publications in leading national and international journals and edited volumes. He has written 9 books and edited 17 books. He has also 15 patents to his credit. Dr. Baldev Raj is a Fellow of the Indian National Academy of Engineering, Indian Academy of Sciences, Bangalore, The National Academy of Sciences, Allahabad, Tamil Nadu Academy of Sciences. He has been honoured with many awards including NDT Man of the Year, National Metallurgist, G.D. Birla Gold Medal and VASVIK award. He has been the Past-President of International Committee on NDT, the prestigeous world body that steers the programmes of professional NDT societies of various countries. His other interests include holistic education, heritage, philosophy and religion.

Dr. Baldev Raj brings with him a vast and rich experience of pursing and managing advanced research and development for the fast reactor programme.

On-Power Frictional Force Measurement of Control Rods in FBTR

Six control rods (CR) containing neutron-absorbing material namely boron carbide form the shut down device of FBTR. They are also used to regulate the reactor power. The CR moves inside individual outer sheaths, which are located symmetrically in the grid plate. Each CR is guided at three locations inside the outer sheath. The diametrical clearance between outer sheath and CR at the foot location is very small (0.2 mm max) to maintain verticality. Two gripper fingers, which are located at the bottom of the lower mobile part of the control rod drive mechanism (CRDM), hold the CR firmly. The vertical up and down movement (total travel 450 mm) of CR is obtained by means of a reversible motor through a gear train and a nut and screw arrangement in CRDM. (Fig1). CRDM is in two parts viz. upper and lower. While the upper part containing the motor, brake and instrumentation is located at –1100 mm level on top of control plug, the lower mobile part extends below –1100 mm level and dips below sodium level. Thus the entire assembly is subjected to a temperature gradient from ambient (< 60 °C) at –1100 mm level to core outlet sodium temperature (520 °C)

The CRDM have two safety functions to perform viz. rapid dropping of the mobile part holding the CR to bottom limit within 500 ms during a scram order and simultaneous lowering of all the CR to bottom limit by drive motor during an order for LOR (lowering of rods). When the reactor is on power and there is no demand for any safety action, one CR is operated by manual raise / lower command for burn-up compensation

During reactor operation both CR and its outer sheath swell due to neutron irradiation resulting in decrease in diametrical clearance. Coupled with temperature gradient and grid plate shift, this results in increased friction. It is essential to ensure that the friction does not hamper the safety and power regulating functions of CRDM. Strain gauges fixed on CRDM upper part provide load signals for friction force measurement. During shutdown, friction force (FF) is measured by raising one CR at a time to 450 mm and lowering it back to 0 mm. Though friction force measurement during reactor shutdown facilitates measurement over the entire range of travel, it does not simulate all operating conditions. Hence, friction force has to be measured during reactor operation as well. This measurement, however, cannot be done for the entire range of travel when the reactor is operating. During on-power friction force measurement, it is essential to ensure that reactor power does not vary. Hence it is required to raise one control rod and lower the other simultaneously to the same extent. But as per the design intent, provision exists to raise or lower only one CR at a time thus necessitating logic modifications. Hence extensive logic modifications were done to facilitate selection and operation of two CR ensuring that only one of them can be raised and the other lowered simultaneously for the purpose of CR exercise. The modifications were engineered such that the procedure and interlocks for normal operation are not affected and also that there is no scope for human error. Most importantly, it has also been ensured that all the safety functions and the interlocks are available during the course of the exercise also. The modification involved provision of additional push button station for selection of CR and additional logic circuitry to facilitate the test when authorized through a key switch and providing the required inputs namely, CR selected for raise / lower operations and their position to the friction force measurement system (FFMS).

