

# BARC

## NEWSLETTER

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## CONTROL SYSTEM FOR BARC-TIFR SUPERCONDUCTING LINAC BOOSTER

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Electronics Division, BARC, has been working in the area of control systems for medium and high energy accelerators for more than a decade. During this period, Accelerator control systems for FOTIA (Folded Tandem Ion Accelerator) at BARC and for the Industrial Accelerator at BRIT were built. The Accelerator Control System for the LINAC is the most recent development. Also, a large number of CAMAC units were developed in-house for use in Data Acquisition Systems and Accelerator Control Systems. Additionally, a number of RF systems like Resonator Controller, RF Power Amplifiers, RF System for Dynamic Phase Generation, etc. were developed during the IX<sup>th</sup> plan term.

The LINAC Control System has been developed for the control and operation of the Linear Accelerator being installed at Tata Institute of Fundamental Research. This is a Distributed Control System (DCS). This consists of identical, geometrically distributed Resonator Control nodes, which reflect the modular nature of the LINAC.

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BARC scientists honoured

## Resonator Control and Information System

The major components of this system are the RF Electronics, CAMAC Systems and the Control & Information Systems. Fig.1 shows different devices placed along the LINAC beam line.

Each node of the DCS is referred to as a Local Control Station (LCS). One LCS controls two cryostat modules. The Local Control Stations are connected over a LAN to the Main Control Station (MCS). The MCS has two PCs which are kept in the Main Control Room. The schematic for each of the local control station is given in Fig.2, showing the Control Computer which is a PC, the

Resonator Controllers and RF Power Amplifiers with the CAMAC front-end.

The three components of the LINAC control System are explained below.

## RF System

The complete RF system for the LINAC can be broadly divided into three parts: RF for the superconducting resonators, RF for the normal conducting resonators and the RF system for the overall reference phase generation. A block diagram showing the various RF systems is given in Fig.3.

