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ZIRCONIUM CRYSTAL BAR FROM Zr-2.5Nb ALLOY SCRAP BY IODIDE REFINING

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Introduction

The demand for high purity zirconium metal has always been of paramount importance in nuclear industry as well as metallurgical research. The requirement of more stringent specifications with respect to mechanical as well as corrosion resistance properties for structural components, in a nuclear reactor has made it all the more important to adopt specialised techniques for preparing this metal in pure form as these properties get severely affected by the presence of a host of impurity elements. Various impurities, present in zirconium, can broadly be classified into two categories, viz. (i) substitutional and (ii) interstitial. The possibilities and methods for removing both types of impurities are quite different. Moreover, taking additionally into account the very high reactivity of zirconium towards oxygen, nitrogen, carbon and hydrogen, it becomes clear why it is especially difficult to produce high-purity zirconium.

Zr-2.5Nb alloy is being used as standard coolant tube material in pressurised heavy water type nuclear reactors owing to its superior mechanical properties as well as lower hydrogen pickup. As the majority of power reactors presently being operated in India fall into the category of pressurised heavy water reactors, the annual requirement of pressure tubes has increased. This leads to generation of significant quantities of scrap during various stages of the fabrication process.

Contents

1. Zirconium crystal bar from Zr-2.5Nb alloy scrap by iodide refining 1
2. Intelligent ethernet Module for distributed control systems on standard EC bus for reactor C & I 8
3. Reactivity control mechanisms for TAPP-4 12
4. BRNS seminar-cum-workshop on "Materials characterisation and surface modification in research and industry using ion accelerators (MCIA)" 13
5. President of India honours Director, BARC, with Padma Shri 16

Additionally, new generations of nuclear reactors demand closer tolerance with respect to impurity levels in the structural components. Heavy scrap that is low in interstitial impurities, chiefly oxygen and nitrogen, can be readily melted with suitable blending and recycled. Light scrap consisting mainly of chips as well as turnings is high in oxygen and nitrogen, necessitating a purification route before it can be recycled.

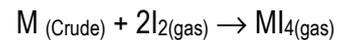
At the same time the storage and subsequent disposal of such scrap poses safety and environmental problems. It is, therefore, attractive to recover a high purity product like crystal bar zirconium from such waste material having low hafnium contamination. With increasingly stringent specifications with respect to impurities such as oxygen, crystal bar zirconium offers blending options to maintain close tolerances.

The high melting point of zirconium allows the evaporation of volatile elements, such as alkali metals, aluminum, iron, chromium etc., by ultra high vacuum (UHV) melting. However, removal of refractory metals and/or their compounds/alloys as well as non-metallic impurities, such as carbon, oxygen and nitrogen, from zirconium are difficult on account of low vapour pressure of these metals/alloys/compounds. In order to reduce the impurity content to acceptable levels, special and often complex refining processes have been applied. The Van Arkel-de Boer iodide process has been found suitable to prepare UHP zirconium in sufficiently large quantities.

Principle of Iodide Refining

The Van Arkel-de Boer process involves the use of elemental iodine and crude metal, in the form of sponge or alloy scrap, to form a volatile metal iodide at low temperature and the subsequent thermal decomposition of the iodide into pure metal and gaseous iodine at high temperature. The pure metal deposits on a resistively heated filament while iodine diffuses back to the surface of the crude metal.

- (i) Iodine gas is allowed to react with crude metal/alloy scrap feed at temperature T_1



- (ii) On the surface of the resistively heated filament at temperature T_2 , ($T_2 > T_1$), the iodide vapor decomposes to deposit pure metal



Zr-2.5Nb alloy scrap reacts with iodine gas to yield volatile zirconium tetra iodide (ZrI_4), which is then decomposed to metallic zirconium at higher temperature on a hot filament made of zirconium wire. The iodine, released during the decomposition process, diffuses back to react with the alloy scrap further. The effective purification of zirconium by iodide process takes place due to the following reasons.

- (i) The interstitial impurities, such as carbon, oxygen and nitrogen, are present in alloy scrap as carbide, oxide and nitride, respectively. These compounds do not react with iodine at the formation temperature of ZrI_4 .
- (ii) Certain metal iodides are too stable to decompose over the surface of the hot filament as their decomposition coefficients are comparatively smaller. For example, the decomposition coefficients of ZrI_4 and ThI_4 at $1150^\circ C$ are 0.32 and 0.048, respectively.
- (iii) Impurities that are highly volatile in nature do not get deposited even if their iodides undergo thermal decomposition reaction over the hot filament surface. For example, the decomposition temperature of TiI_4 and ZrI_4 is much higher than the boiling points of impurities such as arsenic, zinc, magnesium and antimony.
- (iv) Niobium iodide (NbI_5) formation is favoured at temperatures above $400^\circ C$. As a result, feed temperatures around $275-325^\circ C$ enable selective ZrI_4 formation.

However, the possible transport of certain impurities from the Zr-2.5Nb alloy scrap to the crystal bar during iodide refining cannot be ruled out completely. For example, as compared to many other metallic impurities, hafnium and silicon, if present, have higher transfer coefficients. Carbon and hydrogen can be transferred through carbonaceous gases.

In spite of long evacuation and degassing, some residual gases get liberated only when iodine starts reacting with the alloy scrap. It is, therefore, essential to employ a pretreatment unit operation to improve surface characteristics of the alloy scrap to the extent possible. Also, it is equally important to ensure (i) absolute leak-tightness into the deposition vessel, and (ii) corrosion resistance of the structural materials, used for the fabrication of the reaction vessel, and (iii) gasket components.

