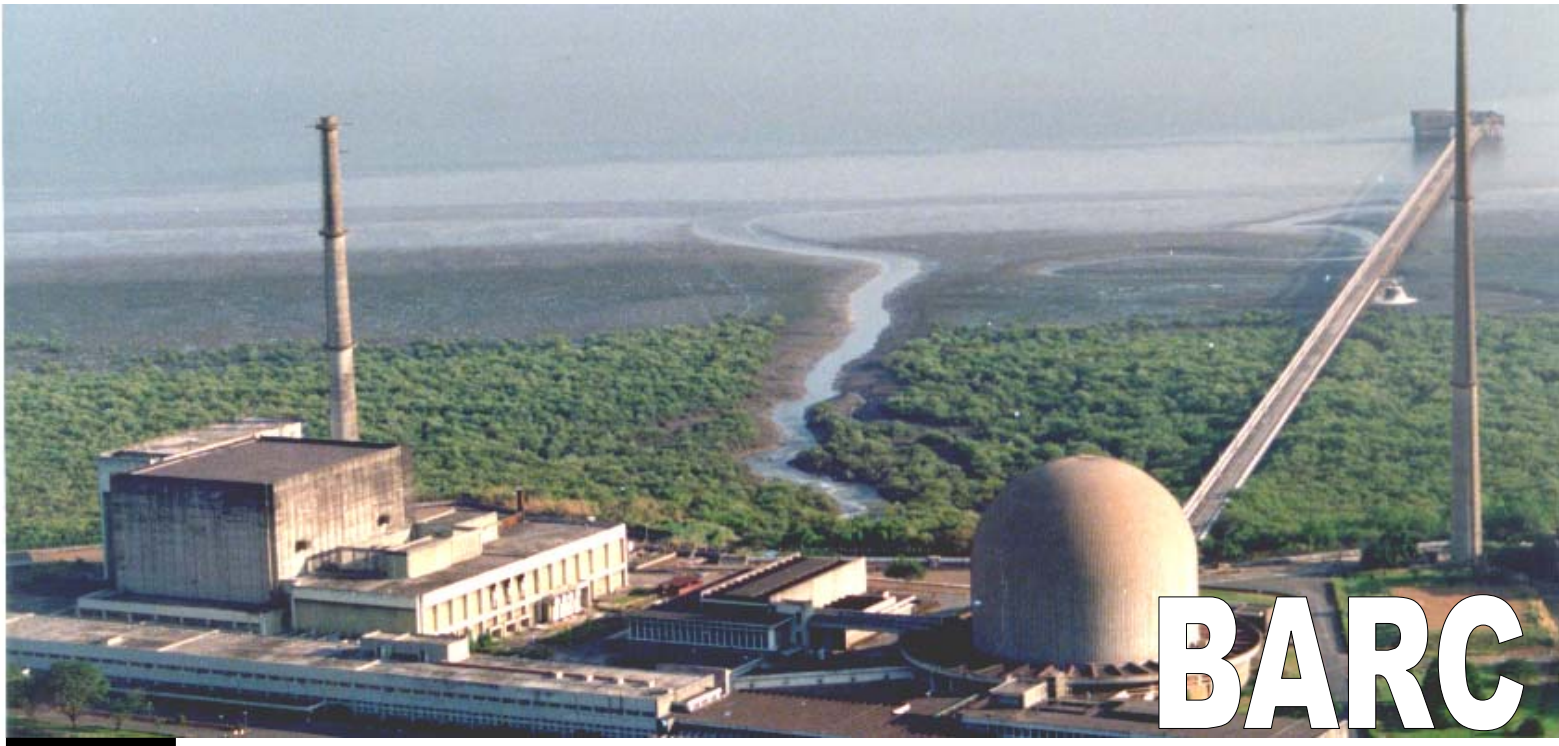

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25 YEARS OF IMPEDANCE PLETHYSMOGRAPHY

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In the year 1978, exactly 25 years ago, the first Impedance Plethysmograph (IPG) System, developed at Electronics Division, BARC, was taken to Department of Surgery, Seth G.S. Medical College & K.E.M. Hospital and Department of Medicine, Grant Medical College & J.J. Hospital, Mumbai, for the assessment of central and peripheral blood flow in the human body. The literal meaning of Impedance Plethysmography is “Recording of instantaneous volume (of an object) by measurement of electrical impedance”. It has, however become a synonym for “indirect assessment of blood volume changes in any part of the body from changes in the electrical impedance of the body segment”.

A typical impedance measuring system is comprised of a sine-wave oscillator followed by voltage to current converter. This converter outputs sinusoidal current of constant amplitude (1-10 mA) which can be passed though the body segment with the help of two band electrodes called the current electrodes I1 and I2. Voltage signal developed along the current path is sensed with the help of another pair of

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electrodes called the sensing electrodes or voltage electrodes V1 and V2 as shown in Fig. 1.

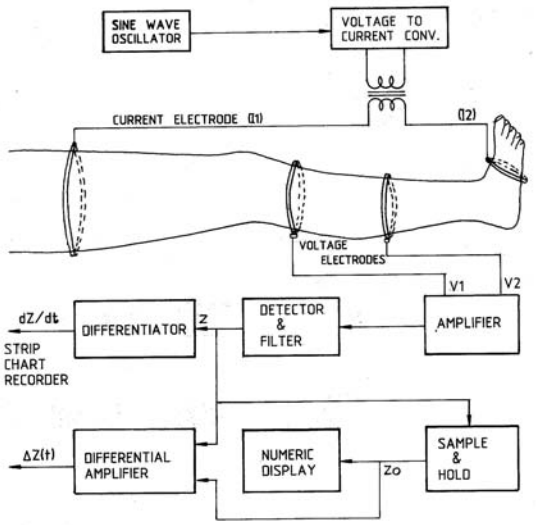


Fig.1 Block diagram of a typical impedance plethesmograph system. Constant amplitude sinusoidal current is passed through the body segment with the help ot current electrodes I1 and I2. Voltage sensing electrodes V1 and V2 are applied at desired location on the body segment along the current path. The amplitude of sensed sinusoidal signal is directly proportional to the instantaneous impedance Z of the body segment between the sensing electrodes. Z is processed electronically yield basal impedance Zo, ΔZ(t) and dZ/dt waveform.

The amplitude of the signal thus obtained is directly proportional to the electrical impedance of the body segment between the electrodes V1 and V2. The amplification and detection of this signal yields an output signal, which is proportional to instantaneous impedance (Z) of the body segment. Initial value of the impedance, also known as basal impedance (Z_o) is obtained from a sample and hold circuit and is numerically displayed on the panel.

Small changes in the impedance of the body segment caused by physiological processes like blood circulation, respiration etc, are obtained by subtracting the initial value of the impedance from the instantaneous impedance and is called the ΔZ(t) waveform. The Z is also differentied with respect to time to get the rate of change of impedance or the dZ/dt waveform. By convention −ΔZ(t) and –dZ/dt are recorded on a strip chart recorder to relate these waveforms with blood volume changes directly and are colloquially called ΔZ(t) and dZ/dt waveforms.

Since ΔZ(t) and dZ/dt are produced by the physiological processes, it is possible to extract the changes produced by one particular process by either suppressing the other process or by signal processing techniques. For example to extract the signal produced by blood circulation, the subject under investigation can be instructed to hold his breath. On the other hand a low pass filter can suppress the changes caused by blood circulation and give the changes produced by respiration. Nyboer's equation, derived from parallel conductor theory, relates the blood volume changes (ΔV) with the changes in electrical impedance (ΔZ) as follows (Nyboer J. 1960):

$$\Delta V = \rho_b \frac{L^2}{Z_0^{\,2}} \Delta Z$$

where ρ_b is the resistivity of blood in ohm-cm, L is the length between sensing electrodes and Z_o is the gross electrical impedance and the body segment.

This equation is modified appropriately to obtain stroke volume/cardiac output from dZ/dt waveform (Kubieck et al 1966) and peripheral blood flow from ΔZ waveform with the help of venous occlusion principle (Kubicek et al 1974).