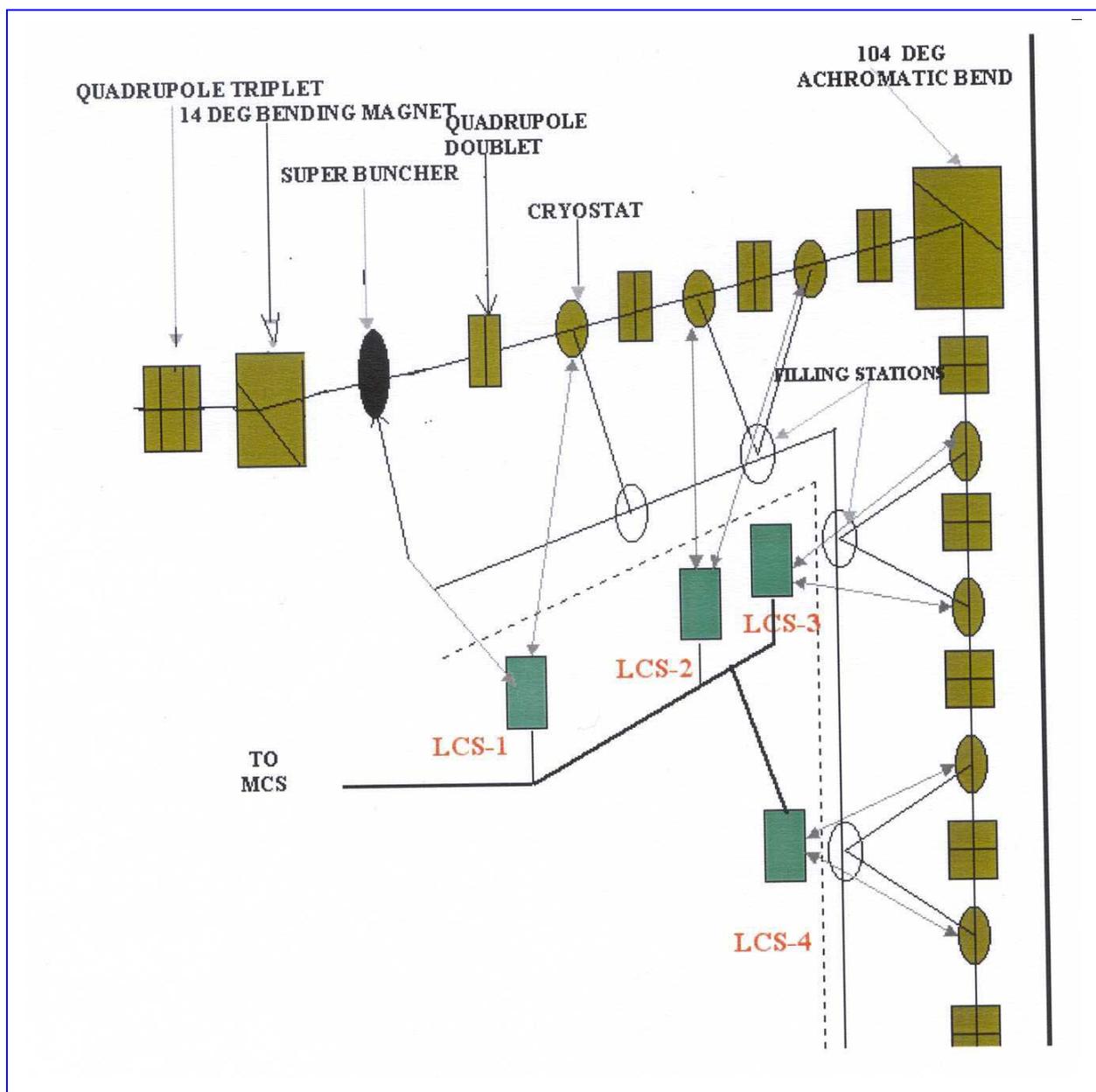


Fig.1 : Layout of the LINAC

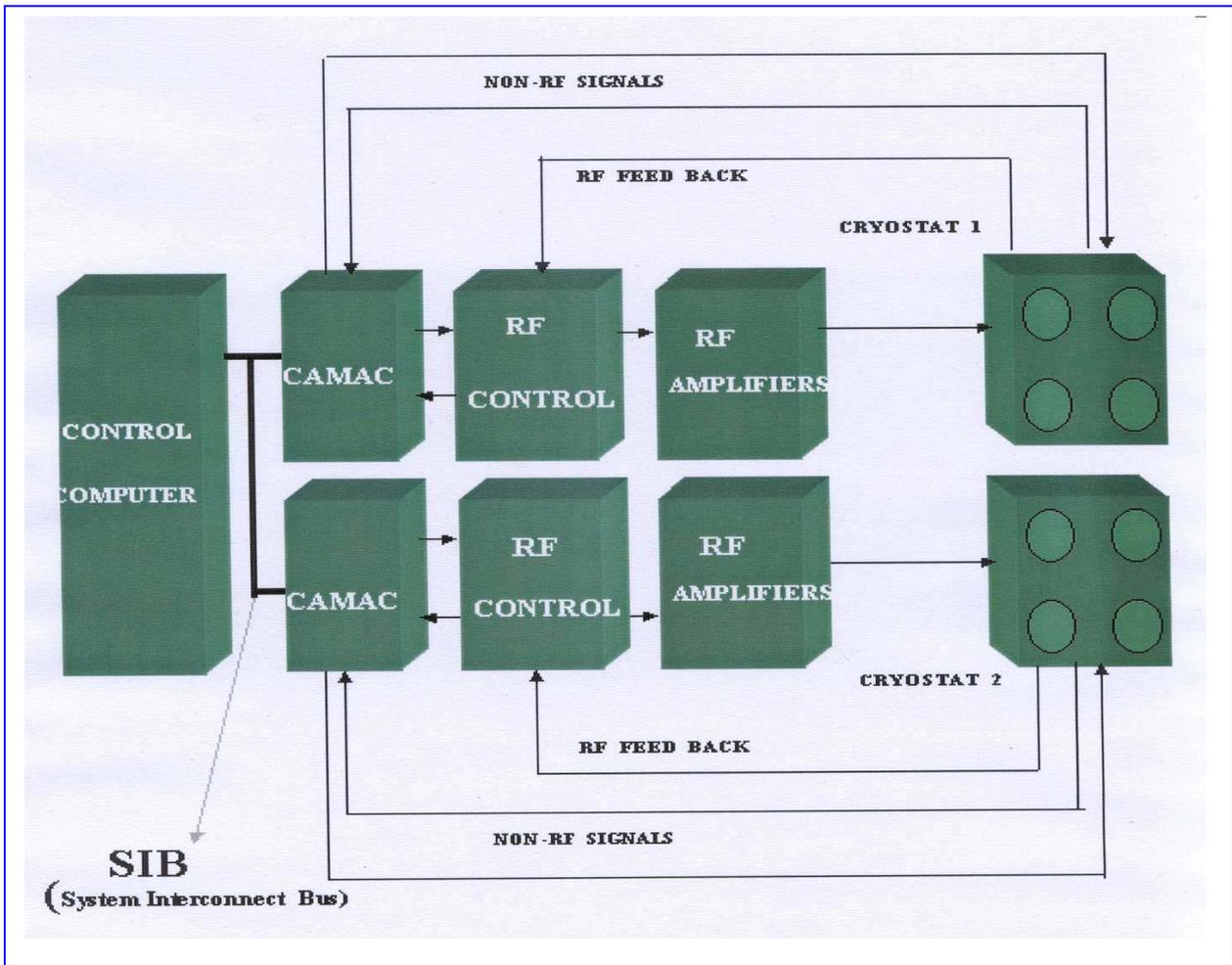


Fig.2 : The local control station

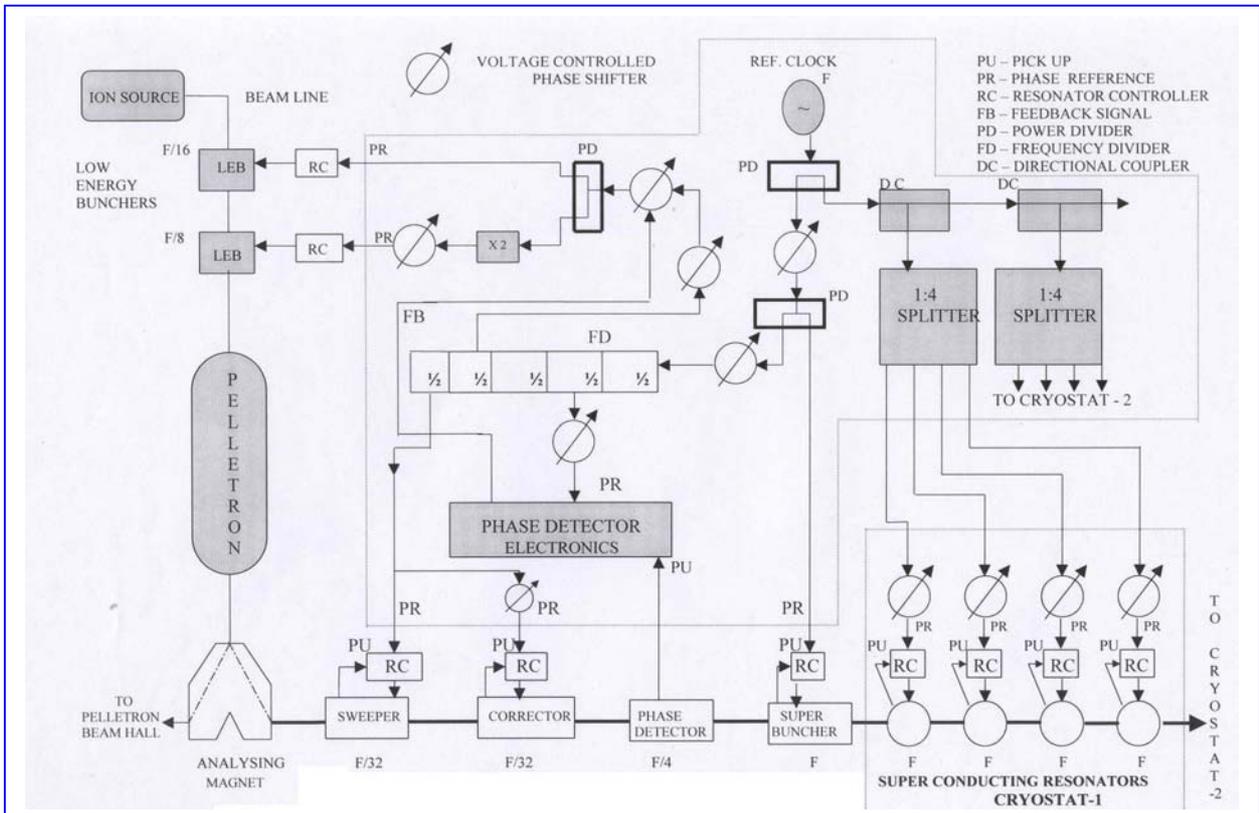


Fig. 3: Block diagram of the RF system for the LINAC booster

### ***RF system for the super-conducting resonators***

The majority of the resonators in the linac are super-conducting. These include one resonator acting as super-buncher and 28 resonators in seven cryostats for acceleration. The centre-frequency of these quarter wave type resonators is 150MHz. All these resonators sustain RF fields at the same frequency but independently settable phases. The job of the RF system is to retain the phase and amplitude stability in the presence of disturbances, primarily in the form of centre frequency changes of these resonators. There are two main components in the RF system for these resonators: Resonator controller and RF power amplifier. The resonator controller performs all the low level signal processing and synthesizes the appropriate drive signal for the amplifier to retain amplitude and phase stability with respect to suitable references. Fig.4 gives a

block diagram of the resonator controller implemented for the BARC-TIFR resonators. It is based on the principle of supplying the required quadrature power as the resonator centre frequency changes. The incident power requirement in this control strategy is given by the product of the peak frequency excursion and energy content of the resonator, under optimal coupling condition. This control strategy has been found very suitable for the BARC-TIFR resonators that have very small centre-frequency excursions. Power requirement for control in these resonators is only of the order of 100watts at an operating field of 3 MV/m. Resonator controllers based on above strategy have been successfully tested at TIFR on numerous occasions and have now been installed in the first phase of the linac, comprising of super-buncher and three cryostat modules.