Molybdenum, Tantalum, Hastelloy B, Hastelloy C and Inconel-600 exhibit excellent resistance to attack by iodine up to a temperature of around 800°C. Platinum, gold, oxygen-free-high

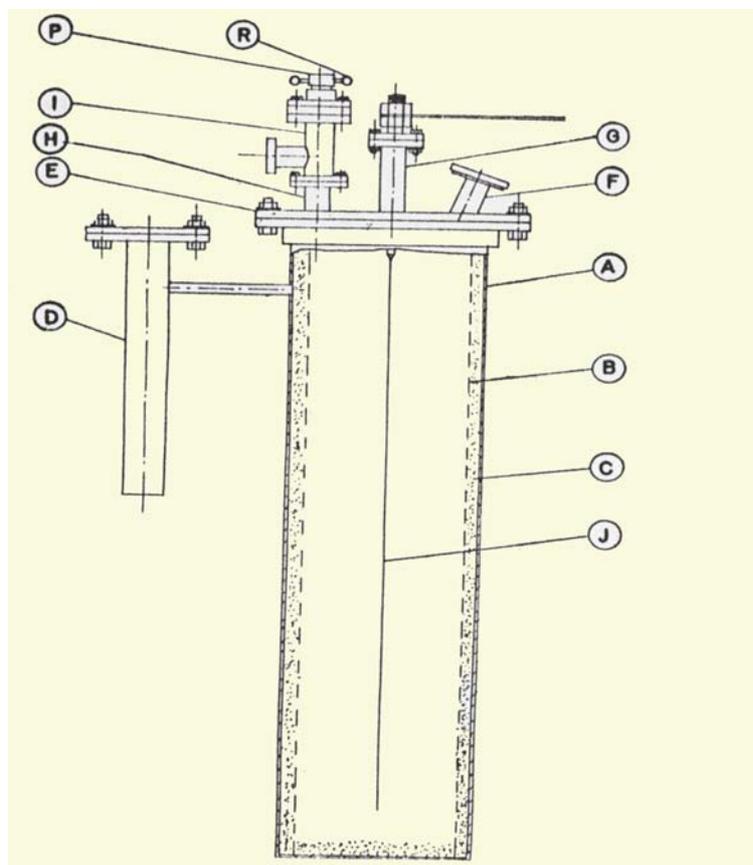
conductivity (OFHC) copper are acceptable as gasket materials at elevated temperatures.

The success of the iodide refining process thus depends upon the efficiency of the vapour transport mechanism which, in turn, depends critically on the proper selection of operating temperatures and pressures as also the nature of the feed material.

Experimental Procedure

Equipment

The assembly for carrying out the refining is shown in Fig.1. The main Inconel-600 retort is heated by an 8.0 kW split-type Nichrome resistance furnace. The power to the furnace is supplied by a Thyristorised power supply controlled by a PID temperature controller enabling precise feed temperature control. The side arm consisting of the iodine chamber is similarly provided with a 2.0 kW furnace along with a power pack of SSR and PID controller.



LEGENDS

- A-Inconel600® Retort
- B-Molybdenum Screen
- C-Feed Metal
- D-Iodine Chamber
- E-Top Flange
- F-View Port
- G-Electrodes
- H-Vacuum Port
- I-Isolation Valve
- J-Pure Metal Filament
- P-Metal Seal Valve
- R-Cooling Coil

Fig.1 Deposition assembly for growing high purity crystal bars

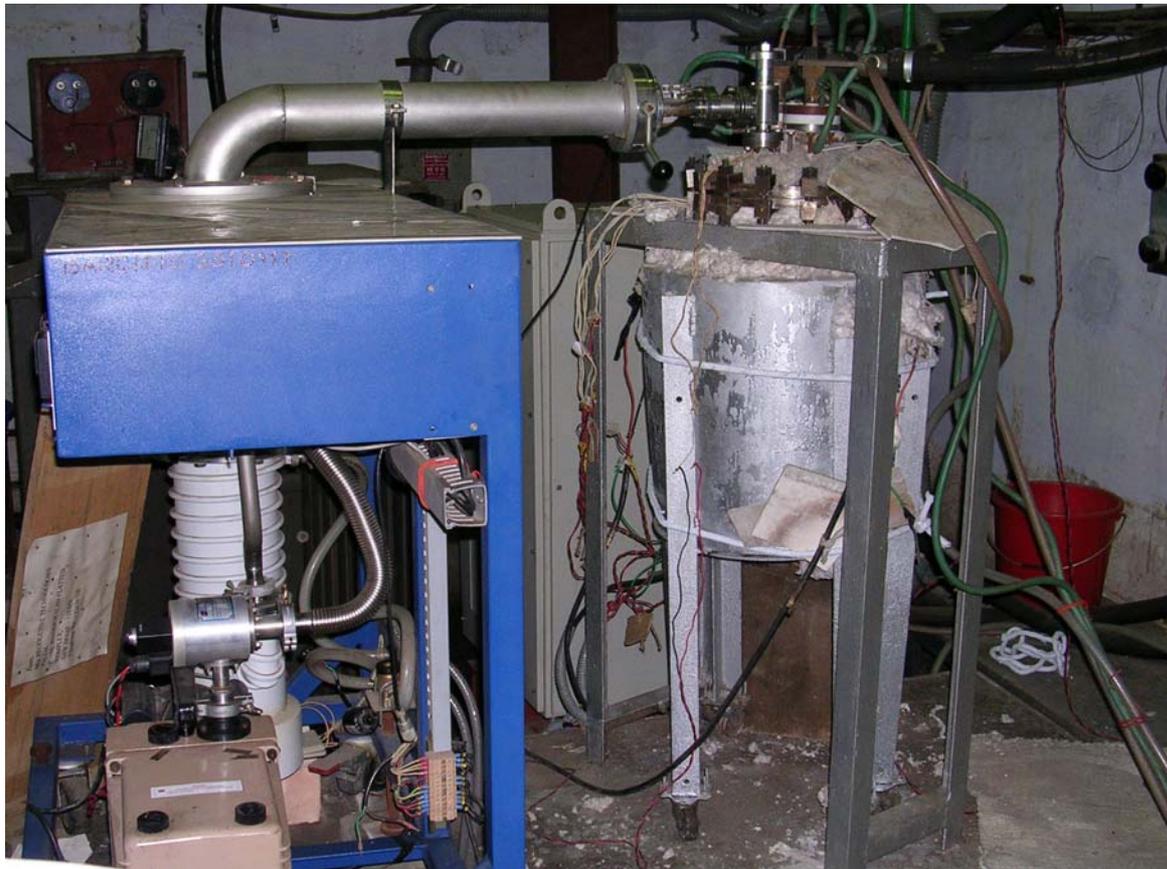


Fig. 2 Refining assembly with vacuum system and water cooled flexible copper cables