With joint efforts of BARC and KEM Hospital, a new method for estimating peripheral blood flow from dZ/dt waveform was developed. This method was not only simple but also yielded peripheral blood flow in real time in several segments of the limb, unlike systems available from abroad (Parulkar et al 1981). With this new method, blood flow index (BFI), differential pulse arrival time (DPAT) and pulse termination time (PTT) could be estimated in different segments of the limb, such as, upper arm, elbow, forearm and wrist in the upper extremity and upper thigh, knee, calf and ankle in the lower extremity, from the basal impedance value and dZ/dt waveform

recorded from the respective segment. Also coefficient of venous stasis (CVS) can be estimated by ratio of BFI in elevated position and that in supine position of the limb. Venous capacitance and maximum venous outflow can be estimated from $\Delta Z(t)$ waveform using venous occlusion principle for detecting diseases of the veins.

Extensive clinical trials on 100 normal subjects and 10,000 patients with peripheral vascular occlusive diseases at KEM Hospital and J.J. Hospital during 1978 to 1990 and comparison of IPG observations with angiography observations in more than 500 subjects revealed the sensitivity and specificity of the indigenously developed technique to be 96% and 98% for the diagnosis of peripheral arterial occlusive disease (Jindal et al 1990 (a)) and more than 80% for the diagnosis of deep vein thrombosis (Jindal et al 1990 (b)). Typical data is shown in Figs 2 and 3.

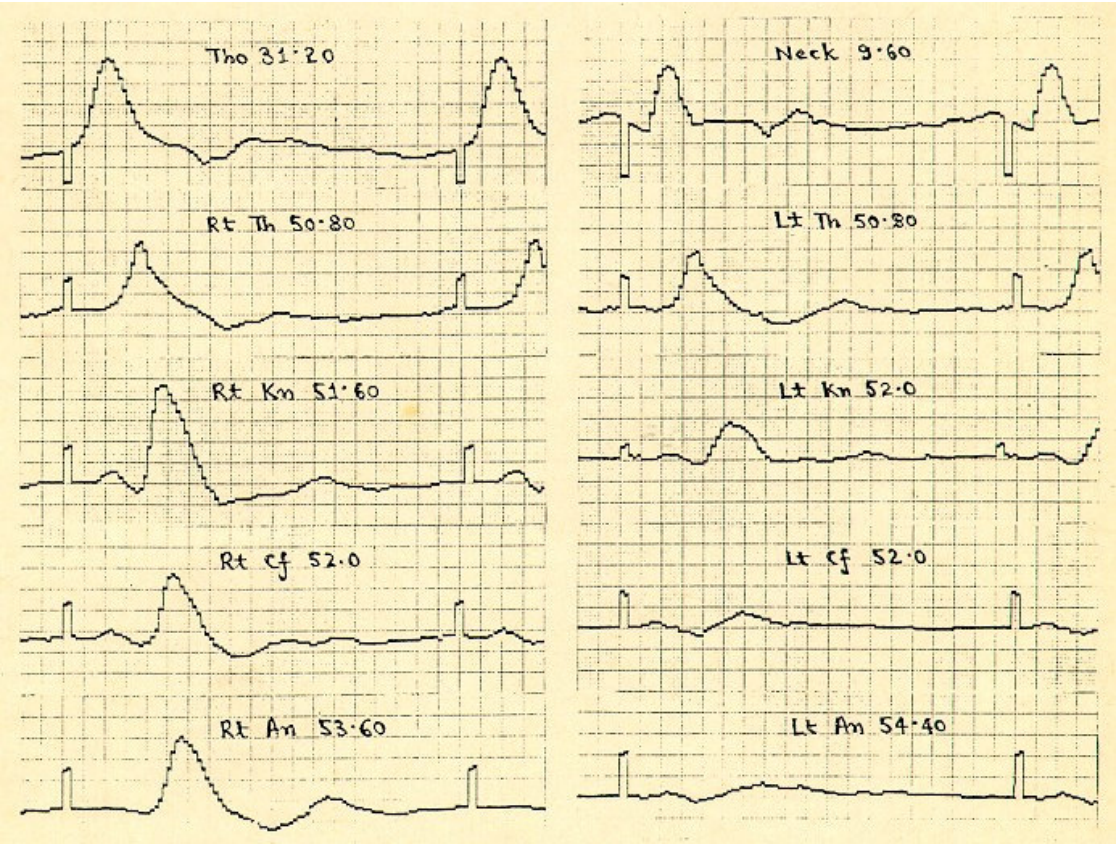
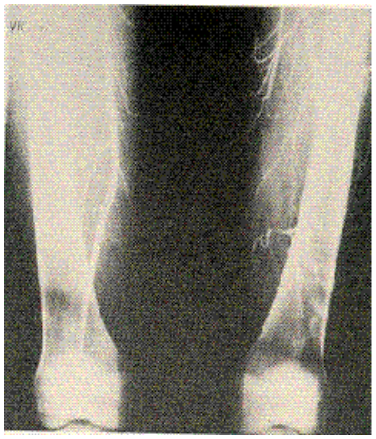


Fig. 2: ICVG waveforms in a patient (RKP-30-M) with femoral artery occlusion in the left leg. The amplitude of the waveform on right side gives normal appearance. Left thigh shows a marginal decrease in the amplitude of the waveform, which becomes moderately lower at knee level and markedly lower at calf and ankle levels. The BFI and DPAT values in this patient are as follows:

Location	Right Side		Left side	
	BFI	DPAT (ms)	BFI	DPAT (ms)
Thigh	1.48	70	1.13	70
Knee	2.12	50	0.85	80
Calf	1.64	-	0.29	-
Ankle	1.68	40	0.23	80



All the BFI values in the right leg give normal appearance. Though DPAT at thigh is very marginally decreased and that at knee is very marginally increased, in view of normal BFI values, right leg is considered normal and minor changes in DPAT are attributed to measurement error. In the left leg there is marginal decrease in BFI at thigh level and moderate decrease at knee level with increase in DPAT at knee level, thus indicating an occlusion at iliac or femoral level. Since the decrease in BFI and increase in DPAT at knee is smaller in this case as compared to that of figure 5.6, the occlusion is more likely to be in the femoral artery than the iliac artery. Below the knee there is marked decrease in the value of BFI and increase in DPAT at ankle level indicating a further block at calf level with few collaterals.

Aortogram in this patient has shown left femoral artery to be narrow and irregular, profunda femoris to be markedly dilated and complete occlusion of the superficial femoral artery. Distal part of the femoral, popliteal and leg branches are not seen to be opacified. This data illustrates that in certain cases aortography is not in a position to give information about post-occlusion blocks, which is well detected by impedance cardiovasography.

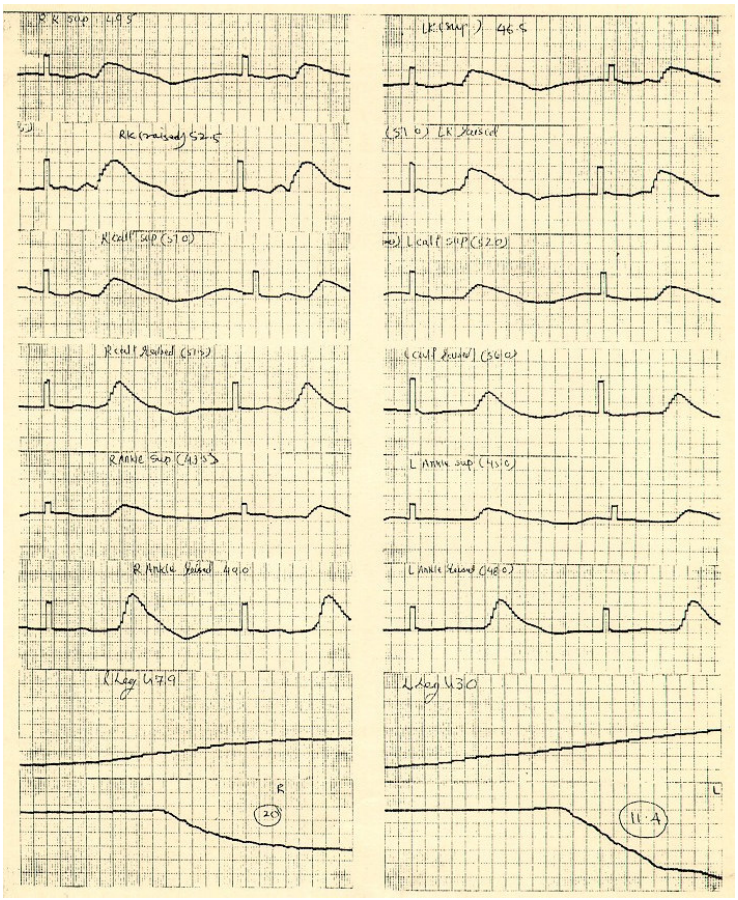
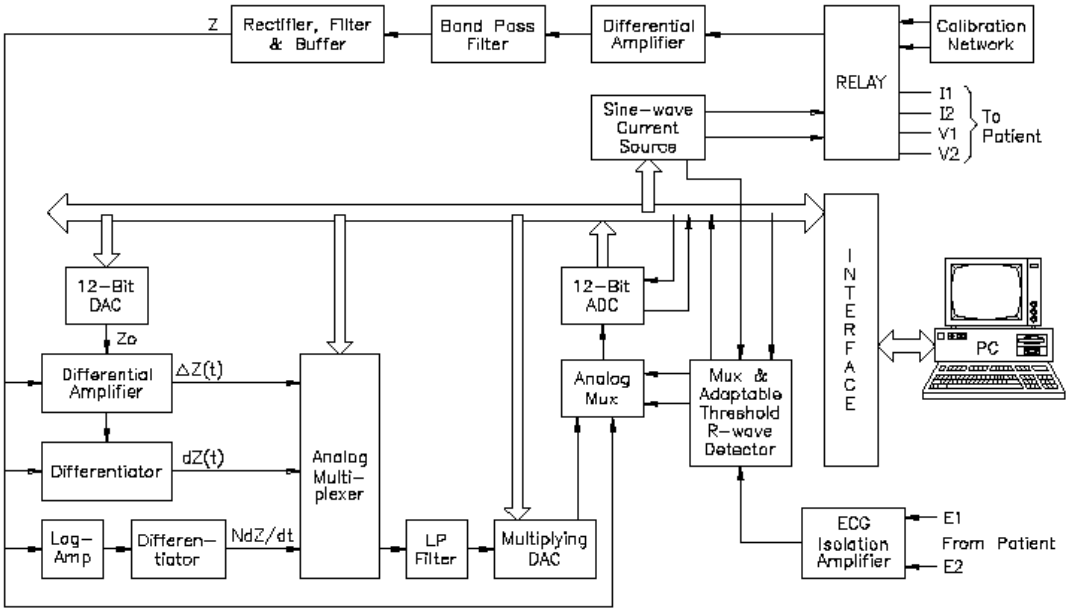