A PC based Data acquisition system has been commissioned for the computation of friction force both during shutdown and reactor operation. Six CR position signals, six load signals from the strain gauges and a signal from an Resistance Temperature Detector (RTD) fixed near the upper part to compensate for variation of strain gauge signal due to change in

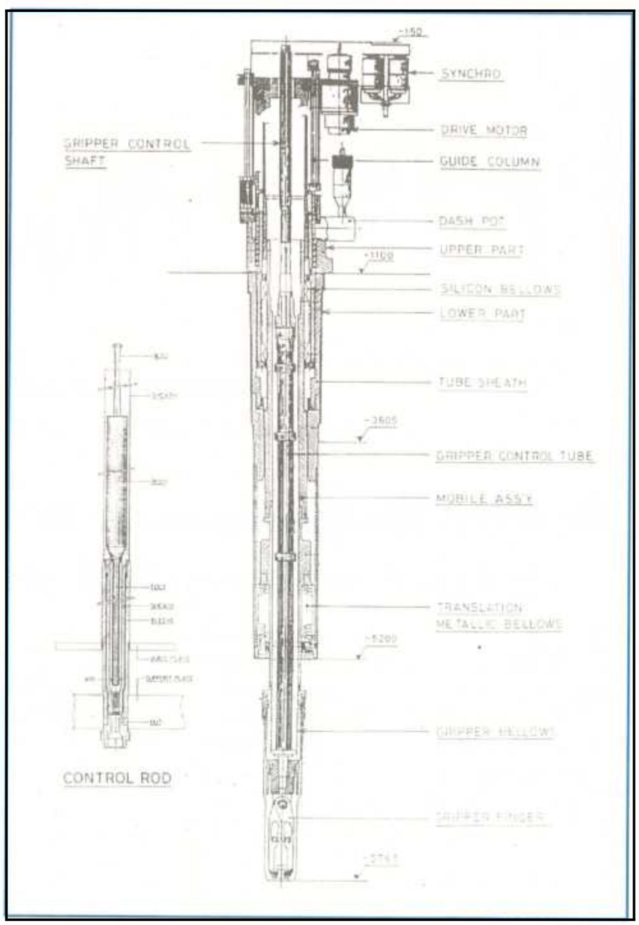


Fig. 1 : Control Rod Drive Mechanism

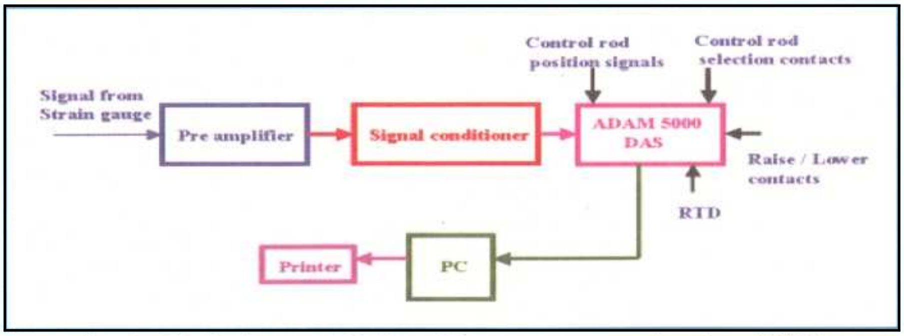


Fig. 2 : Block diagram of frictional force measurement system (FFMS)

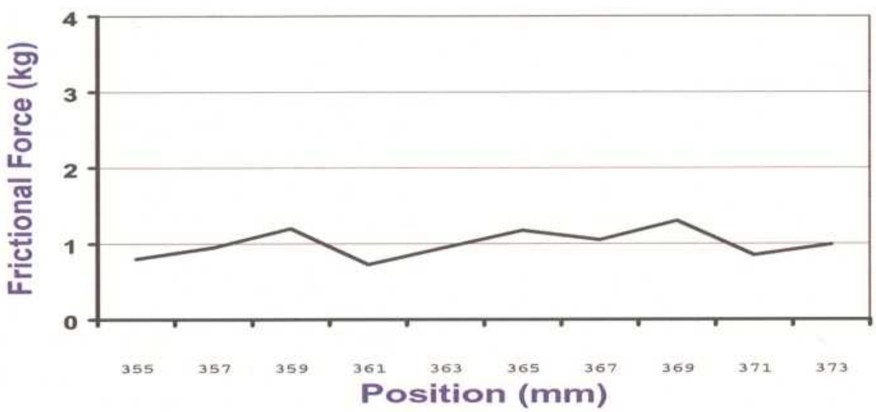


Fig. 3 : Position vs. Frictional Force during Reactor operation.