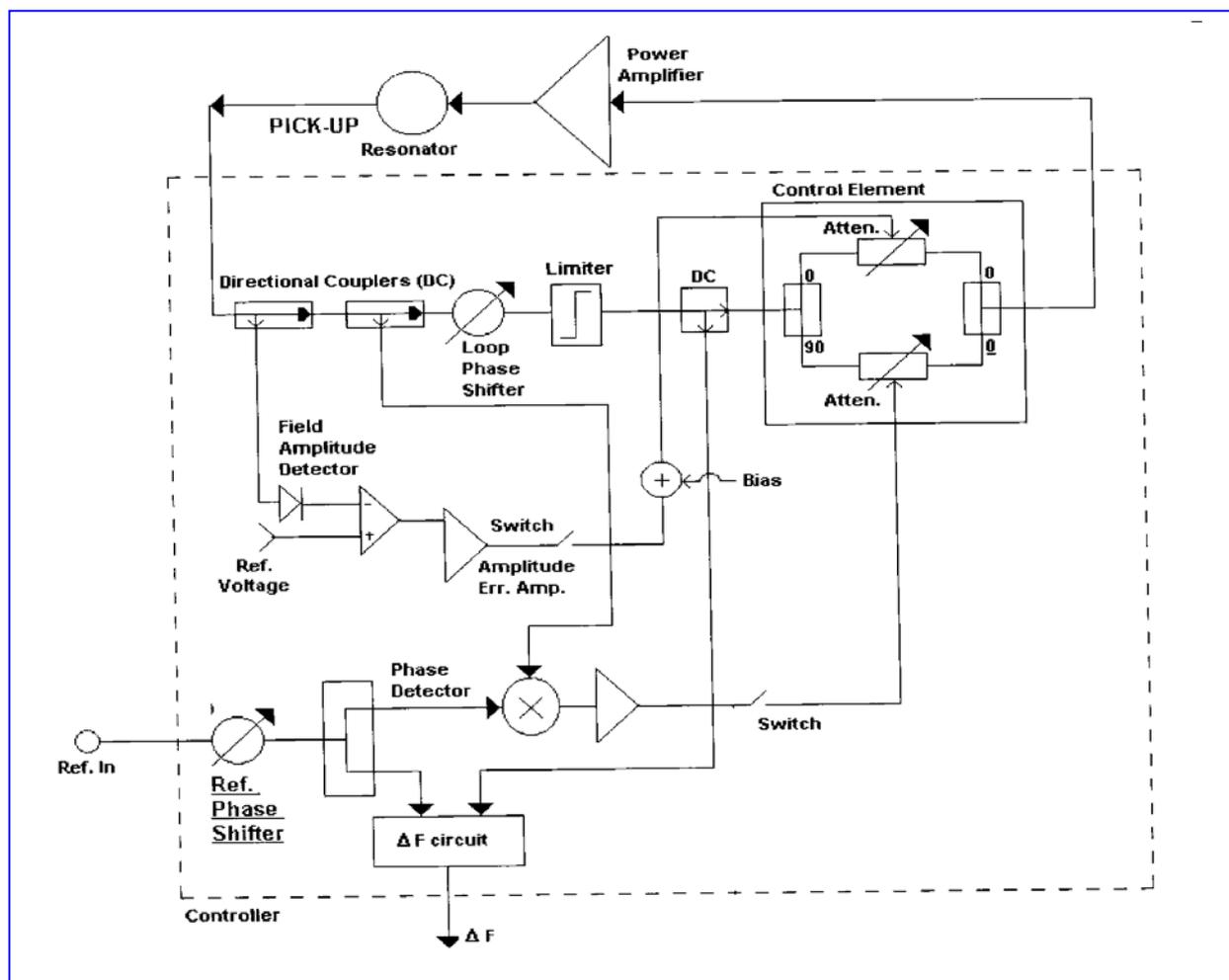


Fig.4 : Resonator Controller

Resonator controller is interfaced to PC via CAMAC hardware. All the low frequency analog and digital input and output signals of the controller are made compatible with the corresponding signals from CAMAC modules.

The development of the RF power amplifier for this project has been a combined effort at NSC, New Delhi, BARC-TIFR and BEL, Bangalore. Initial design was carried out at NSC, New Delhi, that was made suitable for the BARC-TIFR resonators jointly by BARC and TIFR with subsequent production carried out at BEL. 31 units have been supplied by BEL to meet the requirements of the project.

### ***RF systems for the normal-conducting resonators***

Normal-conducting resonators are used to suitably condition the beam for injection into the LINAC. The two low energy bunchers at the entry of the pelletron bunch the ion beam to about one nano-second level. These bunchers operate at  $1/16$  and  $1/8$  of the LINAC frequency. The sweeper and the corrector remove the DC background from the bunched beam. These resonators operate at  $1/32$  of the LINAC frequency. The controllers for bunchers are already in operation. Since these use old electronics having many critical components that are no more available now, the same are being redesigned along with controllers for sweeper and corrector.

### ***RF system for the dynamic reference phase generation***

This system is needed to retain the timing synchronization of beam pulses with the RF fields in the super-conducting resonators under the influence of time of flight variations through the pelletron. This system is built around a phase detector resonator which produces an RF signal in synchronization with the beam. This RF signal is compared in phase with respect to the one present in super-conducting resonators and any deviation is corrected by changing the reference

phase of the low energy bunchers. There are two different approaches for the design of this system. Of these, a system based on the simpler approach has been installed at TIFR and the same has worked very well. This design does not take care of the variation in the centre frequency of the phase detector resonator. In near future, this system will be upgraded with a more elaborate scheme which also takes care of the center frequency variation of the phase detector resonator. The design of the same is in progress.

## **CAMAC System**

Electronics Division, BARC, has developed and supplied a number of different CAMAC units to various organisations. These units are in use at FOTIA, Industrial Accelerator at Vashi, Pelletron at TIFR, etc. The CAMAC system consists of CAMAC crates, functional units like ADC, DAC, digital I/O units, stepper motor controllers, etc. The CAMAC crate controllers are connected to the PC via the SIB (System Interface Bus). Each of the LCS handles about 120 RF related parameters. The in-house developed CAMAC modules include 16 Channel Scanning ADC (12 bits resolution), 8 channel DAC (12 bits resolution), 48 bit digital I/O card and CC8 CAMAC crate controller cards. The dataway units supplied along with the crates are useful for trouble shooting. A CAMAC crate with a number of functional units serves one cryostat (module) containing four RF resonators. The RF systems are connected to the CAMAC modules via junction boxes.

A mini CAMAC crate, which can contain upto 13 CAMAC stations has been specifically fabricated for the LINAC and is likely to find use in other applications also. Each LCS will have two crates. About twenty CAMAC units are required per LCS. Technical know-how has been transferred to ECIL for the production of CAMAC Crate and Modules.

## **Control and Information System**

Each of the LCS consists of a PC connected to two CAMAC crates and connected to the MCS

and other LCS via a LAN as shown in Fig.5. Each of the LCS caters to 8 resonators. Each LCS consists of several threads for scanning of input parameters, communication with other LCS or MCS, etc. It is possible to connect to any LCS from any other LCS or MCS. The system has been designed as a web based system with each of the LCS serving as a web site. The system uses virtual panels for controls, with sliders and

accelerator buttons for analog output control and toggle buttons for digital output control. An LCS home-page is shown in Fig.6. This page shows the resonators data for one LCS along with control features (sliders, accelerator buttons, etc.) Two of the error signals have been digitised using in-house built digitisers (200 MHz) and displayed on the web page.