Fig. 3: ICVG and OIP observations in a patient (RA-32-M) with pain and swelling in both the legs. The presentation of the waveforms a similar to that of figure 5.11. The amplitude of the waveforms is seen to increase significantly on elevation of the legs at all the locations indicating varicosity of the veins. Amplitude of the OIP waveform on both the sides appear to be within normal range with mild decrease in the descent of the curve. The values of ICVG and OIP parameter in this case are given in following table. BFI is seen to be reduced moderately at all the locations in both the legs which increases appreciably on elevation of the legs giving rise to higher values of co-efficient of venous stasis. These observations suggest secondary varicosity in both the legs. OIP observations show normal values of venous capacitance. There is a slight decrease noted in the values of MVO in both the legs. ICVG and OIP observations together therefore, suggest chronic deep vein thrombosis in both the legs. Venography in the patient has shown patchy opacification of deep veins and muscular veins of the calf in both the egs. Proximal portion of popliteal vein, superficial femoral vein, and external iliac vein are seen to be inadequately opacified bilaterally. Secondary varicosity of great and short sapnenous veins has been observed in both the legs. These observations are thus in full agreement with ICVG diagnosis.

Parameter	Right Leg			Left Leg		
	Knee	Calf	Ankle	Knee	Calf	Ankle
Zo	49.5	51.0	43.5	46.5	52.0	45.0
BFI(s)	0.73	0.89	0.57	0.75	0.65	0.67
BFI(e)	1.56	1.31	1.72	1.10	0.78	1.49
CVS	2.13	1.47	3.02	1.47	1.20	2.22
PTT	480	490	490	470	470	540
VC	-----	0.80	-----	-----	0.83	-----
MVO	-----	0.10	-----	-----	0.11	-----

The technique has undergone several renovations during the past 25 years such as development of microprocessor based impedance plethysmograph system, introduction of simple and reliable calibration for dZ/dt waveform (Jindal et al., 1985). Correction of formula for estimating peripheral blood flow (Jindal et al., 1994), introduction of normalised dZ/dt waveform for easy assessment of peripheral blood flow (Jagruti et al 2000) and development of PC-based impedance cardiovasograph system (Jindal et al., 2001).

The microprocessor based impedance plethysmograph system employed ensemble averaging technique to minimize respiratory artifacts, external pick up and internal noise of the system. The patient did not have to hold his breath during investigation as the respiratory artifacts were taken care of. The procedure thus became very simple and user/patient friendly. The technical know-how of this system was transferred in 1989 through Notional Research & Development Corporation.



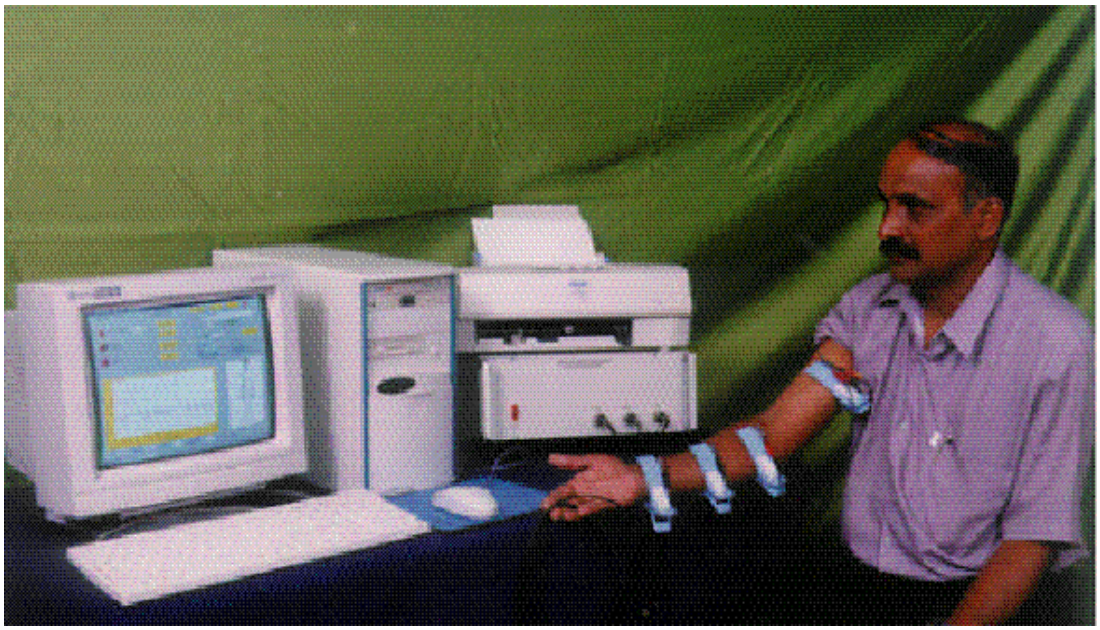


Fig. 4

Fig. 4 shows schematic block diagram and photograph of the latest PC-based impedance cardio vasograph developed at BARC. It is comprised of an EPROM driven sine-wave current generator which passes the user selectable sine-wave current of constant amplitude at 50 KHz frequency through the body segment in patient mode with the help of isolation transformer and a relay. The same generator passes modulated sine-wave current (1% amplitude modulation with triangular wave at 1 Hz frequency) through the calibration network of fixed resistance values in calibration mode (Jindal et al 1985). The voltage signal developed along the current path is sensed with the help of sensing electrodes and amplified using a differential amplifier. The high Q band-pass filter removes the superimposed noise and the output of the filter is rectified, filtered and buffered to obtain a voltage signal Z, which is proportional to the instantaneous electrical impedance of the body segment under investigation.

The Z signal is used to obtain $\Delta Z(t)$ signal with the help of a differential amplifier. The inverting input of this amplifier is fed by the Z signal and the non-inverting input is fed by the Zo signal, obtained with the help of 12-bit DAC from PC, so as to obtain $\Delta Z(t)$ at the output. Z is also differentiated with the help of an electronic differentiator to obtain dZ/dt signal. For obtaining normalized dZ/dt signal, i.e. the dZ/dt signal normalized with respect to the impedance value (NdZ/dt), log Z is obtained with the help of a log amplifier, which is subsequently differentiated by using another electronic differentiator. $\Delta Z(t)$, dZ/dt and NdZ/dt signals are then multiplexed with the help of an analog multiplexer. Either of these waveforms can be selected at the output by the operator through the user interface panel. The multiplexed impedance signal is filtered with the help of a 2^{nd} order low pass filter having a cut off at 40 Hz for smoothening the waveform. The output of the filter is amplified with a programmable gain amplifier implemented by using a multiplying DAC. The amplified output is given to dual analog switch which gives Z signal at the output during the sync pulse and function of Z i.e. $\Delta Z(t)$, dZ/dt or NdZ/dt during rest of the cardiac period. The multiplexed output from the analog switch is connected to a 12 bit ADC for digitization and to be read by personal computer, through interface unit.