Fig. 4 : Position vs. Frictional Force during Shutdown.

ambient temperature are wired to the FFMS. The strain gauge signals are connected to the data acquisition system of FFMS, through a low level amplifier and a signal conditioner as shown in Fig 2. The CR selection contacts, raise and lower switches are wired as digital signals to FFMS.

FFMS calculates the friction force from the lifting force data stored during raising (LF_R) and lowering (LF_L) of the CR vide equation $FF = (LF_R - LF_L) / 2$. The difference in position of any two CR cannot be more than 20 mm during reactor operation to respect pre-alert alarm of LOR on CR level discordance. Hence CRs are exercised in the regime of operating height of CR ± 10 mm to obtain friction force during reactor operation. The CRs are exercised in pairs by raising one CR and lowering the other simultaneously in the operating regime and the power variation was less than 10 kWt. The on-power exercising of CR is done once in a fortnight to ensure operability of the CR.

The system was commissioned in September 2003 and the frictional force values were found to be less than 4 kg. Typical graphs of friction measurement of CR during reactor operation and shutdown are given in Fig.3 and 4 respectively

(C. Gowri, K. Vinolia, V. Ramanathan, S. Usha, M. Subramaniam and V. S. Krishnamachari)

Post Irradiation Examination of Fast Breeder Test Reactor Fuel Subassembly and fuel pins after a burn-up of 100 GWd/t

The indigenously developed mixed carbide fuel (70% PuC, 30% UC), the Mark-I driver fuel of Fast Breeder Test Reactor (FBTR) has successfully crossed a burn-up of 120 GWd/t without any failure. Periodic Post Irradiation Examination (PIE) and performance assessments carried out on irradiated fuel subassemblies (FSA) after various levels of burn-up have played a significant role in the progressive enhancement of the performance of this unique fuel. This article briefly explains the salient results of PIE carried out in the hot cells of Radiometallurgy Laboratory (RML) on an FSA that has crossed a burn-up of 100 Gwd/t.

Visual examination indicated the surface of the FSA to be in very good condition. There was no observable abnormalities, scratches, dents, peeling of chrome plating on the button etc. Dimensional measurements of FSA were carried out to evaluate the irradiation induced increase in dimensions like the width-across-flats and corner-to-corner-distance etc. of the hexagonal wrapper. Fig.1 shows the graphs showing variation of these dimensions along the length of the FSA. These dimensions were seen to be gradually increasing from the ends towards the center of the fuel column. A maximum increase of