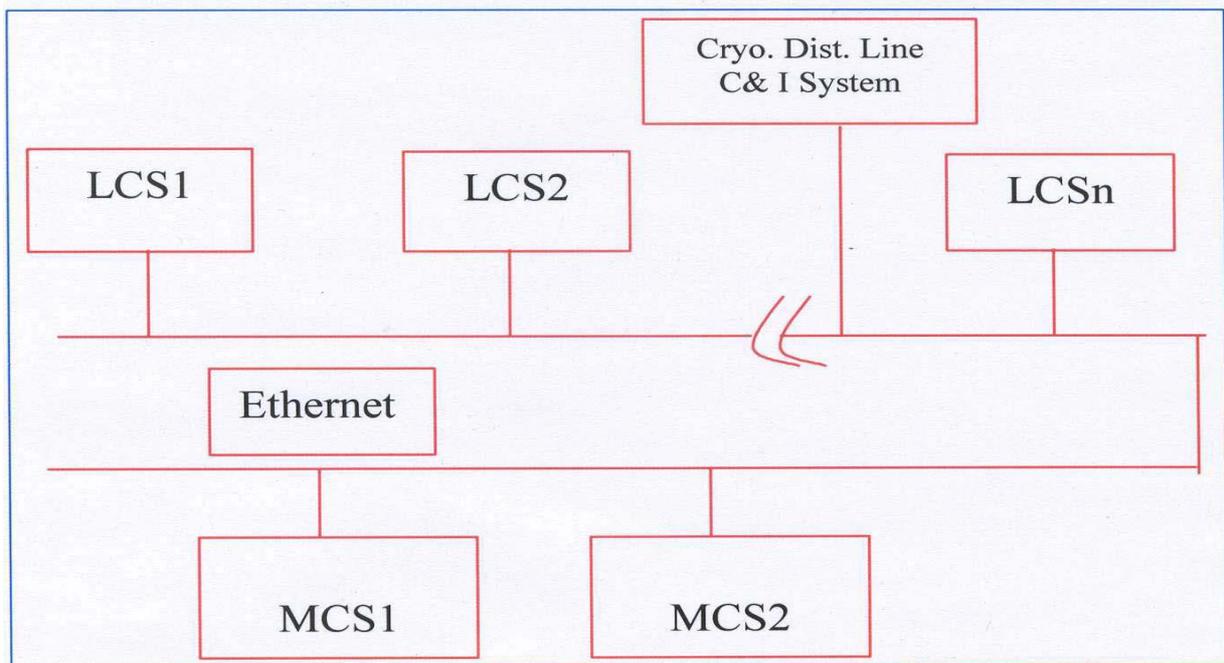


Fig.5 : System Architecture

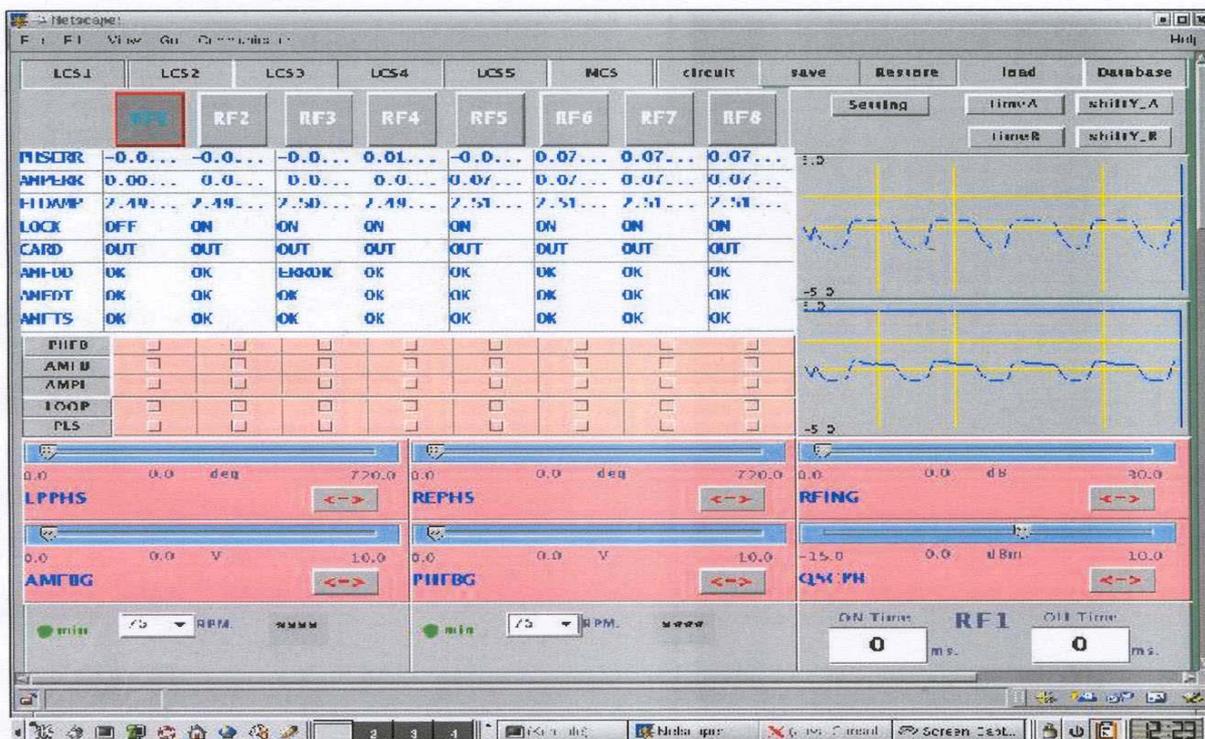


Fig. 6 : An LCS Home Page

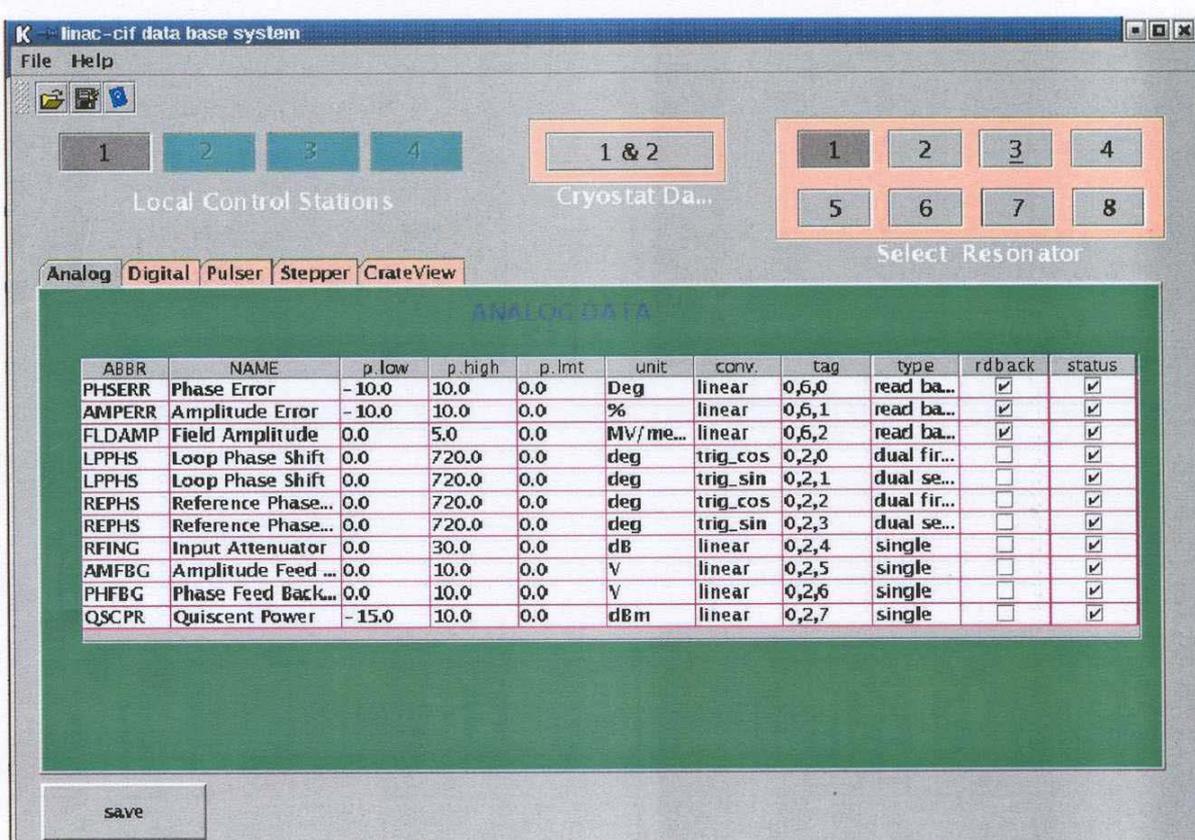


Fig. 7: The Database Facility

Also, a user-friendly database facility has been supported for channel descriptor modifications, as shown in Fig 7.

All the hardware for a single cryostat module is housed in a 19" rack. Fig.8 shows the various hardware units.

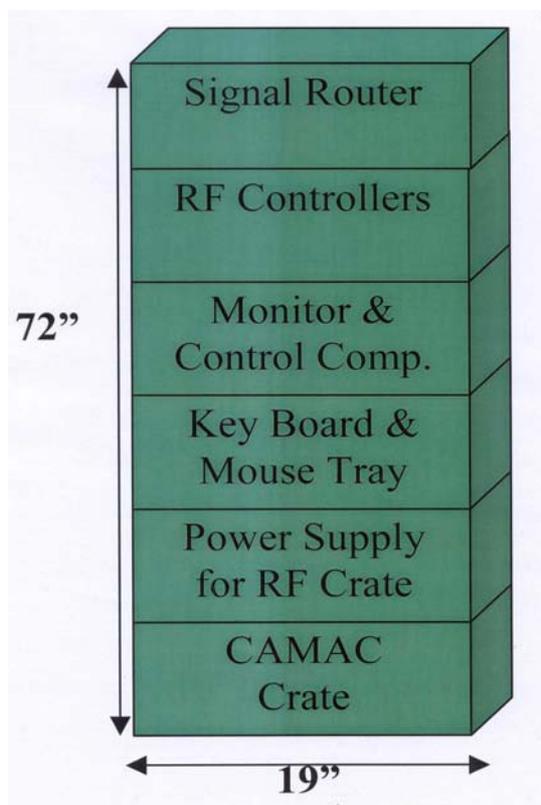


Fig. 8 : Control Instrumentation Housing

The Cryogenics Distribution Line Control and Information System will be one of the nodes of the DCS so that the web pages are available either on any of the LCS or MCS. This system will monitor liquid nitrogen and liquid helium levels in each cryostat and other related parameters like temperature and pressure and will facilitate liquid filling in the cryostat.

### Test Facility

A test facility has been set up to test the superconducting resonators.

This facility has all the necessary hardware and software for controlling one resonator. As shown in Fig.9, it comprises of one resonator controller interfaced to CAMAC modules via a signal router, the control computer with software to control one resonator. The RF output of the resonator controller is given as input to the RF Power Amplifier.