The isolated ECG amplifier senses the ECG voltages from the body surface and amplifies by a gain of 60 dB. The output of this amplifier is given to an adaptable threshold R-wave detector and a multiplexer for giving the synchronization pulse to be used by PC for time sequencing the impedance data. A spike, synchronous with the negative phase of the triangular wave, is used to generate the sync pulse in place of ECG in the calibration mode, and is multiplexed with the ECG signal.

Fig. 5 shows typical user interface panel for IPG investigation. It provides facility to enter personal information of the patient, select the desired investigation, acquire data from the patient or load/display/print the data of a patient acquired earlier. On selecting the investigation, the relevant list of leads appears in the list box, to aid the user. At the end of data acquisition, parameters such as BFI, PAT, PTT etc. are automatically computed and displayed below the graph. For specific application of continuous cardiac output monitoring, the system has been simplified into a small module, called Cardiac Output Monitor (COM). Fig. 6 shows typical user interface panel for COM. The know-how of both the units has been transferred to Larsen & Toubro Ltd., in 2000 for mass production.The clinical applications of impedance plethysmo-graphy do not end with measurement of central and peripheral blood flow but more important applications are in advance stages of development at several institutes. For instance, the fluctuations in peripheral blood flow or cardiac output are being explored to study the effect of different diseases on the autonomous nervous system (ANS). In this application, continuous IPG signal is recorded from a body segment for a period of five minutes. BFI values

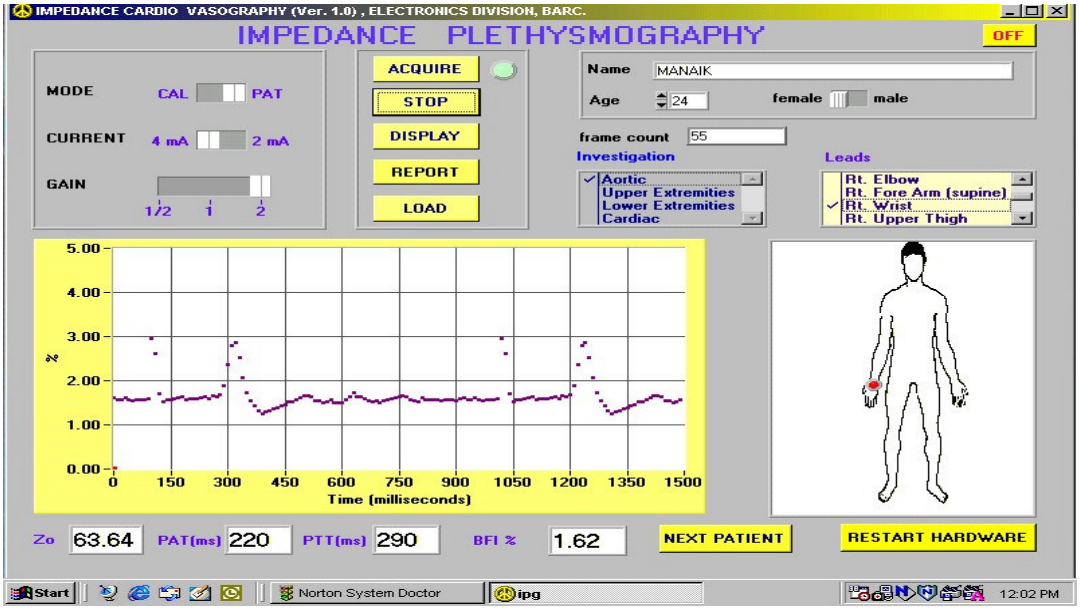


Fig. 5

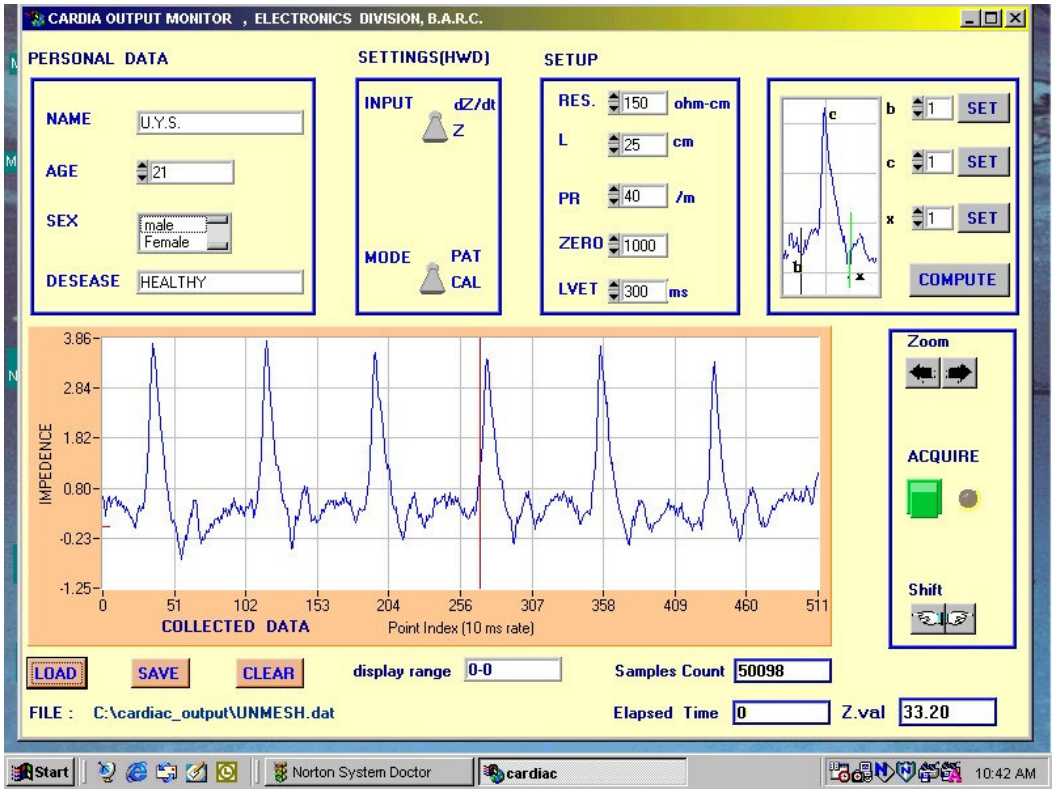


Fig. 6

are then obtained as a function of time from this signal and interpolated to get equi-spaced values. Fourier transform of this time series then gives the periodicity with which the fluctuations are taking place. Fig. 7 shows typical blood flow fluctuations in time and frequency domain obtained from a normal subject. The peak at 0.012 Hz. represents activity of thermo-regulation/baro-receptor reflex/sympathetic nervous system and those at 0.189 Hz. and 0.236 Hz. represent activity of parasympathetic nervous system and respiration, respectively (Deepak et al 1996).