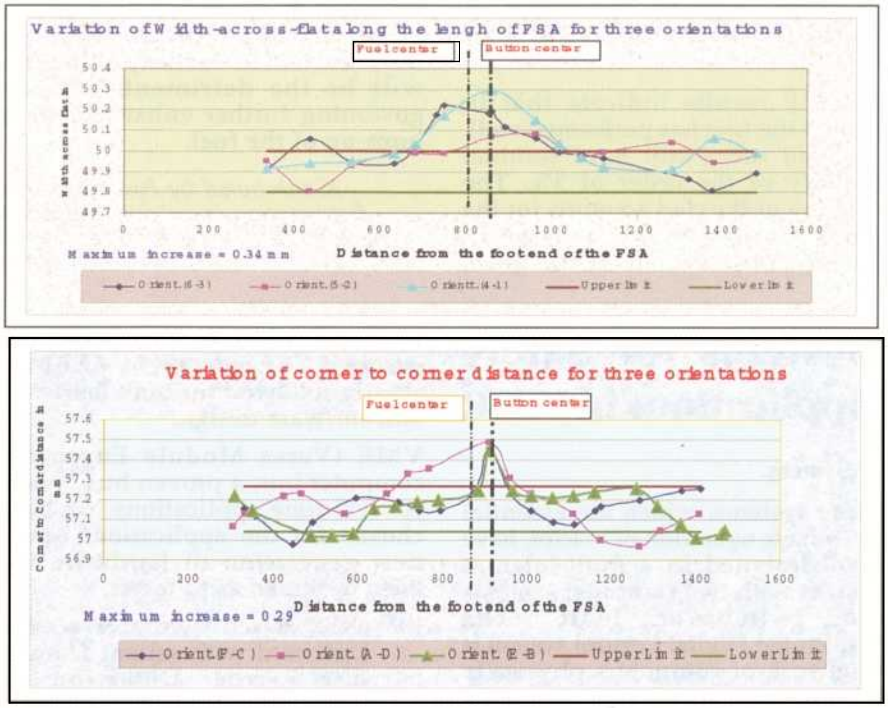


Fig.1 : Variation of width-across-flats and corner-to-corner distance of hexagonal wrapper along the length of FSA

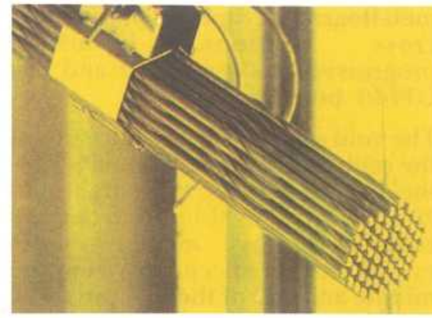


Fig.2 : Photograph of fuel pin bundle

about 0.7% was observed in the width-across-flat and 0.5% in the corner-to-corner distance. Head-to-foot misalignment of the FSA was found to be 4.3mm. No significant increase was noticed in the length of the FSA. The observed changes in dimensions are not likely to hamper fuel-handling operations in the reactor.

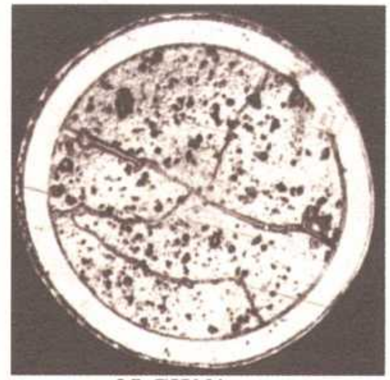
The fuel pins extracted from the FSA was found to be in very good condition. Fig. 2 shows a photograph of the fuel pin bundle. Dimensional measurements on nine selected fuel pins, which lie along a diagonal of the fuel pin bundle in the FSA, were carried out using a specially designed bench and a length measurement set up. The length of the fuel pins has undergone a maximum increase of 0.4%. Diameter of the fuel pins has increased in the fuel region, with maximum occurring at the center of the fuel column. The increase in diameter varied from pin to pin and maximum increase was 1.6%. This increase is caused by both creep and swelling on the clad tubes.

Eddy Current (EC) testing of the fuel pins did not reveal any significant defects on the clad tubes. X-radiographic examination revealed that the pellet-to-pellet gap and pellet-to-clad gap have closed at the central region of the fuel column. The fuel pellet stack lengths were seen to have increased from the original values. The increase ranged from 1 to 2.6% with an average of 1.73%. This increase when compared with the results of earlier PIE carried out on FSA after 25 to 50 GWd/t burn-up is seen to be linear as a function of burn-up.