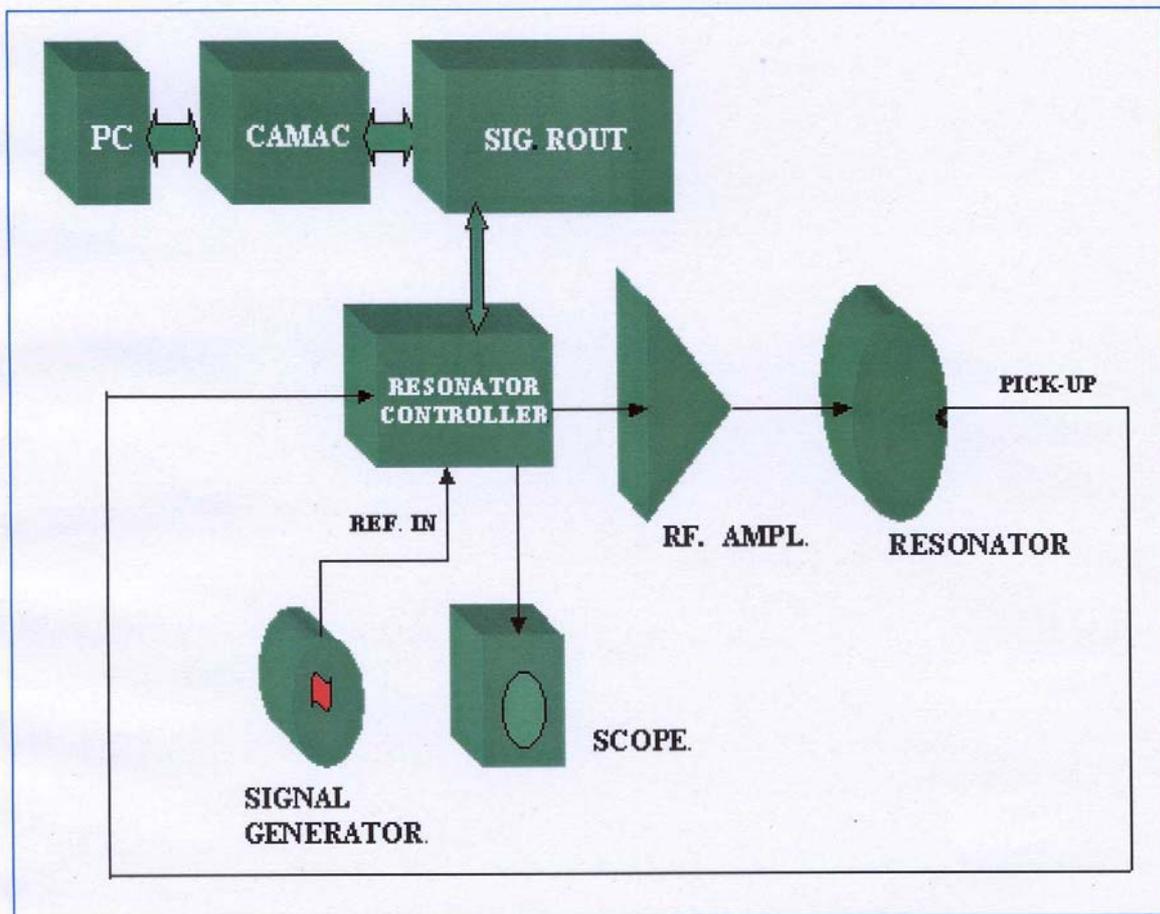


Fig. 9 : Test Facility

For testing the resonator, different modes of operation: ON/OFF/PULSING can be set via control computer. Duty cycle in the PULSING mode can be controlled with independent control for ON and OFF times. Incidentally, this facility can also be used to test the resonator controller as well. This facility has been extensively used in the lab for testing of the resonator controller modules.

### LINAC C&I Software

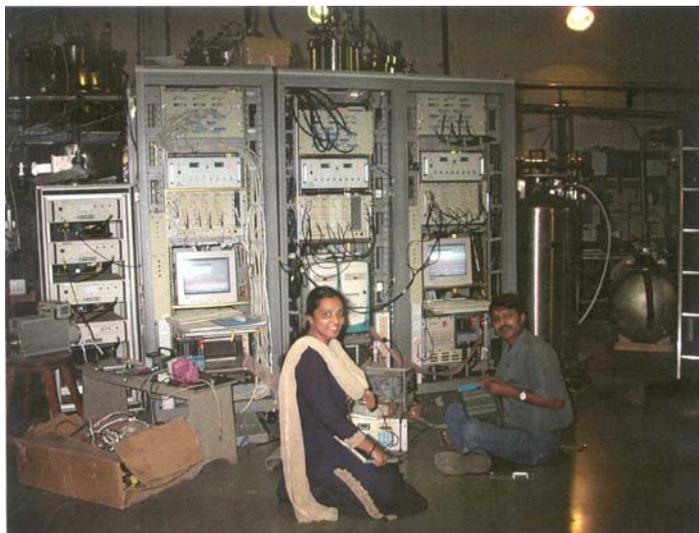
Linux has been chosen as the Operating System for this Control System. This is because Linux is freely available, is an Open Source software and is one of the most rugged and stable Operating Systems. Also, it is becoming increasingly popular among the Physicists community. The System has been designed as web based system as mentioned earlier. Java has been chosen as the language platform since a number of vendors are supporting Integrated Development

Environment for Java under Linux. Also, this is naturally suited for the distributed systems. In addition, Java is portable across different Operating Systems like MS Windows, Solaris, etc. The only change that needs to be done is the Java Native Interface code for accessing data from hardware via the device drivers, which also depends on the Operating System. A number of Java beans have been developed for usage on a web page which can be of use in other applications as well (web-based or others).

### Salient Features of the LINAC Control & Information System

1. Distributed Control System with identical nodes,
2. Easy expandability in terms of number of nodes
3. LINUX as the operating system for each of the nodes,

4. WEB based user Interface for access from any OS platform,
5. Usage of Java for the software (except device drivers) provides for easy portability,
6. CAMAC as front-end for which in-house expertise is available,
7. Diagnostics support for detection of CAMAC



*Fig. 10 : Instrumentation Rack at TIFR*

crate failure.

## First Beam through the First Half of the LINAC

On September 22, 2002, first beam was taken through the first half of the LINAC. Various distinguished visitors including Dr. Anil Kakodkar, Prof. S.S.Jha and Dr.S.S.Kapoor were present on the occasion. All the various systems of the LINAC, viz., cryogenics, magnet, vacuum and RF, worked very smoothly. The performance of the LINAC control system was found to be very satisfactory. Fig.10 shows the instrumentation racks installed TIFR.

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6. "Software Development for Super-conducting LINAC Control and Information System" (International Symposium on Nuclear Physics, December 18-22, 2000, BARC) by Sujo C.I., K. Jha, R. Skapatral, T.S. Ananthakrishnan and S.K. Kataria. Electronics Division, BARC, and S.K. Singh and B. Srinivasan, Nuclear Physics Division, BARC.
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# MANUFACTURING TECHNIQUES FOR R.F. LINAC CAVITIES DEVELOPED

Centre for Design and Manufacture (CDM) has undertaken the mechanical design and manufacture of many of the sub-systems for the 10 MeV RF Linear Accelerator, being developed by APPD and to be installed at EBC, Khargar, Navi Mumbai. The critical and important part of this are RF Cavities. These cavities are manufactured out of OFHC copper with high degree of precision involving dimensional and geometrical accuracy. Precision CNC lathe (See Fig.1) was deployed for machining of these cavities with diamond tool having custom designed tool geometry. (See Fig.2)

Initially, the process has been evolved using ETP copper and subsequently 9 cell sets were manufactured out of OFHC copper. Fig. 3 shows engineering drawing of one cavity.