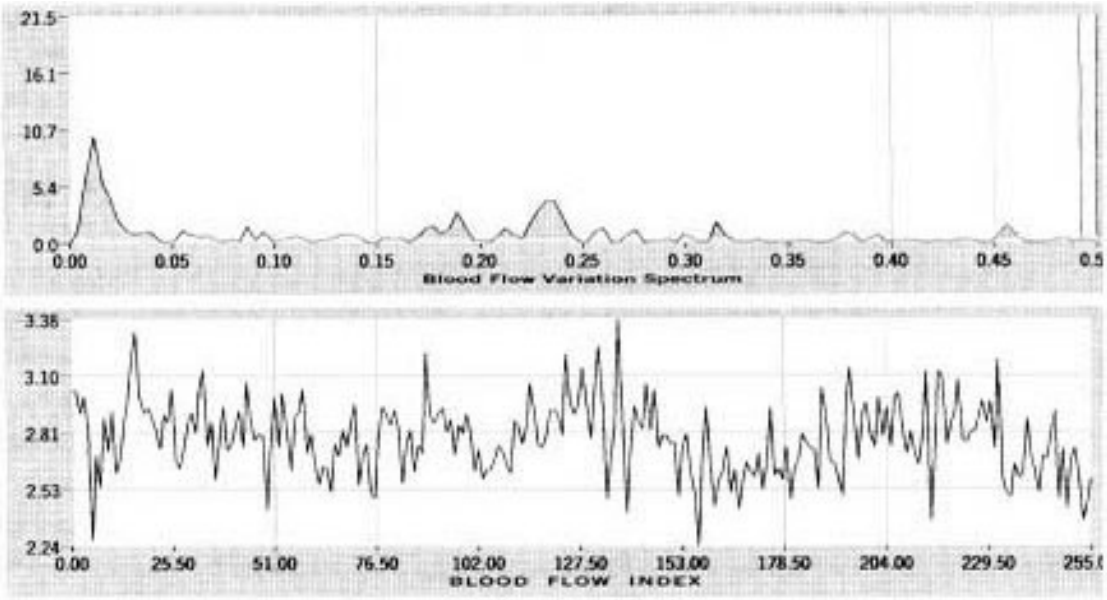


Fig.7 Typical peripheral blood flow fluctuations in time (lower) and frequency domain (upper) in the right wrist of a normal subject. Presence of multiple peaks indicates more noise in the power spectral density; however, two peaks are prominently centered around 0.012 and 0.236 Hz. The mid-frequency peak at 0.189 Hz is smaller in magnitude.

The Medical Analyzer system developed at BARC is the continuation of the work carried out during past 25 years, for studying the activity of ANS under the influence of different diseases (Jindal et al. 2003). The unique feature of this system is that it yields heart rate variability, respiration rate variability, cardiac output variability and stroke volume variability/ peripheral blood flow variability (Left/Right) from a single data acquisition from the subject which is not feasible with any other commercial instruments. Preliminary study carried out on 300 subjects show that ANS activity gets selectively modified which is specific for the disease. To converge this application into a diagnostic tool, data collection on large no. of subjects is in progress.

Fig. 8: Second panel discussion sitting from left to right: Dr. Alaka K. Desphande, JJ Hospital, Mumbai, Prof. Vinod Kumar, Electrical Engineering, IIT Roorkee, Prof. Sneh Anand, Biomedical engineering, IIT, Delhi, Dr. K. Mohandas, Director, Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram, Prof. A. S. Paintal, V.P. Chest Institute, Delhi, Dr. I. B. Singh, Advisor, Insrtumentation and development, Deptt. of Science and Technology, Delhi, Dr. G. D. Jindal, Electronics Division, BARC, Mumbai and Dr. Ashima Anand, V. P. Chest Institute, Delhi, Dr. Madhuri Behari, Neurology, AIIMS, Dr. K. K. Deepak, Addl. Prof, Deptt. of Physiology, AIIMS deliberating on "Developing our own Electro- diagnostic Techniques".

The workshop on "Non-invasive Measurement of Peripheral Blood Flow and Cardiac Output" organised at All India Institute of Medial Sciences, New Delhi, during April 15-17, 2003, witnessed an overwhelming response from the medical community from all over the country. Two units each of impedance cardiovasograph and cardiac output monitor from Electronics Division, BARC, were used to give live demonstration on peripheral blood flow estimation and cardiac output monitoring and

provide hands-on experience to all the participants in the workshop.

Panel discussion on 'Rheography by Impedance Plethysmography in Medicine', moderated by Dr. P.K. Banerjee, Director, Defence Institute of Physiology and Allied Sciences (DIPAS), Delhi, concluded with the following remarks:

"Let us congratulate Bhabha Atomic Research Centre for bringing out state of the art technology on Impedance Plethysmography. It is probably the first indigenous technology to come in final usable form. The use of the same in continuous monitoring of cardiac output is beyond doubt. As far as its applications in the diagnosis of peripheral vascular occlusive diseases are concerned, BARC has conducted extensive studies on clinical validation in collaboration with KEM Hospital and J.J. Hospital, Mumbai. Their experience is more than satisfactory, as second block some times missed on arteriography is sensed by this technique and the information not available in Colour Doppler investigation on collateral circulation and distal arterial run off is readily provided by this technique. It is for the medical fraternity to come forward and carry out adequate trials to make it a routine clinical investigation".

During the second panel discussion of the workshop on "Developing our own Electro-diagnostic Techniques", moderated by Dr. K. Mohandas, Director, Sree Chitra Tirunal Institute for Medical Sciences & Technology (SCTIMST), Thiruvananthapuram, road map for the objective was shown. It was emphasized that there is need to establish institutions for drawing specification, issue certifications and regulate the products. Greater participation from industry and medical fraternity was also stressed. Also need for distinguishing basic research and import substitution programme and promotion of both was highlighted. Director, SCTIMST, also expressed his happiness on their proposed collaboration with BARC in the field of Biomedical Engineering.

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AN AUTOMATED SHIELDED CHAIR WHOLE BODY MONITOR

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and

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Introduction

Whole body/organ counting plays an important role in assessing, limiting and controlling the intakes of radioactive materials by the workers of a nuclear research centre as well as of nuclear industry. The Internal Dosimetry Division of BARC, besides designing, developing, supplying and installing the whole body/organ counting facilities at DAE's nuclear installations, also operates such facilities for radiation workers of BARC and BRIT [1-2]. A totally shielded steel room whole body counter located at BARC Hospital is used for the measurements of body/organ burdens of low energy photon (LEP) emitters like Pu/Am and U which emit photons of energy mostly below about 200 keV. For the assessment of internal contamination due to various fission and activation products like ^{141}Ce, ^{131}I, ^{137}Cs, ^{58}Co, ^{60}Co, ^{125}Sb, ^{106}Ru-^{106}Rh, ^{95}Zr-^{95}Nb etc. which generally emit photons of energy greater than about 150 keV, 'shadow shield bed' and 'shielded chair' types of whole body monitors located side by side at the whole body monitoring laboratory at Modular Lababoratories, BARC are used. These systems have been operating for more than three decades. Thousands of measurements on the radiation workers of BARC have been made under different types of internal monitoring programmes. The practice followed here has been that all workers are first monitored in the shielded chair, which serves as the quick screening counter. The selected few, who may show significant internal contamination, are then monitored in the shadow shield bed for detailed information. The shadow shield bed has also been employed to conduct in-vivo biokinetic studies of radionuclides present in the human body even at much lower levels (fractions of Recording Levels).

Thus, of the two whole body counters, the maximum counting load is handled by the shielded chair. This workload can be expected to be even more in radiation emergency situations. If a radiation emergency occurs after office hours, when the system operator / supervisor is not available it may not be possible to operate the counter immediately. At present, whole body counting facilities do not have an operator round the clock.

In view of the above considerations, we have converted the quick monitoring 'shielded chair' whole body counter into an automated, computer controlled, unattended, walk-in type of counter for internal monitoring of radiation workers. In this paper, the details of various hardware and software components of this system are presented along with the procedure how a

radiation worker can monitor himself without the system supervisor's help.

Materials and Methods

Shielded Chair Whole Body Counter

The shielded chair whole body counter which has been converted into an automated system is shown in Fig. 1. It is a self-shielding chair designed on the basis of the widely used Argonne tilting chair geometry [1-5]. In this configuration, the subject sits in a chair, which is shielded with about 15 cm thick mild steel from all around except the front and the topside. A (10 cm dia. X 7.6 cm thick) NaI(Tl) scintillation detector shielded with 5 cm lead all around except the face is mounted on a plate hinged to the side of the shielded chair through ball bearings and views the body from head to knees. Its shield weight is about 3 tonnes and it occupies a floor space of about 1m x 1m. The shielded chair, apart from its compactness, allows the monitoring time of a subject to be adjusted according to the level of activity in the body. Very often, it can provide useful information on the radiation status of a worker in just a counting period of 2-3 min., thus, making it extremely useful in radiation emergencies. However, it cannot provide any information on the location of radioactivity in the body which must be inferred either from the biokinetics of the detected radionuclide or by additional measurements in the shadow shield whole body radioactivity monitor.

Fig. 1. Photograph showing the shielded chair whole body monitor. Mounted on the top right side is the electrical motor along with its gear and pulley mechanism.