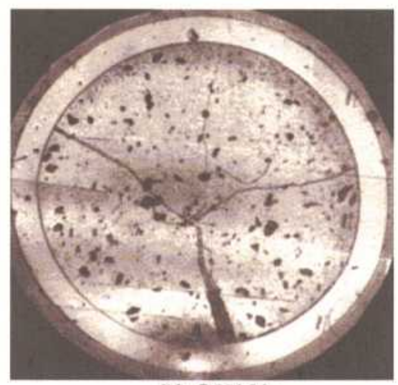
The percentages of fission gas released to the plenum estimated independently at RML & Radio-chemistry Laboratory (RCL) by puncturing and analysis indicated that the maximum gas release is only 14%, which is less than anticipated..

Mechanical property evaluation of clad tube indicated that the uniform elongation of the clad is around 3 % at 430 C, the estimated nominal mid-wall operating temperature of the fuel pin clad.

Metallographic examinations carried out on fuel pins indicated that the fuel-clad gap has closed at the center of the fuel column. The pattern of fuel cracking has been found to change from radial to circumferential after 100 GWd/t burn-up, indicating that radial cracks are getting annealed due to fuel-clad-mechanical-interaction (FCMI). No significant clad carburization has been observed where the fuel has come in contact with the clad. Fig. 3 shows a comparison of



25 GWd/t



50 GWd/t

100 GWd/t

Fig.3 : Comparison of metallographic images of fuel pin cross sections at the middle of the fuel column after 25, 50 and 100 GWd/t burn-up

metallographic images of fuel pin cross sections examined progressively after 25, 50 and 100 GWd/t burn-up.

The void swelling of the clad tube at the centre of the fuel column, where the dpa is estimated to be highest (~ 70 dpa) was evaluated from the remote density measurements carried out on specimens from the middle and end of the fuel pins. The swelling induced reduction in density was seen to be of the order of 4.3%.

The PIE results indicate that in general the fuel has performed well. The clad tubes still have residual ductility of the order of 3%. The swelling of the clad accounts for the major portion of the increase in diameter observed on the fuel pins. Swelling of the fuel with resultant exhaustion of porosities, FCMI and the reduction in ductility of the clad will be the detrimental factors governing further enhancement of burn-up of the fuel.

(Contributed by Post-Irradiation Examination in-service Inspection, Remote handling & Robotics Section (PIR) Section

Real Time Computer Systems for Safety Critical & Safety Related Applications in PFBR

The PFBR, the first of many fast breeder reactors to be set up has been designed with emphasis on Safety and Electronics Division is responsible for all the Safety Critical systems except Neutronic & Sodium instrumentation, Safety related systems and Systems not related to safety. The safety systems that are responsible for the primary safety of the reactor are all hard wired systems except the Core Temperature Monitoring System, which is based on triplicated real time computer systems. The two logic systems that initiate safety action to shutdown the reactor under emergency conditions are based on diverse design and technologies to eliminate common cause errors.

The safety systems are backed up by safety related systems to ensure the safe operation of the reactor and consist of the following:

- Alarm generation system
- Discordance supervision system
- Reactor Start-up system
- Transfer Arm Control system
- CSRDM Control system
- DSRDM Control system &
- Distributed Digital Control System.

These systems, which are essential for the safe operation of reactor, have been designed in a fault-tolerant manner with two computer systems and switchover logic. The Distributed Digital Control system is a network of computers physically and logically distributed across the entire plant and interconnected by a dual Fibre optic Local Area Network. Separate data highways are provided for Safety Critical and Safety related signals. This distribution has reduced the cabling cost to a great extent. Nearly 20,000 signals from the plant are processed, stored and analysed on this computer system thus enabling the operators and designers to access the plant data in any permutation and combination.

The computer systems to be used in these applications have been designed and built indigenously and subjected to harsh environmental tests to ensure maximum reliability. While the reliability of hardware can be analysed, predicted and demonstrated, software reliability cannot be quantified. However, following engineering practices such as Verification & Validation can ensure it. The codes set by AERB are strictly followed for both hardware and software design.