Another important task was to braze all these cavities to form a 9 cell (proto-type) assembly of LINAC, maintaining the geometrical accuracy and precision. The SS 304 conflat flanges are joined at the end cavities to facilitate vacuum testing of assembly. Fig. 4 shows the 9 cells cavity assembly. The joint between SS 304 conflat flange and the end cavity was developed by diffusion bonding process. Later on, all the cavities are to be brazed in a hydrogen furnace or vacuum furnace. This requires a fixture, which will hold all the cavities along with the brazing material in position during brazing. CDM, by using innovative ideas, has designed and manufactured the fixture. (See Fig.5)



*Fig. 1 : R.F. Cavity being machined on a CNC precision lathe*

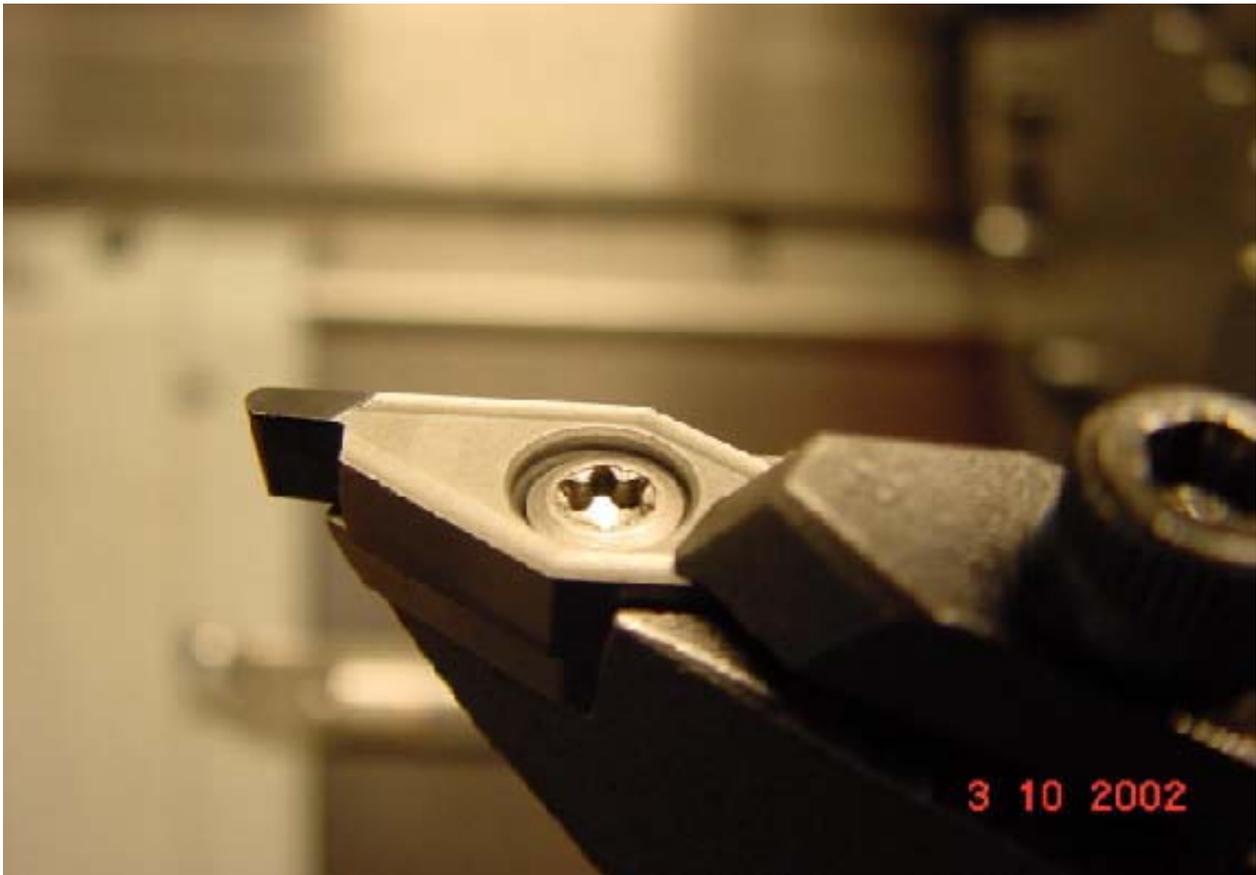


Fig.2 : Customized diamond point cutting tool for machining of cavity profile to achieve surface finish of 0.4 $\mu$ m

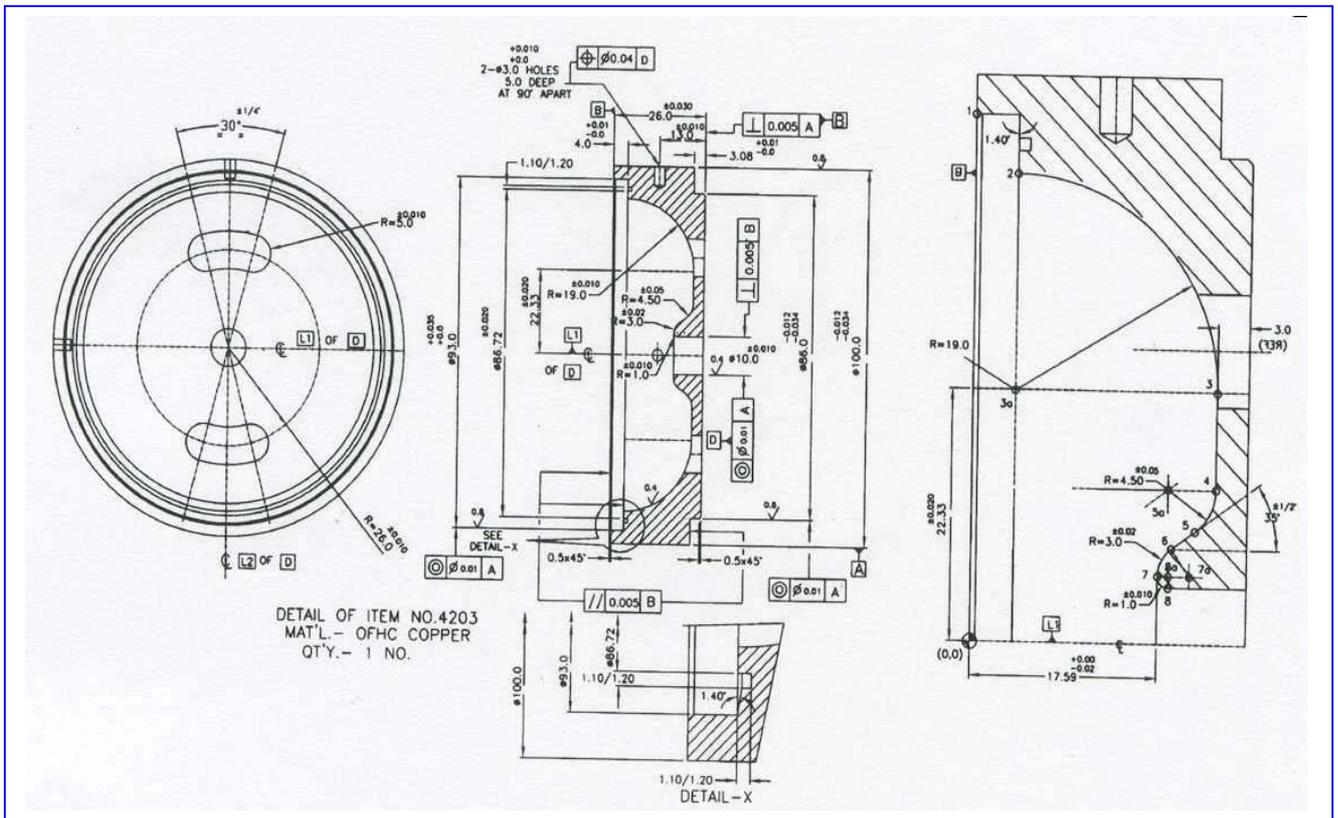


Fig.3 : Engineering drawing of cavity



Fig. 4 : Holding fixture along with the 9 cells assembly

This fixture has been manufactured, which holds these assemblies like a pendulum (See Fig.4), thereby ensuring the following requirements:

1. Verticality of the assemblies was maintained in line with the earth gravity irrespective of the level of supportive base. This is to ensure the equal braze joint brazing filler-wire in horizontal plane for all cavities.
2. To take care of the expansion of cavity without disturbing the verticality. This was achieved by using a low stiffness stainless steel