Hardware Components

For data acquisition and recording, standard instruments for gamma ray spectrometry, like preamplifier, amplifier, and multi channel pulse height analyzer (4K MCA - HPD model) connected to a PC with display unit, have been used. A schematic diagram of the hardware components is shown in Fig. 2. A 110 volts DC shunt motor with 100 mA current was geared down to two rpm and two end micro-switches were fixed for sensing the open and closed conditions of the door. The subject's sitting position is sensed by a set of micro- switches mounted under the seat on the chair and connected in parallel. Two DC relays (manufactured by M/s O/E/N India Ltd.) are used in the motor control unit for changing the polarity of the armature voltage for reverse movement of the motor.

A PC Add-on card type PCL-730 (32 channel opto-isolated digital I/O, manufactured by M/s Advantech Co. Ltd.) senses the status of the chair door (open or close), seat (occupied or unoccupied) and accordingly sends the command signal to motor drive to perform the required operation.

Software Components

Computer software for the unattended shielded chair whole body monitor has been developed to

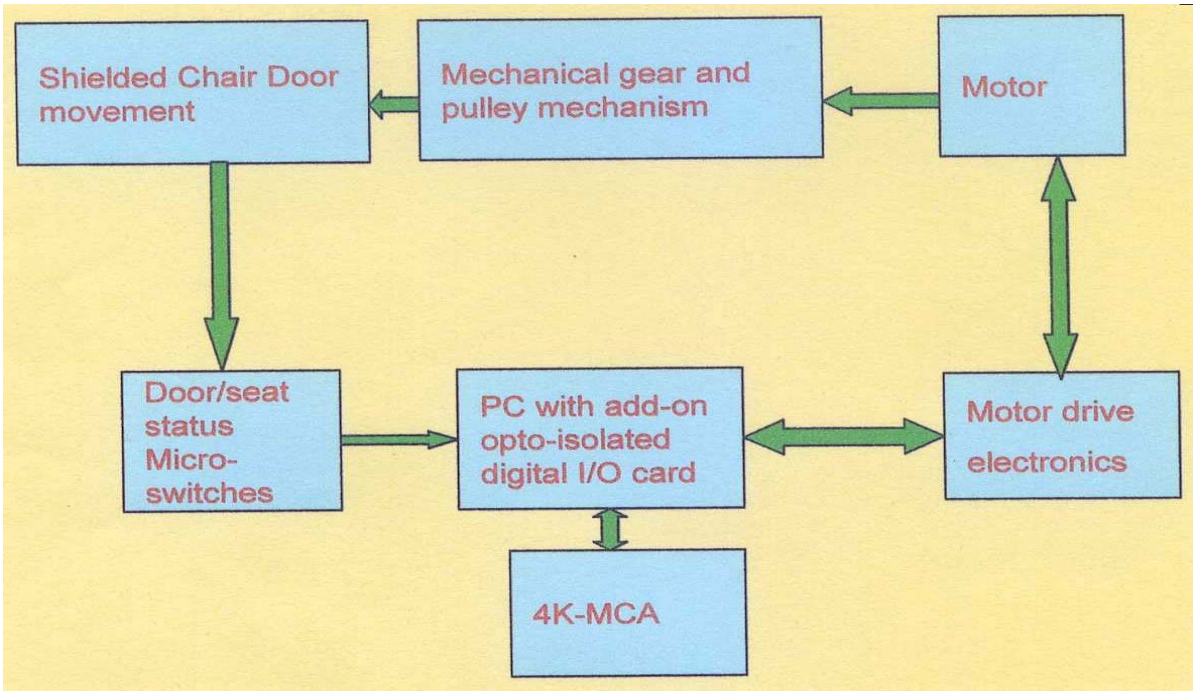

Fig. 2 Schematic diagram of the hardware of the shielded chair whole body counter showing various control and communication systems

cater to the different functions, viz., the control of electrical motor driven door mechanism of the chair for human access to the seat, data communication with pulse height analyser (4K-MCA), transfer and processing of gamma ray spectrum, calculation of intake and committed effective dose, maintenance of database for personnel, monitoring information and report preparation. The software uses Windows operating system and is developed by using Microsoft Visual Basic development tool with several modules. The block diagram of software modules for the automated whole body counter is shown in Fig. 3. A brief description of these modules is given below:

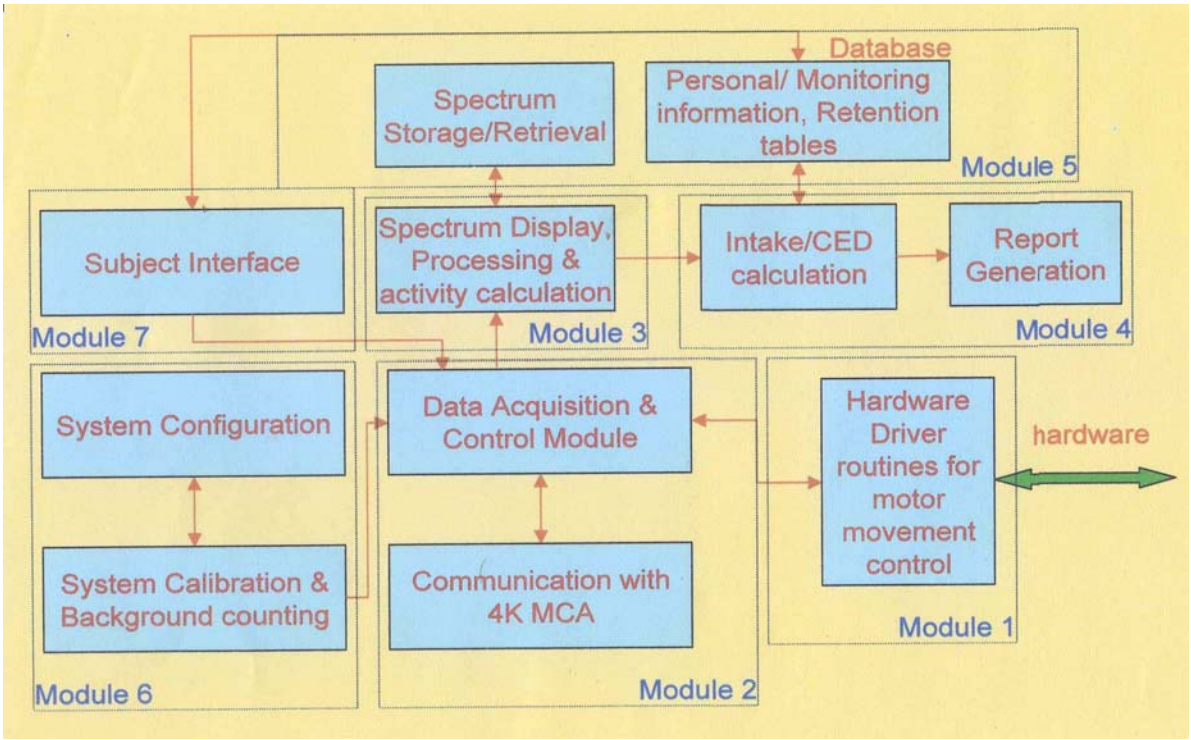

Fig.3 Block diagram of the software modules for the automated whole body counter

Module 1: Motor movement control and chair status sensing: This module is responsible for switching the motor on or off, rotation of motor in forward or reverse direction for opening or closing the chair door and sensing the status of the door and seat i.e. door open/close and seat occupied/unoccupied. This has been done by programming PCL-730 opto-isolated digital I/O card.

Module 2: Data acquisition and communication: This part of the software interfaces the serial communication port of the computer with the multichannel pulse height analyser for configuring various parameters of the analyser, automatic start and stop of data acquisition after sensing the occupancy status of shielded chair and transfer of the recorded spectrum to PC.

Module 3: Spectrum processing and activity calculation: This module helps the system supervisor perform calculation of normal uncontaminated subject background with the aid of weight and height ratio of the radiation worker, analysis of spectrum using simultaneous equations/stripping method and the calculation of retained activities of various radionuclides of interest inside human body using phantom calibration factors stored in the computer database.

To calculate subject background from the system background, empirical correlations between these two parameters and the W/H ratio of the subjects were developed (W- weight (kg), H- height (cm)). For this purpose, a large number of normal subjects of different physiques who worked in an inactive area were monitored. This method takes care of the variation in ^{40}K contents with body size and daily variation in the system background. The background with a water filled phantom without ^{40}K contents is also available in the computer memory which can be used for detailed analysis of the body scatter background without ^{40}K contributions.