VME (Versa Module European) computer bus, a proven bus system for real time applications has been chosen for the applications and a new generation of hardware has been designed as follows:

(i) 68020 based Central Processor Unit card with salient features like Error Detection & Correction logic for memory and on-line testable watchdog timer

(ii) 42 Channel Analog input card

(iii) 32 Channel Digital input card

(iv) Digital output board

(v) Analog output board

(vi) Synchro to Digital Connector board

All these boards have been designed using Very Large Scale Integrated Circuits to reduce component count and interconnections to offer high reliability. The designs have been simulated, verified and prototype boards made for detailed testing and evaluation. Figure 1 shows the Photographs of some of the boards that were developed.

(Contributed by Electronics Division)

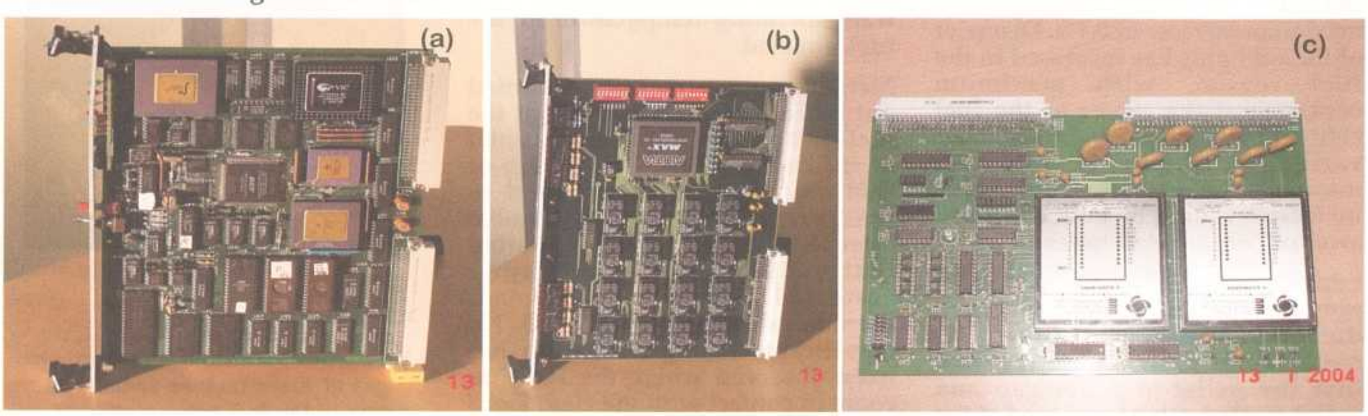


Fig. 1 : VME Bus compatible boards (a) CPU board ; (b) Relay output board ; (C) Synchro to Digital converter board

In-house development of Computerised Work orders Management System (CWMS) by Central Workshop (CWS)

A number of Work Orders (WOs) are received by CWS regularly from various divisions of this Centre. The jobs covered by these work orders involve machining, fabrication and inspection. Between the receipt of WOs from Sections/Divisions/ Groups and the delivery of completed jobs to the end-user, a number of stages are involved as given below:

Detailed process sheet describing (a) the processes involved (b) the sequence of the processes (c) the machine and the operator needed for each process and (d) time duration, is prepared by planning section of CWS. Since these work orders have to be completed using the fixed resources (man & machine) available in the shop, a detailed resources loading chart has to be prepared depending on the priority of activities of various WOs and time duration for each of the activity and the machines involved. Wherever a particular machine or particular type of operator is over loaded, we have to resort to "leveling " the resources so that the total time duration is stretched proportionately. In a mass production shop where the same sequence is followed for long period these loading charts can be prepared manually. However, the nature of each WO received in CWS is very unique with respect to dimensions and profiles involved. There fore it is necessary to prepare the resources loading chart for each WO as and when received. Considering the variety of machines involved in many of these work orders and the large number of work orders to be handled, it is practically impossible to prepare or update such machine loading chart manually for each work order. Thus difficulties were experienced in arriving at the scheduled start and finish dates of these work orders.