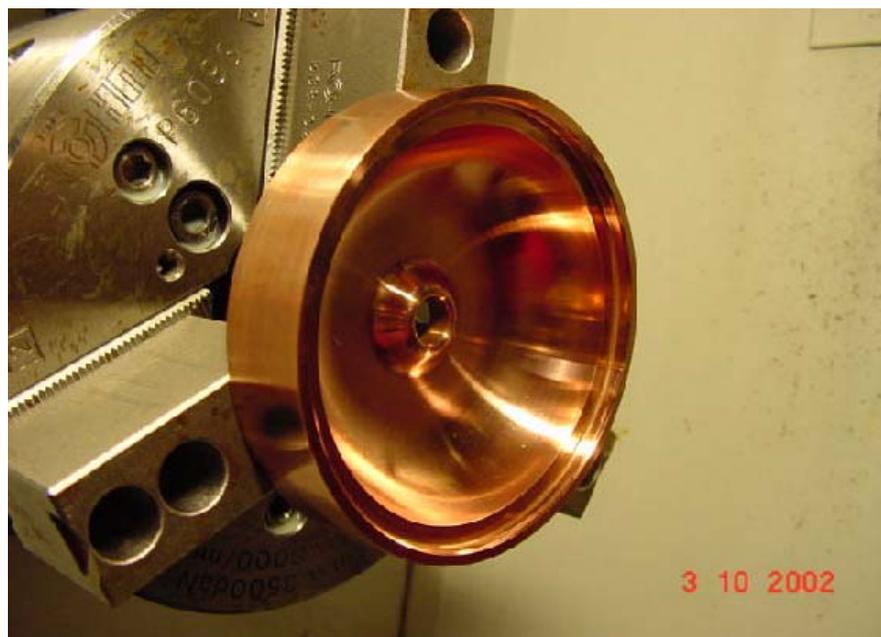


Fig. 6 : A typical brazing groove on CNC lathe under machining

spring at the top of the assemblies, which absorbs the linear expansion of cavities.

3. Damping of free oscillation was achieved by providing ball contact point under spring

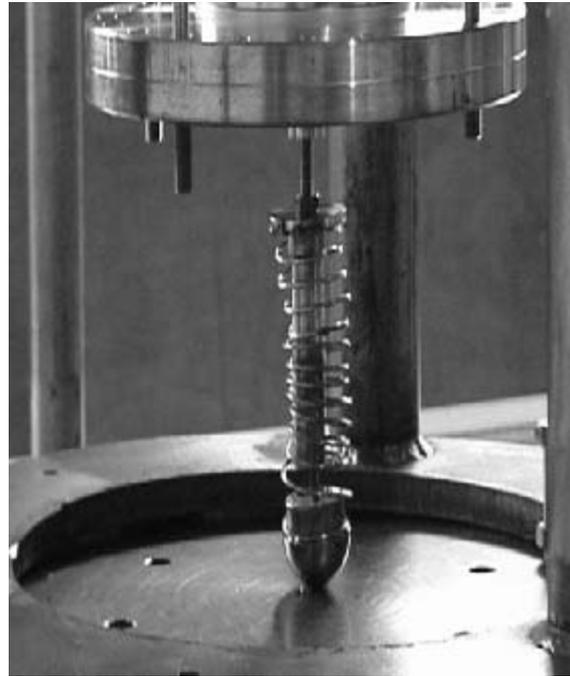


Fig. 5 : Ball contact point mechanism for damping oscillation

load. (See Fig. 5).

The material used for construction of fixture is Numonic (high temperature alloy). A typical brazing groove has been engineered to take care of easy flow of filler material and to have positive contact between cavities. (See Fig.6).

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These processes have yielded the dimensional tolerance within  $20\ \mu$  and the surface finish as  $0.2\ \mu$ . The brazing fixture was used for brazing the 9 cell cavity in the hydrogen furnace at SAMEER which is now ready for testing.

Thus, CDM has developed the machining process of RF Cavity using diamond turning tool and the hydrogen – vacuum brazing process technique with the use of innovative fixtures, designed and manufactured in-house. CDM is now ready to manufacture the 33 numbers of actual OFHC RF Linac cells assembly.

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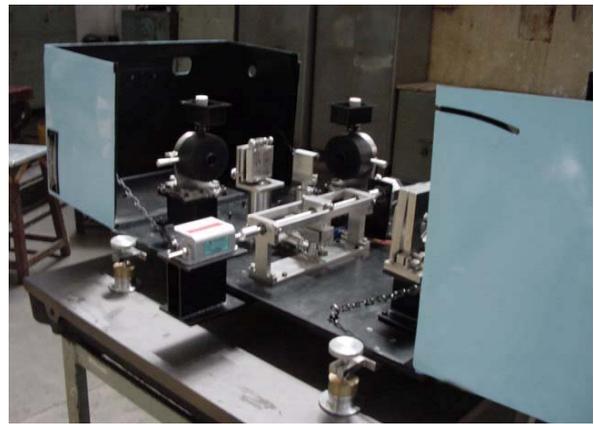
## MULTI-CHANNEL SPECTROGRAPH

Centre for Design and Manufacture (CDM) and Spectroscopy Division of B.A.R.C. jointly developed a Multi-Channel Spectrograph using Charged Coupled Device (CCD) as a detector for Raman spectroscopic applications. This spectrograph covers a useful range of electromagnetic radiation, i.e. from  $4000\ \text{Å}$  to  $7000\ \text{Å}$ . The spectrograph consists of one concave spherical mirror as a collimating element, another spherical mirror as a focusing element and a grating as a dispersing element.



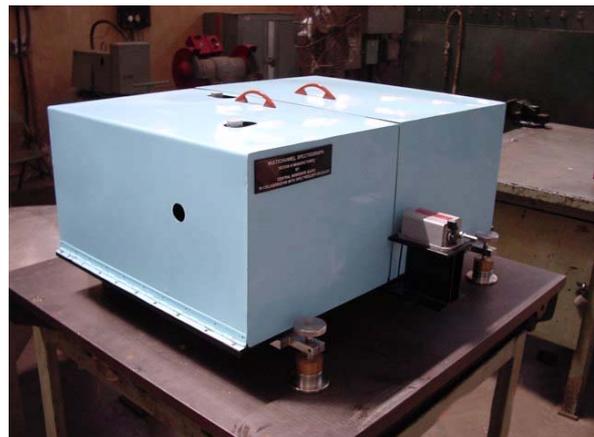
*Fig. 1. Layout of grating and mirror mounts*

Mounting brackets of all the optical components have the facility for very precise adjustments. The grating is rotated by a backlash free sine drive mechanism, which is coupled to a stepper



*Fig. 2. Details of sine drive mechanism*

motor, encoder and a mechanical counter. Link connecting the grating mount and sine drive mechanism is in two parts and both parts are coupled with a wedge assembly for adjusting the length of the link within 10 microns accuracy. The resolution and repeatability of the Multi-Channel Spectrograph depends on how accurately the length of the link has been adjusted.



*Fig. 3. Multi-Channel Spectrograph*

This spectrograph has been tested for its wavelength resolution. It has been coupled to a Raman imaging microscope to record the Raman spectrum of the materials. The Multi-Channel Spectrograph has recently recorded the Raman spectra of various liquids and solids. The efficiency of this Multi-Channel Spectrograph has been judged by recording the extremely weak third order Raman spectrum of silicon with 2 seconds exposure time, which is otherwise difficult to record in the conventional Raman spectrometer with a longer exposure time. The experimental results show that the Multi-Channel Spectrograph will be useful for Raman

spectroscopic studies of the various materials i.e. solids as well as liquids.

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## TRAINING COURSE IN "BASIC RADIATION PROTECTION"

The BARC Safety Council (BSC) Secretariat, Radiation Safety Systems Division (RSSD), conducted the sixth three-day training course in basic radiation protection at the D Block Auditorium, Modular Laboratories, BARC, during December 18-20, 2002 for the staff members of those Divisions which do not handle radioactive materials.

Dr K.L. Narasimharao, Course Director, welcomed the participants and invitees, and said that the sixth training course was being conducted after seeing the overwhelming response for the five earlier ones conducted for the scientific and technical staff of the Radiological Laboratories, Nuclear Recycle Group, accelerator and irradiator facilities, research reactor facilities and the front end of the nuclear fuel cycle. Dr M.C. Abani, Member-Secretary, BSC and Head, RSSD, in his opening remarks, said that this was the first time that a course was designed for the people who do not handle radioactive materials and that the people working in BARC should know what are the hazards of radiation, especially since the latent period is very long in the case of low-rate exposures. He also said that this course specially tailored for them would introduce in a very simple way the concepts of dosimetry, radiation biology, measuring instruments, environmental monitoring, transport of radioactive material and industrial hygiene and safety.