The power to the pure metal filament is provided by a 105 kVA, 0-40 volt step down, dry type, air-cooled, transformer. The water-cooled tungsten electrodes are connected to the transformer by flexible, water-cooled copper cables as shown in Fig.2. As the direct monitoring of the filament temperature is not accurate, an indirect technique, involving the adjustment of voltage and current to the filament, is successfully adopted. At constant temperature, for a given filament length, regardless of diameter,

$$E I^{1/3} = K$$

where

$$K = L(4\rho\pi\sigma^2 e^2 T^8)^{1/3}$$

L - filament length, cms

ρ - resistivity, ohms-cm

σ - radiation constant,
 5.735×10^{-12} w/cm² K⁴

e - emissivity

T - filament temperature, K

π - 3.1416

E - potential, Volts

I - filament current, amps

The precise control of the filament voltage and current, and thereby the filament temperature, during the entire refining operation, is carried out by a PLC. Such control loop results in less fluctuation in filament temperature thereby minimising premature filament failures. Further, close control over process parameters also leads to less variation in impurity content in the product. Typically, the initial filament of about 650 mm length and 2.5 mm diameter is heated to a temperature of 1200°C by supplying 30 amps at 6.0 volts. However, as the filament grows to around 20 mm diameter, the current requirement exceeds 1300 amps at about 4.0 volts. All the variables, measured as well as computed, are continuously recorded and displayed by a EURO THERM® 5100V 12-channel chartless recorder.

Procedure

Before carrying out the refining run, the Zr-2.5Nb alloy scrap in the form of turnings is subjected to a hydriding/dehydriding pretreatment. During this treatment, around 7.0 to 8.0 kg of the scrap is degassed at 775-800°C under a vacuum better than 3×10^{-5} mbar and hydrided at 400°C. The feed, after dehydriding, is packed in the annular space of the deposition assembly, sealed with the demountable flange employing an OFHC Copper gasket, which carries the filament of zirconium fixed to water-cooled tungsten electrodes.

The experimental assembly is heated, under dynamic vacuum, to a temperature of 500°C. The assembly is cooled to room temperature and filled with high purity argon. The iodine chamber is opened, charged with calculated quantity of resublimed iodine, typically around 100g, and sealed using OFHC Copper gasket. The iodine chamber is kept refrigerated with liquid nitrogen while the deposition assembly is heated to a feed temperature of 250-320°C under vacuum. The system is isolated from the vacuum assembly with the help of a bellows-sealed all metal valve. The filament is heated to the desired temperature with the help of the PLC. Refrigeration of iodine chamber is discontinued and heated to around 120°C to sublime iodine into the deposition assembly. The iodine reacts with the feed to form ZrI_4 vapours that transport to the hot filament wherein the iodide decomposes to deposit pure zirconium.

After an incubation period lasting 2 to 5 hours, an increase in the conductivity (I/E , mho) of the filament signals the start of the deposition process. The sustained growth is observed by a steady increase in the filament current. The temperature of filament is kept constant at all values of the filament current by appropriate decrease in the filament voltage.

As deposition progresses, the diameter of the filament increases, resulting in increasing heat loss due to radiation from the filament. This leads

to a progressive decrease in the power supplied to heat the feed. The external heating of the feed is subsequently discontinued and air-cooling is resorted to during the final stages of the deposition process. The process is discontinued by shutting-off power to the filament and the assembly is opened under a protective atmosphere. The top flange carrying the crystal bar was carefully lifted, and immersed in cold water bath, washed thoroughly and preserved. The residual feed, enriched with respect to niobium content, can be reused for further refining operation after suitable treatment.

Results

Online monitoring of deposition

The on-line monitoring of the weight of the zirconium crystal bar and its diameter, at any time during the process, is determined by the following empirical equations :

$$W \text{ (gm)} = d \rho L^2(I/E)$$

and

$$D \text{ (mm)} = [1.27 \times 10^2 L \rho (I/E)]^{1/2}$$

where :
d - density (g/cm^3)
L - filament length (cm)
 ρ - resistivity (ohms-cm)
 I/E - conductivity (mho)

The chartless recorder can be programmed to display either the weight or the diameter, or both, along with the conductivity.

Growth of crystal bar as a function of time

Table 1 indicates the impurity levels in the scrap feed as well as the crystal bar obtained. As can be seen, the niobium content has significantly reduced to around 0.1 wt% from an average scrap concentration of 2.5 wt% Nb. Figure 4 shows the typical growth pattern (I/E) of the crystal bar as a function of temperature and time. It is clearly seen from the figure that the growth pattern is sluggish in initial phase of the deposition process. However, the growth pattern

Table-1 : Impurity levels in feed and crystal bar zirconium

Extent of Purification		
Element	Feed (ppm)	Crystal Bar (ppm)
O	>2000	<300
N	300	<30
C	130	<100
H	100	<25
Fe	80	<50
Al	30	<25
Hf	170	100
Nb	2.5wt%	1000-1200
Zr	Balance	Balance