An analysis carried out on the above issues pointed to practical limitation in the preparation of schedule and resources loading sheets by manual methods. Updating these documents based on the revised status of activities was practically impossible. Therefore it was felt that computerization of the above activities is the only practical solution for the problem.

The requirement for developing a computer programme for the above nature of activities could not be straightaway fitted into any of the available packages. The closest package available for the same was MSP project software, which was available in CWS. Significant efforts were put in-house for the development of the above programme in MS Project software. After a number of trials and corrections, a working programme was developed. The same has also been implemented with effect from 1st May 2003. As a result of the successful implementation of the above programme, the following details are readily available now with respect to various WOs.

a) Detailed schedule for each WO up to the latest one. b) The loading chart for each resource available. (This has helped in locating the resources, which are overloaded, and action taken for outsourcing.) c) A variety of reports are made available which help in reviewing the progress achieved and taking corrective measures to minimize delays. d) Communication with user section at various stages has become very effective. e) The jobs, which are to be loaded for each machine by the workshop foremen, are easily available to them in the form of sequential loading chart and not left to any random decision.

In short, the whole process of planning and execution of various Work Orders have become very user-friendly and effective due to the development and implementation of the computerized WO scheduling system.

(M. Krishnamoorthy, R. S. Raghavendran and M. A. K. Iyer)

HIGHLIGHTS OF SYMPOSIA/SEMINARS/CONFERENCES

The 17th National and 6th ISHMT-ASME Heat & Mass Transfer Conference (January 5-7, 2004)

The 17th National and 6th ISHMT-ASME Heat & Mass Transfer Conference was held at the Convention Centre, Anupuram, during 5-7, January 2004. Shri S.B. Bhoje, Director, IGCAR presided over the inaugural session. He brought out the complex thermal hydraulics phenomena in fast breeder reactors and the challenges faced in normal and accidental situations. He emphasized on the inputs obtained through large interactions with educational institutions and R&D institutions within the country for the Prototype Fast Breeder Reactor. Dr. Anil Kakodkar, Chairman, AEC and Secretary, DAE, in his inaugural address indicated the important role the biannual conferences of Heat & Mass Transfer have played in bringing together the academic and R&D institutions. Indicating the strong interests of DAE in this area, he mentioned about the challenges faced in understanding the thermal hydraulics of the pressurized heavy water reactors. He also mentioned areas where integral approach was difficult and solution by parts had to be resorted to. He also brought out the desire of the Department to go in for 700 MWe PHWR with the present design of 540 MWe PHWRs but by allowing little boiling in the core. He made a mention about the Advanced Heavy Water Reactor (AHWR) where the normal circulation through the core is by thermosyphon. He also briefly touched upon the program of the department with respect to Accelerator Driven System (ADS), where one has to face high energy density removal and compact high temperature reactors.

The Conference comprised of 2 plenary talks, 18 keynote lectures and 164 contributed papers. The talks covered Micro / Nano fluidics, wall function approaches for turbulent flow, advances in Numerical heat transfer, Heat transfer in thermal spray cratings, Measurement of thermo-physical properties by noncontact methods, Heat transfer in fast reactors, Simulation of laser and electric beam Melting problem and Heat pipes.

200 delegates out of whom 28 were from abroad attended the Conference. The deliberations provided a good interaction with the Heat & Mass Transfer Community. This was the first Conference held at Convention Centre, Anupuram.

The delegates felt that the Conference venue along with SRI Guest house provided an ideal environment and were in praise for all arrangements and timely completion of all technical sessions.