Analysis of a photon energy spectrum of body radioactivity requires the identification of radio-nuclides responsible for its individual features. First, the calculated subject background is subtracted from the subject spectrum and then the net subject spectrum after back-ground subtraction is analysed. The stripping is used for unfolding the spectrum if the maximum number of radionuclides present is two and there is no overlapping of the peaks like in case of ^{131}I, ^{137}Cs and ^{60}Co. This is done by removing, one at a time, the components associated with each energy spectrum by comparison with previously determined calibrated spectral data. In each successive step, one component is removed and the resulting curve calculated, until by this stripping process, the entire curve is analysed. If gamma spectra is complex and has several closely spaced overlapping peaks, then the simultaneous equations method is used for analysis. For this, Compton fractions of photo-peak counts of various radionuclides in other regions of interest are determined using known amount of activity inside BOttle MAnnequin ABsorber (BOMAB) whole body calibration phantom[4]. The number of simultaneous equations, which are equal to the number of regions to be analysed, are solved using matrix algebra. If C is the column matrix of the total counts observed in various selected photo-peak regions and F is the matrix of Compton fractions of these radionuclides in various other regions of interest, then the column matrix P of the net counts due to these radionuclides in their respective selected photo-peak regions is given by [6]: $P = F^{-1}C$; where F^{-1} is the inverse of matrix F.

For the calibration of shielded chair whole body counter, locally made BOMAB phantom, filled with water, is used. Calibration data were obtained using photon energies, which cover the complete range for high-energy photons commonly occurring at the work place. Using this data, a graph between photon energy (keV) and the system efficiency (cpm. kBq^{-1}) is plotted for 100% emission. The calibration factors for other detected radionuclides are interpolated from this graph with the help of the percentage emissions of their relevant gamma ray energies.

Module 4: Intake, committed effective dose and report generation: The purpose of this module is

to extrapolate intake from the estimated retained activity of a radionuclide and then to calculate the committed effective dose. A database has been created from ICRP [7] graphs for inhalation, ingestion and injection cases of important radionuclides for the predicted activity m(t) as a function of time for unit intake. Two sizes of aerosols, viz. 1 µm and 5 µm AMAD, have been incorporated. Default value of 'mode of intake' is taken as inhalation and that of size of aerosols as 5 µm AMAD (in accordance with ICRP guidelines). If required, system supervisor can select other modes of intake as well as the aerosol size.

The time of intake for special and task related monitoring is known, but for routine monitoring the time of intake is generally, unknown. So, for routine monitoring, following ICRP guidelines, it is assumed that intake took place in the middle of the monitoring interval of T days. The intake is calculated from the measured quantity M [7], Intake I = M/m(t).

The intake is multiplied by the default ICRP dose coefficient value taken from ICRP Publications 68, 78 [7, 8] to get the committed effective dose. An intake in the preceding monitoring interval can influence the actual measurement result obtained. A correction is, therefore, made if more than 10% of the actually measured quantity is found attributable to the previous intervals, for which intake and dose have already been assessed. The calculated committed effective dose is compared with the recording level as well as with the investigation level. If committed effective dose exceeds recording level, then the result is recorded in the worker's dose record, otherwise it is ignored. If committed effective dose exceeds the investigation level, the reasons for it are examined and further investigations, e.g., follow-up measurements, are suggested for refining the internal dose estimates.

Module 5: Database handling: This module is responsible for the creation, editing, retrieval and maintenance of the personal information of the employees. It also stores the subject's monitoring data and the final results in the appropriate format. By the use of simple data entry screens, personal information can be fed to the computer.

Module 6: Main screen / system configuration: The top line of this screen is the pop-up menu. This consists of functions like file, communication, system configuration, user screen, computation, queries, report and quit. In file menu, there are options for loading a subject spectrum, a background spectrum or calibration spectrum for carrying out an analysis based on the earlier counting result. An option is also provided for saving the currently displayed spectrum in a file for future use. On clicking the communication menu, a communication window for interaction between the computer and MCA appears. The system configuration menu has options for energy calibration, selection of various spectral regions of interest (ROI), selection of counting time, background counting, etc. which the system supervisor can adjust according to the requirement. Computation and report options are used for computation of retained activity/intake/ committed effective dose and the report preparation. In query option previous monitoring history of a person can be recalled and analysed. Access to the system configuration module is password protected. By clicking user screen (subject interface screen), the system is kept ready for the automatic monitoring of the radiation worker where he enters his computer code.

Fig. 4 shows the main screen. Subject information along with the monitoring information i.e., subject and background counts per minute (cpm) in the selected ROIs, can be clearly seen. The main screen also displays the gamma ray spectrum acquired by 4K MCA and saved in the computer memory. The scale of displayed spectrum has provisions of reduction, enlargement and scrolling of cursor for giving

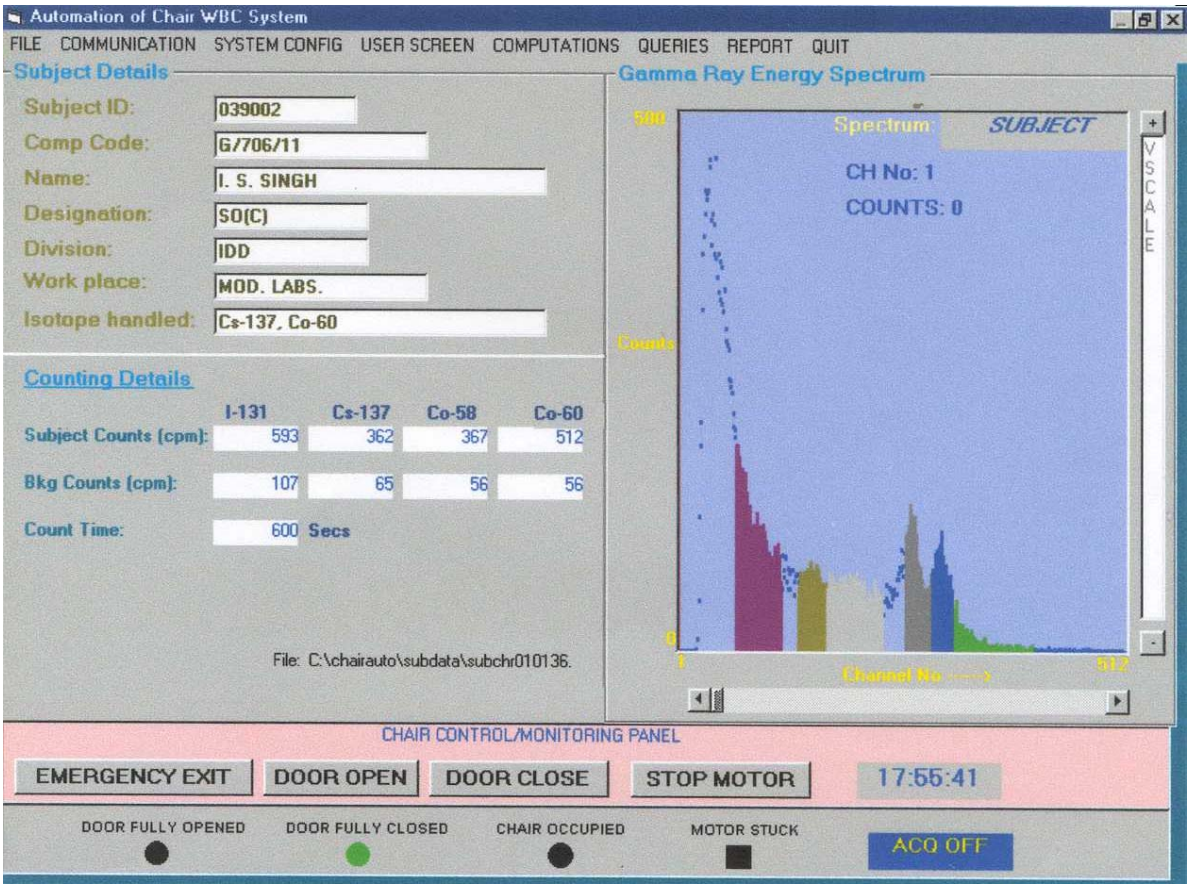

Fig. 4 Main screen of the computer display unit showing the subject information along with the monitoring information

channel versus counts information. Spectrum analysis includes most of the important radionuclides handled at the site. The 'Isotope handled' information is taken to critically analyse those radionuclides. The list of radionuclides under 'Subject counts' indicates the most commonly handled radionuclides which is built in the computer memory. Therefore, computer first displays the activity contents of these four radionuclides. Details of other radionuclides including those entered by the worker under the heading 'radionuclides handled' can be seen by clicking the pop-up menu 'computation' and 'Retained activity' respectively.