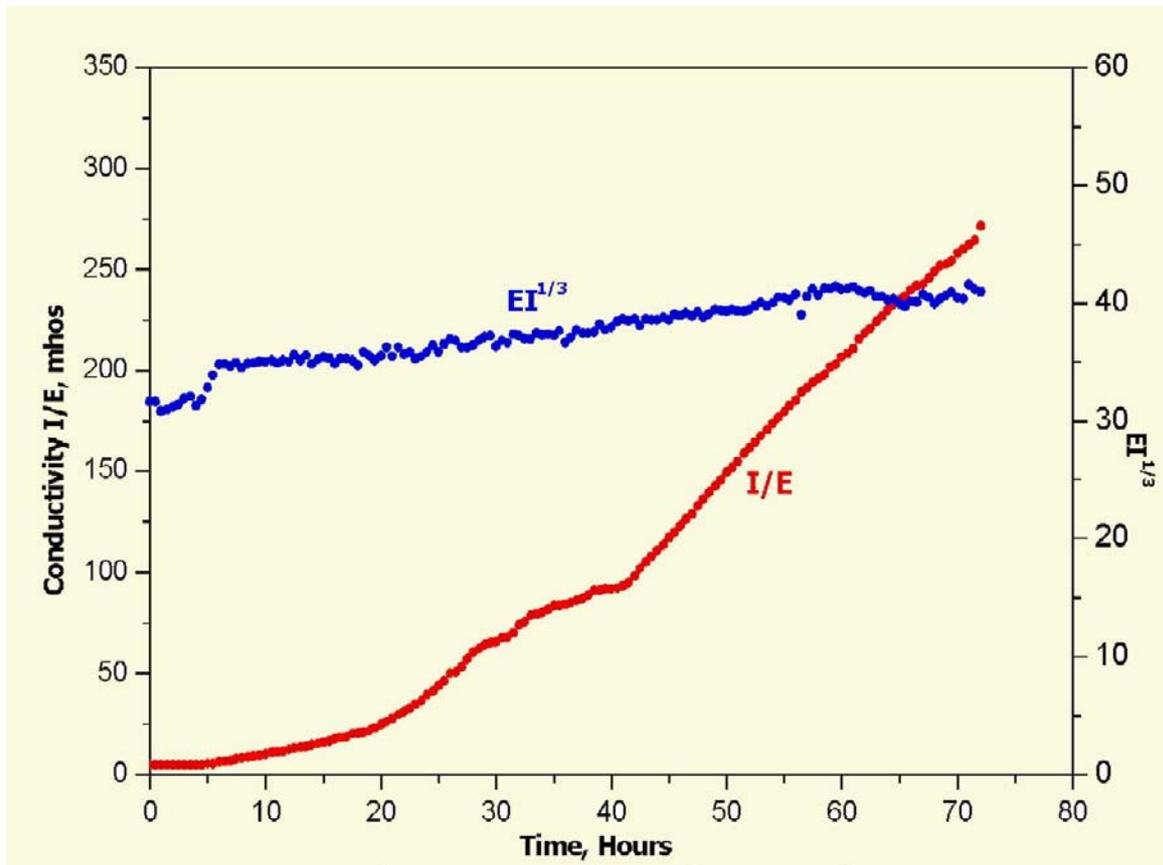


Fig.3 Filament growth as a function of time

shows a steady increase after a period of about 45h. The increase in I/E ratio was found to be sluggish after about 72 hours of the process owing, probably, to the condensation of iodine/iodine vapours on the cooler parts of the chamber like quartz window as well as the water-cooled electrode flanges. It is also clear from the figure that the value of $EI^{1/3}$ was almost constant during the deposition run.

It is possible to grow a crystal bar of 16 mm diameter at a feed temperature of 300-350°C and filament temperature of 1150-1300°C. Figure 5 shows the magnified portion of a section of the crystal bar. The chemical analysis and hardness of the feed as well as crystal bar are given in Table 1. Experimental evidence indicate that the purity of the crystal bar depends on factors, such as (i) system pressure (i.e. high vacuum),



Fig.4 Macrostructure of a section of crystal bar zirconium



Fig.5: Crystal bar zirconium with the retort cover flange (upside down)

(ii) chemical quality of the crude metal/alloy scrap and (iii) precise control of the feed and filament temperatures. The contamination of oxygen, nitrogen and carbon arises from leaks and ineffective vacuum pumping practice. Precise temperature control ensures that the impurity concentrations fall within a narrow range. The type of pretreatment adopted is likely to affect the reactivity of the feed metal or alloy scrap.

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INTELLIGENT ETHERNET MODULE FOR DISTRIBUTED CONTROL SYSTEMS ON STANDARD EC BUS FOR REACTOR C & I

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Introduction

Network based multiple nodes class B system requires a reliable network. A failure of network will endanger system failure, as system will not be able to exchange the control information. Hence, redundant networks are to be used to ensure higher reliability of nodes interconnectivity. We started with EC bus based Non-Buffered Ethernet Module (NBEM) board development for Ethernet network interface. In order to get optimum codes for co-processor and hardware design and testing, Intelligent Ethernet Module (IEM) board was developed.

A single node can install multiple IEM cards for connecting to multiple networks. Thus IEM board gives redundancy up to board level. IEM have onboard 80186 that relieves host 8086 of implementing protocol stack as well. IEM has

been used in RRS and DPHS-PCS system in TAPS 3&4 and is running successfully. Compared to usage of COTS as advocated since long in reactor critical C & I, the fundamental development of this type does give confidence and validation to account for each and every bit flow. The longevity and repair capability to maintain plant C & I is enhanced due to in house design. Efforts are being to upgrade the same for 100 Mbps. The board has undergone standard climatic tests at ECIL, which has taken the technology.

Why Ethernet?

Ethernet technology was adopted for standardisation by the LAN standards committee of the Institute of Electrical and Electronics Engineers (IEEE 802). The IEEE standard was first published in 1985, with the formal title of

"IEEE 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications." The International Organisation has since adopted the IEEE standard for Standardisation (ISO), which makes it a worldwide networking standard. From the time of the first Ethernet standard, the specifications and the rights to build Ethernet technology have been made easily available to anyone. This openness, combined with the ease of use and robustness of the Ethernet system, resulted in a large Ethernet market and is another reason why Ethernet is so widely implemented in the computer industry.

This is why we started development of Ethernet boards for EC bus made by Reactor Control Division, BARC. We started our development with Non Buffered Ethernet Module (NBEM). This card helped us to have validated and optimised code for LAN coprocessor 82586 for final design. This card was not suitable for redundant network, because EC bus cannot accommodate more than one NBEM card and the card does not provide multiple network connections.