Mr G. Govindarajan, Director, Electronics & Instrumentation Group and Automation & Manufacturing Group, BARC, in his inaugural address, said that, though the entire staff of

BARC may not be involved in handling radioactive materials, they should have some knowledge of working in a radioactive environment. He also said that though many of them do not handle radioactive materials directly, they are associated indirectly as they prepare instruments that work in a radioactive environment. He added that this was a very good course for improving their knowledge of the current concepts of radiation protection. Dr Pushparaja, Head, Radiation Hazards Control Section (RHCS), RSSD, presented the vote of thanks.

Twenty-five participants nominated by the Heads



*Mr G. Govindarajan, Director, Electronics & Instrumentation Group and Automation & Manufacturing Group, BARC, inaugurating the training course.*

of twenty-one Divisions from Atomic and Condensed Matter Physics Group, Automation & Manufacturing Group, Bio-science Group, Chemical Engineering & Technology Group, Chemistry & Isotope Group, Electronics & Instrumentation Group, Engineering Services Group, Materials Group, Medical Group, Physics Group, Reactor Projects Group, and Reactor Design & Development Group attended the course. The faculty included Dr M.C. Abani, Member-Secretary, BSC & Head, RSSD, Dr B.C. Bhatt, Head, Radiological Physics & Advisory Division (RP&AD), Dr P.R. Bongirwar, Medical Officer-in-Charge, Trombay Dispensary, Dr D.N. Sharma, Head, Radiation Instrumentation and Methods Section (RIMS), RSSD, Mr S. Kannan, Head, Radiation Protection Instrumentation

Section (RPIS), RSSD, Dr Pushparaja, Head, RHCS, RSSD, Dr B.S. Rao, Head, Radiation Dosimetry & Training Section, RP&AD, Dr R.K. Singhal of Health Physics Division, and Mr A. Raju, Mr N. Kalyanasundaram, Dr K.S. Pradeepkumar and Dr K.L. Narasimharao of RSSD. The course consisted of 13 lectures covering various subjects namely philosophy of radiation protection, radioactivity, radiation units and dosimetry, interaction of radiation with matter, health physics instruments, biological effects of radiation, radiation protection in industrial and medical facilities, industrial hygiene & safety, environmental monitoring, preparedness and response for nuclear and radiological emergencies, health physics procedures, transport of radioactive materials, and occupational health. Visits to Site Emergency Response Centre, Medical Decontamination Facility, Dhruva Reactor and RPIS were also arranged. Mr R.K. Sinha, Associate Director, Reactor Design & Development Group, BARC, in his concluding remarks, said that the requirements for handling radioactive materials are very much different from those of normal materials and that unfounded fears should be cleared. He also said that the course is very valuable for the department as it prepares the staff for an informed approach to radiation emergencies.

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## TECHNOLOGY TRANSFER OF THE SPECIAL SEALING PLUG

Periodic In Service Inspection (ISI) of the coolant channels is carried out to monitor the health of the coolant channels in PHWRs. BARC Channel Inspection System (BARCIS) is in use for doing ISI in water-filled condition. BARCIS carries out the inspection of the channel through special seal plug. This plug has been developed by Refuelling Technology Division, which enables the installation of the inspection head remotely in the channel to be inspected by the fuelling machine

and also allows the entry of drive tube to be connected to inspection head for transferring the collected data by inspection head to outside. Thus, special seal plug plays a major role in ISI operation. Different versions of the plug have been evolved and used for ISI of more than 600 channels in 220 MWe PHWRs. Based on the experience during ISI, MK-IV design has been evolved. This design is matured, sturdy, operator-friendly and saves further manrem expenditure and time. Maintenance frequency required is also less. MK-IV design of the plug has been recently used for more than 30 channels of ISI at Madras Atomic Power Station successfully.



*Photo of Special Seal Plug (Mark IV)*

To cope up with the need of ISI at all operating stations, it is required to fabricate several numbers of this new design of plug. It is also required to provide continuous support to sites for providing spares of these plugs. In view of increased scope of work, it is difficult to cater to the need of all operating stations. Hence, for technology transfer of the special sealing plug, a Memorandum of Understanding (MoU) has been signed between BARC and NPCIL. BARC has handed over the design drawings of Mark III (modified) and Mark IV design of special sealing plugs along with operation & maintenance manual and specification for manufacturing of special sealing plugs to NPCIL to enable them to manufacture the plug and to take full responsibility for the operation and maintenance of the plug. A Memorandum of Understanding was signed between Mr G. Govindarajan, Director, A&M Group, BARC and Mr Umesh Chandra, Executive Director (R&D -C&I), NPCIL, at the office of Director, A&M Group, BARC. Mr

R.G. Agrawal, Head, Refuelling Technology Division, Mr R.J. Patel, Head, Fuel Handling Design & Development Section, RTD, Mr Prabhatkumar, Associate Director (R&D), NPC, Mr D.N. Sanyal, Dy. Chief Engineer (R&D), NPC, and Mr S. Roy, RTD were present during the occasion.

## भा.प. अ. केन्द्र के वैज्ञानिकों को

### सम्मान

## BARC SCIENTISTS HONOURED



- सर्वश्री ए. के. सिंह, एम. एम. हुसैन, एस.पी सिंह, और वी.जी.दाते द्वारा लिखित ' लो टेम्परेचर सुपर कंडक्टर फेब्रिकेशन एन्ड एप्लिकेशन' शोधपत्र पर भा.प.अ.केन्द्र के

परमाणु ईंधन प्रभाग के श्री ए.के.सिंह ने सर्वोत्कृष्ट मौखिक प्रस्तुति के लिए जी.एस.तन्दुलकर पुरस्कार जीता है। यह प्रस्तुति उन्होंने बड़ोदरा में 14 से 17, नवम्बर 2002 के दौरान फेरस तथा नान-फेरस, धातु विज्ञान वर्गों के समक्ष भारतीय धातु संस्था की 56वीं वार्षिक तकनीकी सभा में दी। यह पुरस्कार उन्हें प्रशस्ति-पत्र तथा राशि के रूप में दिया गया।

भा.प.अ. केन्द्र के परमाणु ईंधन प्रभाग में विभिन्न प्रयोगों के लिये बहुतंतु NB-Ti की अतिचालक तारों और केबलों के विकास एवं निर्माण हेतु एक पूर्णतः विकसित सुविधा का स्थापन किया गया है। श्री ए. के. सिंह इस क्षेत्र से सक्रिय रूप से जुड़े हैं।

V.G. Date of Atomic Fuels Division, BARC, presented by Mr A.K. Singh, has won the GS Tendulkar prize for the overall best oral presentation among Ferrous, Non-Ferrous, Metal Science Groups at the 56<sup>th</sup> Annual Technical Meeting of Indian Institute of Metals held during November 14-17, 2002 at Vadodara. This carries a cash award and a citation. A full fledged facility for development and fabrication of multi-filamentary Nb-Ti superconducting wires and cables for various applications has been set up at AFD, BARC. Mr A.K. Singh has been actively engaged in this field.



- पॉवर रियक्टर ईंधन पुनर्संसाधन संयंत्र, तारापुर के डॉ. एन.एस. राथोड, ने वर्ष 2001-02 का "युवा वैज्ञानिक" पुरस्कार प्राप्त

किया। उन्हें यह पुरस्कार विश्लेषणात्मक एवं पर्यावरण रसायनिकी के क्षेत्र में "हॉलो फाइबर मेंब्रेन कॉन्टैक्टर: नॉवल एक्सट्रैक्शन डिवाइस फार प्लुटोनियम एक्सट्रैक्शन लेख पर जबलपुर मध्य प्रदेश के आर.डी विश्वविद्यालय में अक्टूबर 24-26, 2002 के दौरान हुए भारतीय रसायन वैज्ञानिक परिषद के 21वें वार्षिक सम्मेलन में लेख प्रस्तुतिकरण के लिए दिया गया।

Dr N.S. Rathore of Power Reactor Fuel Reprocessing Plant, Tarapur, won the "Young Scientists" award for the year 2001-02 in the field of Analytical and Environmental Chemistry for his paper entitled, "Hollow Fiber Membrane Contactor : Novel Extraction Device for Plutonium Extraction", presented t the 21<sup>st</sup> Annual Conference of the Indian Council of Chemists, held during October 24-26, 2002, at R.D. University, Jabalpur, Madhya Pradesh.

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