(G. Vaidyanathan, M. Rajan and S.C. Chetal)

DAE – BRNS National Symposium on Nuclear Instrumentation – 2004 (NSNI – 2004) February 17-20, 2004

The Electronic Divisions of BARC & IGCAR jointly organized a National Symposium on Nuclear Instrumentation (NSNI-2004) at Convention Centre, Anupuram from 17th to 20th February 2004. Shri S. B. Bhoje, Director, IGCAR inaugurated the symposium and emphasized the need for self-reliance in nuclear instrumentation right from sensor onwards. The function was presided by Shri G. Govindarajan, Director A&M and E&I groups, BARC. Shri G. P. Shrivastava, Chairman & Managing Director of ECIL, Hyderabad delivered the keynote address covering the entire spectrum of technical activities that are provided by ECIL for nuclear reactors and ECIL's capability of handling latest technology to meet the diverse needs ranging from Safety systems to Security systems.

The response to the symposium was overwhelming with 23 invited talks, 60 oral presentations and nearly 100 papers in poster sessions. Over 300 delegates from Space, Defence, BARC, IGCAR, ECIL, BEL, DST, educational institutes and industry participated in the symposium. The topics that were covered are Programmable Logic design, Reactor Instrumentation, Radiation Detectors, Computers and Networks for Nuclear Instruments and Bio-Medical Instrumentation. An industrial exhibition was also arranged in which ten private firms participated along with ECIL. IGCAR & BARC also demonstrated their products, developed in-house.

A felicitation function was also organized on the first day evening for Shri G. Govindarajan, BARC and Dr. S.M. Lee, IGCAR on the eve of their attaining the age of sixty and various speakers recalled the services rendered by them to the Department and the Nation. On the second day evening, Dr. Mondal, TIFR gave a very informative and interesting talk on "High energy physics instrumentation" and a few industrial presentations were made on the third day evening. The delegates expressed satisfaction with respect to the technical content and hospitality arrangements of the symposium.

(B. Krishnakumar and S. Ilango Sambasivan)

Inauguration of Video Conference Facility

A video conference facility, based on Tanderg 2500 with two wide-angle view cameras, two 29" XGA Monitors, a Document camera and a LCD projector, has been installed at IGCAR. It is designed to enable four-party simultaneous video conferencing. ISDN connectivity is used for interacting with Industries and V.35 connectivity for other DAE units through ANUNET. This facility will enable more frequent discussions with various agencies like manufacturers, suppliers, consultants etc. during various stages of PFBR construction and it will also aid better communication among various DAE units. Dr. Anil Kakodkar, Chairman, AEC & Secretary, DAE has inaugurated the facility on February 28, 2004.

Shri R. Prabhakar, Director (Technical), BHAVINI, Shri S.B. Bhoje, Director, IGCAR, Dr. Anil Kakodkar, Chairman, AEC & Secretary, DAE and Shri S.C. Jain, CMD, NPCIL and other senior officials, during the inauguration of Video Conference Facility.

National Science Day Celebrations

As part of the "National Science Day" celebrations and for encouraging scientific awareness in the community, an essay and slogan competitions were conducted for the School students of Thirukalikundram Taluk. Around one hundred students from thirteen schools participated in the function. The essay competition was conducted at AECS School premises at Anupuram on 13–03-2004. This was followed by a lecture on Nuclear Energy in Tamil by Dr. A. Natarajan, Head, RSD and prize distribution at the Convention Centre, Anupuram. Library & Information Services and Tamil Nadu Science Forum, Kalpakkam Chapter coordinated the program.

As part of the public awareness program and to disseminate the message of Atomic Energy among the professional students, a visit for students of Adiparashakthi Engineering College, Melmaruvathur, Tamil Nadu, was arranged on 28-02-2004. The students were given an introductory lecture on the activities of the Department of Atomic Energy with a special emphasis on Fast Reactor program. Later they also visited FBTR.

(Reported by Shri M. Somasekharan)

Honourable Minister of State for Atomic Energy, Govt. of India, Shri Satya Brata Mookherjee visited IGCAR and other DAE units at Kalpakkam on January 31, 2004

Chairman, Editorial Committee : Dr. Baldev Raj, Advisory Members : Shri S.C. Chetal.
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