NBEM was using bus DMA to transfer data from host to co-processor. Hence, Intelligent Ethernet Module (IEM) board was developed. Though IEM also does not provide multiple network connections, multiple IEM cards can be used on EC bus. This method was chosen because it allows online replacement of faulty IEM card, where another healthy redundant IEM card takes network load. Redundant IEM can also be used during normal operation thereby increasing network bandwidth. IEM card has higher performance and functional capability than NBEM card. Host is relieved of implementation of protocol stack, as it will be taken care of by on-board processor 80186. A single node can install multiple IEM cards for connecting to multiple networks. Thus, network redundancy, fault tolerance and availability can be provided from having different physical media and different network interface, each running the same or different protocol stack.

Description of Intelligent Ethernet Module (IEM) on Standard EC Bus

IEM is based on RCnD made EC bus. It sits as slave board on EC bus. Host 8086 board is master and access IEM as memory device, which is provided by DPRAM. An IO port is also provided for resetting IEM using software function. Remaining resources on IEM are not accessible to host.

The card will be used as network interface card for thick (10BASE5) / twisted pair (10BASE-T) Ethernet applications for single or redundant networks. On board transceivers gives direct connection to twisted pair medium through RJ45 connectors. AUI port is always active; jumper settings select UTP interface. The card provides only one interface at a time. AUI port should be left open if UTP is used. Multiple numbers of cards can be used to provide multiple networks for redundancy.

Fig 1. shows the block diagram of IEM board.

Board features

- Provides interface for IEEE 802.3 10BASE5 and 10BASET applications.
- Intelligence provided by on board 16-bit microprocessor 80186. Thus, protocol stack is run by 80186, relieving host processor of doing communication task.
- Interprocessor communication between host CPU and 80186 is through DPRAM.
- Multiple numbers of cards can be used to provide multiple networks for redundancy.
- Board features following resources – 256 KB EPROM, 512 KB SRAM, one serial port, one ASCII display & 16-bit watchdog timer.

These resources are not available to host CPU. DPRAM is the only interface given to host CPU.

- Three ports are provided – AUI port – for 10BASE5, connected to external transceiver using AUI cable. UTP port – for 10BASET, connected to twisted pair cable. RS232 port – for point-to-point serial communication.

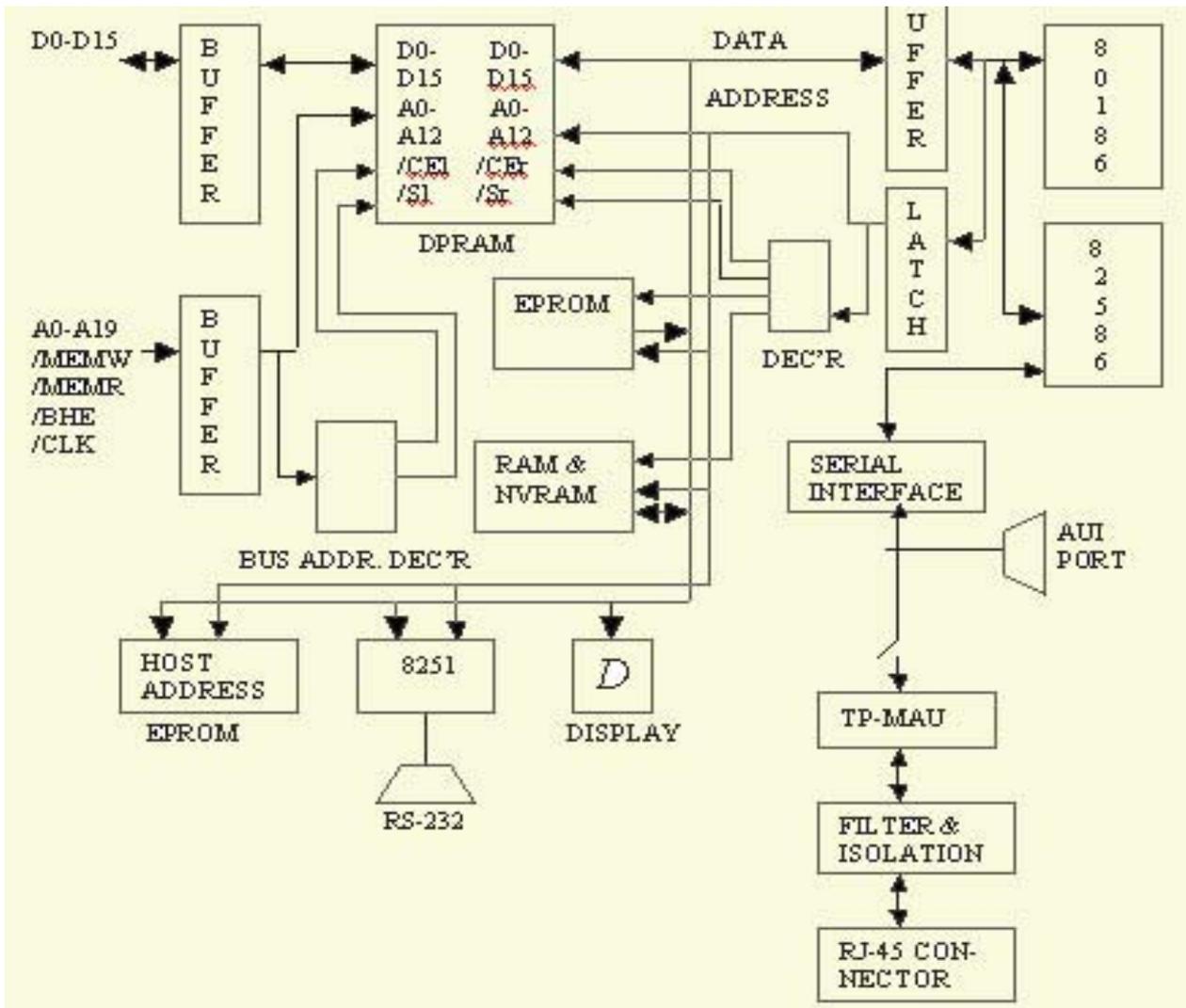


Fig.1 Block diagram of IEM EC bus board

- Jumpers are used to connect Ethernet signals to on-board twisted pair MAU. But, AUI port should be left open, as these signals are always coming on AUI port.
- LED indications are provided with purpose as described below :

TX – indicates board is transmitting frame.
 RX – indicates board is receiving frame.
 CDT – indicates collision has occurred on cable.
 LNKST – indicates link status for twisted pair cable.
 RXPOL - indicates polarity of signal received on twisted pair cable.
 SYSOK – driven by software to indicate proper functioning, watchdog timeout makes this signal inactive.

Timing Measurement to Establish Distributed Control System (DCS) Dead Time

An experimental setup was made to find delay between nodes communicating on Ethernet using IEM. Fig. 2 shows the setup.

Analog input is scanned by Input node; sent to output through intermediate node. At output, analog signal is reconstructed to determine the delay. TEKTRONIX AFG310 Function generator is used for signal source. Ramp signal of 10 Hz and 0-5 V p-p is fed to channel one of ADA12 card in Input Node. Output node outputs on first channel of ISOCTX card. This output is terminated with 100 Ω to produce 0.4 – 2.0 V, corresponding to 0-100 % ISOCTX output. ISOCTX 0% = 4 mA & 100% = 20mA.

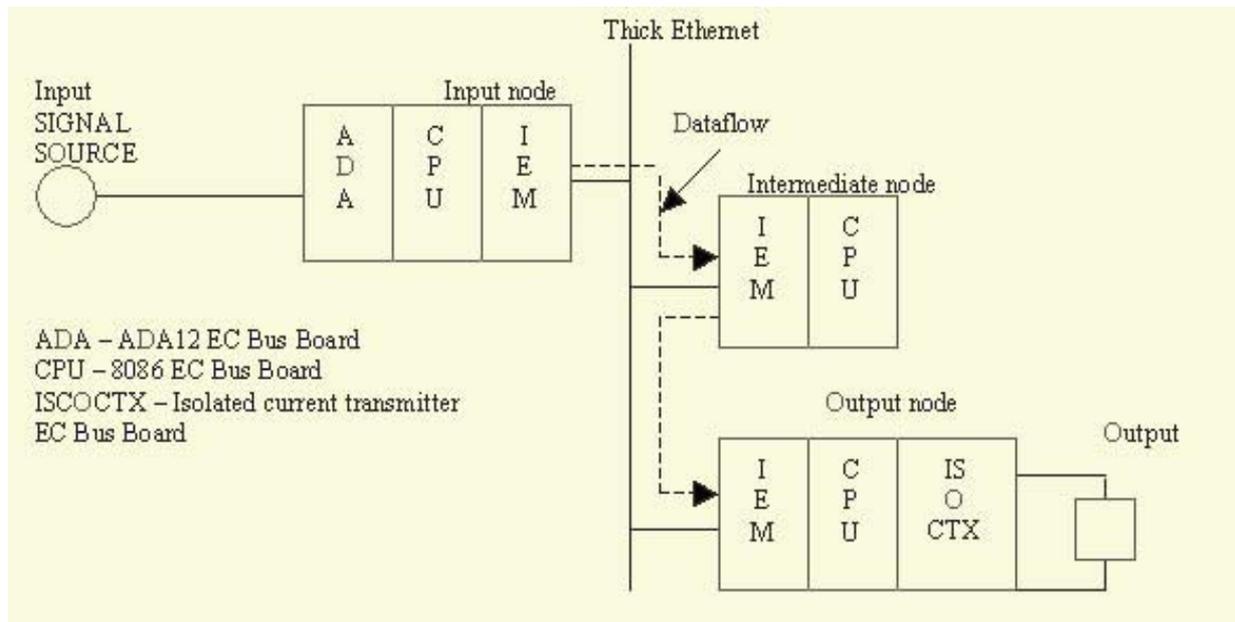


Fig.2 Data flow between signal source and output



Dacn0566 (2560x1920x24 jpeg)

Delay between input and output signal measured was around 25ms. Many factors contribute to the delay, such as acquisition time, time to write/read from DPRAM by host 8086 and 80186 (on IEM), time taken by MAC driver, actual transmission time on network, etc.

Later, various timing measurements are carried to determine these individual timings. The round trip time, i.e. time take by MAC driver, between

sending and receiving back the packet, is shown in following table.

Packet size (Bytes)	Time taken (ms)
256	10.2
512	13.0
768	15.5
1024	20.0
1280	24.0
1500	29.0

Conclusion

The IEM board has been successfully fabricated and tested to meet all its requirements. Failure rate of this board is calculated and found to be 23.57 failures/10⁶ hours. It is being used in RRS and DPHS-PCS for TAPP 3&4 units. So far, its performance is satisfactory and it is working smoothly. Design details and all other documents had been handed over to ECIL for fabrication and

supply of these boards to NPCIL for above-mentioned system for TAPP 3&4. ECIL has taken up this technology for industrialisation in NPP. We have finished documenting the IEM User manual, which give details about the board hardware, MAC driver and development tools. The product is complete with standard TCP/IP stacks and is being used in TAPP.

REACTIVITY CONTROL MECHANISMS FOR TAPP-4

BARC and NPCIL had entered into an MoU for design and development of reactivity control mechanisms for adjuster rods, control rods and shut-off rods for TAPP-3&4. This development work was taken up at Division of Remote Handling & Robotics (DRHR), BARC.

Reactivity control mechanisms of TAPP-3&4 are electromagnetic type, having sheave rope arrangement. However, the design is significantly different from that used in Dhruva and 220 MWe PHWRs.

The control mechanisms for TAPP-3&4 are designed with a number of advanced features, like modular construction giving ease of maintenance, 90% free fall for shut-off rod/control rods giving high reliability and consistent rod drop performance, on-line test facility for shut-off rods to ensure rod availability on demand while reactor is under operation, and partial release and re-arresting of control rods for reactor stepback function.

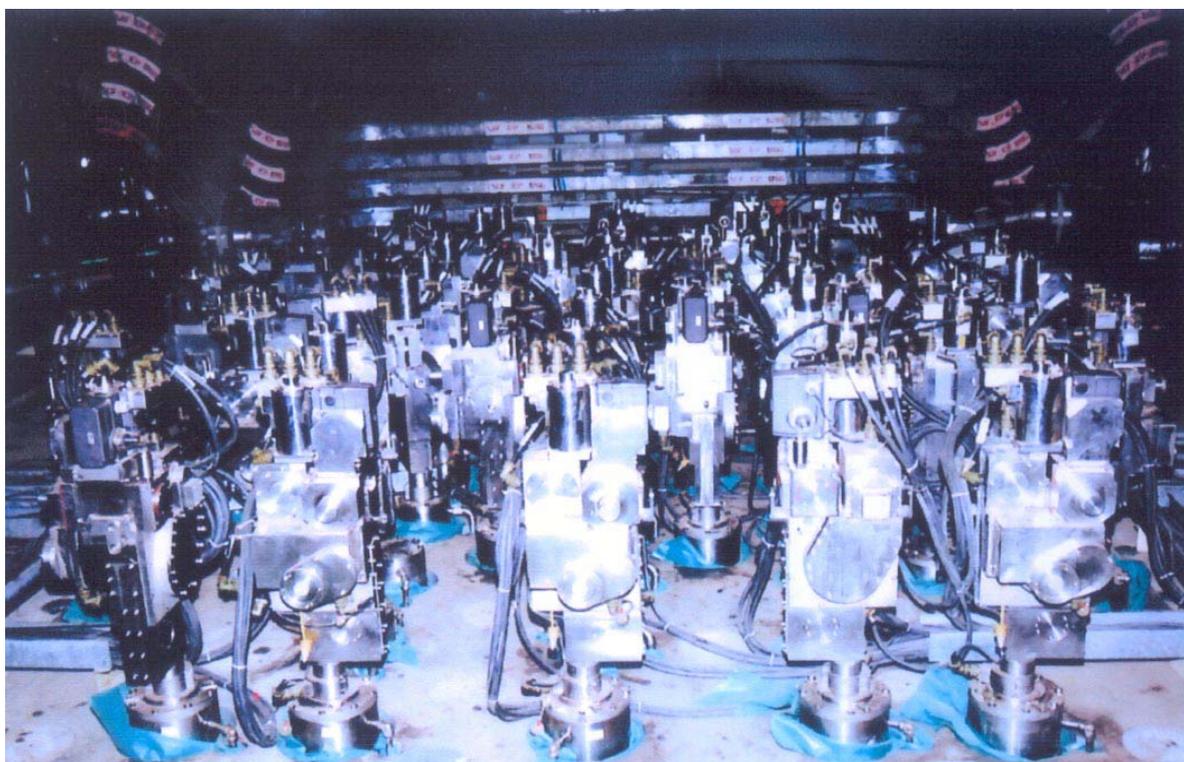


Fig. 1 Photograph showing reactivity control mechanisms on deck plate of TAPP-4 reactor

TAPP-3&4 utilises 28 shut-off rods (total rod worth 72 mk), 4 control rods (total rod worth 4 mk) and 17 adjuster rods (total rod worth 17 mk), i.e., total of 49 drive mechanisms per unit. Shut-off rod drive mechanism (28 nos.) forms part of the shut down system SDS#1. The principal purpose of this system is to provide shut down capability to the reactor under normal as well as under any undesirable condition including prolonged shut down. Control rod drive mechanism (4 nos.) forms part of reactor regulating system. These are used for rapid power reduction if required (reactor step-back function), to bring average zonal compartment level into normal operating range and to compensate for reactivity gain following transition from full power to hot standby condition. Adjuster rod drive mechanism (17 nos.) form part of reactor regulating system. These are used for flattening of neutron flux distribution, Xenon override and reactivity shim (during extended fuelling machine outages).

In case of shut-off rod/control rod, total rod travel is 6600 mm, while that for adjuster rod it is 5900 mm. Weight of absorber rod for shut-off rod/control rod is about 50 kgs., while that for adjuster rod it is about 15 kgs. Rod withdrawal time for shut-off rod/control rod at maximum speed is 150 ± 10 sec, while that for adjuster rod (at maximum speed), it is 70 ± 10 sec. Reactivity addition rate is limited to 0.33 mmk/sec for shut-off rods, while it is limited to 0.10 mk/sec for control rods/adjuster rods.

The prototype control mechanisms were manufactured, assembled and subjected to design qualification and life cycle testing on a full-scale test set up at BARC. Life cycle testing for shut-off rod drive mechanism was carried out with tank water temperature maintained at 80°C and with elevated temperature of 65°C at mechanism location. Prototype shut-off rod drive mechanism was tested for full drop for more than 6000 cycles and this was also tested for on-line testing for more than 3000 cycles (rod was released for three times in one cycle, establishing

on-line testing for more than 9000 times). The prototype control rod drive mechanism was tested for partial release tests (for 48% travel) for more than 5000 cycles. The prototype adjuster rod drive mechanism was tested for more than 8000 cycles (motorised up/down movement). The design was qualified based on satisfactory performance and life cycle testing of prototypes at BARC. All the design drawings (general assembly, sub-assembly and component level), technical specification, development activity-wise performance test reports and life cycle test reports were issued to NPCIL. As per the design and drawings supplied by DRHR, BARC manufacturing of total 120 drive units for reactor use was arranged by NPCIL. Manufacturing was done at M/s Godrej Ltd. and M/s Larsen & Tubro (60 drive units each).

The commissioning of all drive units for TAPP-4 reactor has been completed. Fig.1 shows control mechanisms installed on the thimble above deck plate elevation of TAPP-4 reactor.

BRNS SEMINAR-CUM- WORKSHOP ON “MATERIALS CHARACTERISATION AND SURFACE MODIFICATION IN RESEARCH AND INDUSTRY USING ION ACCELERATORS (MCIA)”

The Surface and Profile Measurement Laboratory at National Centre for Compositional Characterisation of Materials (NCCCM), Hyderabad, has been engaged in developing Ion Beam Methods for advanced materials characterisation using the 3 MV Tandem Accelerator being one of the major facilities. This facility has solved several surface related

problems in surface compositional characterisation and depth distributions of light elements to the department and to different end users from industry and research. To spread the awareness of the ion beam analytical techniques using accelerators to a wider network of research groups in the country, it was decided to organise a seminar and workshop on "Materials Characterisation and Surface Modification in Research and Industry using Ion Accelerators (MCIA)". BRNS had agreed to sponsor this event at the CCCM during February 9-11, 2005.

This seminar was planned to provide a forum for interaction and exchange of information and ideas among the researchers and industry in finding solutions to surface related problems. Eminent scientists from different ion beam laboratories were requested to give invited lectures on a variety of topics in materials characterisation and surface modifications using ion beams.

The Seminar cum workshop was inaugurated by Dr S. Banerjee, Director, BARC, on February 9, 2005 in the lecture hall of the Centre, with Dr J.Arunachlam, Head, CCCM, inviting the



Dr S. Banerjee, Director, BARC, delivering the inaugural address at the seminar

guests. The theme of the Seminar was introduced by Dr Tulsi Mukherjee, followed by an overview of the scenario of the accelerators for basic and applied research by Dr S. Kailas.



Seen on the dais from left to right are : Dr V.S. Raju, Convener, Organising Committee, Dr S. Kailas, Chairman, Organising Committee, Dr S. Banerjee, Director, BARC & Chairman, Advisory Committee, and Dr T. Mukherjee, Member, Advisory Committee



Participants seen at the BRNS Seminar-cum-Workshop

Dr S. Banerjee, Director, BARC, released the Seminar program book and delivered the keynote address on "Ion Beam Analysis -an Outline". He has stressed the importance of Ion Beam Analysis and materials modification to meet the futuristic challenges ahead. Dr V.S. Raju, Convener of the seminar proposed the vote of thanks. There were a total of 170 guests for the inauguration including 85 participants coming from various universities and research institutions.

Scientists from different national centres and laboratories gave 14 invited lectures on various related topics. The topics included characterisation and ion beam modification at micro and macro dimensions and upcoming technologies. They also included topics on Trace elements in clinical practice and Biological applications of Ion Beams.

All the participants were shown two of the IBA experiments involving nuclear reaction analysis and backscattering spectrometry used as analytical tools by the group headed by Mr Sanjiv Kumar and Dr J.V. Ramana. All the participants

were issued a participation certificate along with a CD containing the lecture materials as presented. The participants had good interaction with the facilities available at CCCM. The interactive session with the participants on the 3rd day reflected their enthusiasm for further interactions with the Centre's facilities.

Prof. V.N. Boraskar's briefing on UGC DAE CSR's facilities at different locations and Dr Mukherjee's talk on the BRNS research projects were very informative to the participants.

A meeting of the invited speakers and senior members of audience was held on the second day afternoon. They were of the opinion that this seminar, for the first time, brought together specialists from most of the ion beam laboratories and covered topics from diverse fields. It was also felt that there is a need for mootng a forum among the users of ion beams in identifying new areas of research and address some of the emerging fields. It was suggested that the theme of MCIA should be continued in the future with seminars /symposia held annually or biennially.

भारत के राष्ट्रपति द्वारा भाभा परमाणु अनुसंधान केंद्र के निदेशक, पद्मश्री से सम्मानित

PRESIDENT OF INDIA HONOURS DIRECTOR, BARC, WITH PADMA SHRI



डॉ. श्रीकुमार बॅनर्जी, भाभा परमाणु अनुसंधान केंद्र के निदेशक को भौतिक धातुकी एवं पदार्थ विज्ञान के क्षेत्र में विशिष्ट योगदान के लिए भारत के राष्ट्रपति डॉ. अब्दुल जे. कलाम के द्वारा पद्मश्री पुरस्कार से सम्मानित किया गया। डॉ. बॅनर्जी ने ज़िरकोनियम एवं टाइटेनियम मिश्रण पर आधारित धातुकी पर मूल अनुसंधान किया और विभिन्न नाभिकीय रिएक्टर घटकों की थर्मो - मेकेनिकल ट्रीटमेंट विधि के विकास में, उनके प्रयोग पर कार्य किया। इनका कार्य नाभिकीय रिएक्टरों में स्ट्रक्चरल पदार्थों की रेडियेशन स्थिरता के विश्लेषण का आधार प्रदान करता है।

डॉ. बॅनर्जी एवं इनके सहकर्मियों का शेप मेमोरी धातु के विकास तथा उनका ताप शिंकेबल कपलिंग्स में प्रयोग, हलके लडाक् विमान परियोजना में व्यापक रूप से प्रयोग हो रहा है।

एक प्रतिष्ठित वैज्ञानिक, डॉ. बॅनर्जी को कई पुरस्कारों से सम्मानित किया जा चुका है। ये कई प्रमुख अकादमियों के सम्मानित सदस्य भी हैं।

डॉ. बॅनर्जी को मार्च 29, 2005 को राष्ट्रपति भवन के अतिविशिष्ट समारोह में कई प्रतिष्ठित व्यक्तियों तथा उच्च पदाधिकारियों की उपस्थिति में पद्मश्री पुरस्कार से सम्मानित किया गया।

Dr Srikumar Banerjee, Director, BARC, was honoured by the President of India, Dr Abdul J. Kalam, with Padma Shri in recognition of his contributions in the field of physical metallurgy and materials science. Dr Banerjee has contributed extensively in basic research on metallurgy of zirconium and titanium based alloys and their applications in the development of thermo-mechanical treatments for processing several nuclear reactor components. His work provides a basis for analysing the radiation stability of structural materials in nuclear reactors.

The contributions of Dr Banerjee and his colleagues with regard to the development of shape memory alloys and their applications in heat shrinkable couplings are finding extensive applications in the light combat aircraft project.

A distinguished scientist, Dr Banerjee has been the recipient of many awards and honours. He is also Fellow of many prestigious Academies.

The Padma Shri was awarded to Dr Banerjee at a glittering function at Rashtrapati Bhavan on March 29, 2005, in the presence of many luminaries and top government officials.

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