Highlighted dark bands visible in the spectrum are the energy regions covered for the radionuclides given under the list of 'subject counts'. The energy regions for other radionuclides can be highlighted by activating their ROIs. The bottom of the main screen has buttons, which provide functions like door open, door close, motor stop, emergency exit, etc. Online status of the whole body counting system, such as acquisition ON/OFF, door open/close, seat occupied/unoccupied etc. is displayed on the status line. A monitoring report gets generated from the system at the end of a counting schedule for communication to the worker's work place authorities. Detection limits (minimum detectable activity equivalent to 3σ of background) of this system for the important radionuclides like ^{131}I, ^{125}Sb, ^{106}Ru, ^{137}Cs, ^{95}Zr-^{95}Nb, ^{58}Co and ^{60}Co are 0.2, 0.275, 0.692, 0.230, 0.106, 0.2 and 0.121 kBq respectively for a counting period of 10 min. The detection limits for four commonly handled radionuclides are usually given in the monitoring reports.

Module 7: Subject interface screen: This module provides interface between the worker and the whole body counter. When the subject interface screen is on display, the worker to be monitored enters his computer code. If the personal record information of the radiation worker already exists in the computer memory, it will be retrieved and displayed on the screen. The personal details of a subject stored are - computer code, name,

division, work place, date of birth, date of joining the department, radionuclides handled or expected in the workplace and weight and height of the subject. If the subject's information is not available in the system, it has to be entered by the individual. Additional information required to be entered is subject's identification number, monitoring type, i.e., routine, operational or special. If the subject has been involved in handling ^{131}I, then it will ask for the date of Iodine handling because of its short physical half-life and importance from the viewpoint of radiation hazard. If these parameters are not entered, then the system takes the in built default values. Once this information is complete, the worker goes for automated mode of monitoring by pressing start-counting button.

General Methodology

The automated whole body counting system can be considered as consisting of two parts- the first being system configuration and the second subject – system interface. The system configuration is password protected where the system supervisor can perform the operations like energy calibration of the system, selection of regions of interest, background counting, analysis of spectrum, calculation of retained activity of radionuclides of interest inside human body, calculation of intake and the committed effective dose by entering the type of monitoring and finally, the preparation of monitoring report for communication to the respective plants/divisions. After performing operations like energy calibration, selection of regions of interest and counting time by the supervisor, system is ready for monitoring of workers. If the new calibration has not been performed, then the system will take the latest calibration data stored in the computer.

The monitoring of a subject in the absence of the supervisor is performed in the following sequence. The subject, ready for counting (after a thorough shower and change over to premonitored clothes), enters his computer code through the computer terminal attached with the system, (having 'subject interface screen' displayed) which then displays the subject's bio-data if available in the record and asks for modification/entry. After this, on clicking the start counting button motorized door opens, and the system asks the worker (audio instructions) to sit in the chair. The door then closes and the counting starts automatically for a preset time. At the end of counting, the door opens and the subject gets the message that the monitoring is over. The subject's monitoring information is saved in the database for future processing. After the subject leaves the chair, the door closes automatically and the system is ready for the monitoring of next subject. The system supervisor can assess and analyse all the data at any convenient time, and recommend further actions for those exceeding the recording levels.

Conclusion

A standard shielded chair whole body counter has been developed as a computer controlled, unattended, walk-in-type of whole body monitor for assessing internal contamination of radiation workers due to gamma emitting radionuclides. The system does not require the presence of an operator for in-vivo monitoring of the worker. The radiation worker himself initiates the processes for whole body monitoring by entering his personal computer code through the attached computer terminal. After the counting is over, he can simply walk away. The system supervisor can come at any convenient time and get the monitoring report printed for mailing to the appropriate authorities. The system has the required database and the software for calculating intake and the committed effective dose from the measured retained activities. The hardware and software developed are of generalized nature. With some modifications, they can be employed for automation of similar systems elsewhere. This type of system with trained staff is expected to be of immense value in case of emergencies as a quick monitoring system.

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BARC TRANSFERS TECHNOLOGY OF "ON-LINE DOMESTIC WATER PURIFIER"

The technology of "On-line domestic water purifier" has been developed by Desalination Division, BARC. This device is based on polysulfone type of ultrafiltration membrane, which is coated on a unique cylindrical configuration. This device on connecting to dometic tap purifies the domestic water with respect to micro-organism, colour, odour, suspended solids and organics. It is very effective as it removes bacteria to the extent of 99.99% (4 log scale) and removes complete turbidity and produces crystal clear water. This device does not need electricity or addition of any chemical. It is almost maintenance free except occasional cleaning of suspended solids which deposit on membrane surface and this does not take more than few minutes.

While signing the agreement on the occasion of technology transfer ceremony, seen from left to right are : Ms Renu Gupta, Director, M/s Ardee Hi-Tech Pvt. Ltd., Visakhapatanam, Dr G. V. Ramana, Director, M/s Ardee Hi-Tech Pvt Ltd., Visakhapatanam, Mr V.K. Upadhyay, TT&CD, BARC, Dr R.B. Grover, Associate Director, TC&IRG,BARC, and Dr B.M. Misra, Head, Desalination Division, BARC

It produces about 40 litres of pure water per day at about 5 psig head and works from 5 psig to 35 psig. The device filters out bacteria with no dead bacteria in the final filtered water. (All the raw materials required are produced within the country and are available locally).

Dr R.B. Grover, Associate Director, TC&IRG, BARC, handing over the Technology Transfer Document to Mr N.K. Baghla, Marketing Manager, M/s Filfab Corporation, Jaipur, after signing the agreement. Others seen from left to right are : Mr T.H. Salunke, TT&CD, BARC, Mr V.K. Upadhyay, TT&CD, BARC, Mr Sanjay Goel, Manager - Technicals, M/s Filfab Corporation, Jaipur, Mr A.M. Patankar, Head, TT&CD, BARC, and Dr R.C. Bindal, Desalination Division, BARC

Photograph after signing the agreement with M/s Natural Appliances, Neemuch (M.P.). Seen from left to right are : Mr V.K. Upadhyay, TT&CD, Dr R.C. Bindal, Desalination Division, Mr Aashish Agarwal, Engineer, M/s Natural Appliances, Neemuch, Mr Prakash Agarwal, Proprietor, M/s Natural Appliances, Neemuch, Dr R.B. Grover, Associate Director, TC&IRG, BARC, Dr B.M. Misra, Head, Desalination Division, BARC, Mr M.S. Hanra, Head, STS, Desalination Division, BARC, Mr A.M. Patankar, Head, TT&CD, BARC, and Mr B.K. Pathak, TT&C, BARC

While signing the agreement on the occasion of technology transfer ceremony, seen from left to right are : Dr R.C. Bindal, Desalination Division, BARC, Mr V.K. Upadhyay, TT&CD, BARC, Ms Snehal Kunwar R. Rathod, Partner, M/s Alfatech Fabricators, Thane, Mr R.S. Rathod, Manager - Technical, M/s Alfatech Fabricators, Thane, Dr R.B. Grover, Associate Director, TC&IRG, BARC, Dr B.M. Misra, Head, Desalination Division, Mr A.M. Patankar, Head, TT&CD, BARC, Mr B.K. Pathak, TT&C, BARC, amd Mr M.S. Hanra, Head, STS, Desalination Division, BARC

Dr R.B. Grover, Associate Director, TC&IRG, BARC, handing over the working model of Domestic Water Purifier to Ms Rajni Ram Chadha, Proprietor, M/s Aakar Technocrats, Nasik, after signing the agreement being watched by Mr Ram Chadha, Technical Consultant, M/s Aakar Technocrats, Nasik

Dr R.B. Grover, Associate Director, TC&IRG, BARC, handing over the working model of Domestic Water Purifier to Mr A.V. Suresh, CEO, M/s Aquamall Water Solutions Ltd., Hyderabad, after signing the agreement. Others in the picture, from left to right are : Mr R. Vednarayan, Sr. Product Manager, M/s. Aquamall Water Solutions Ltd., Hyderabad, Mr V.K. Upadhyay, TT&CD, BARC, Mr A.M. Patankar, Head, TT&CD, BARC, Mr S. Hanra, Head, STS, Desalination Division, BARC, Dr R.C. Bindal, Desalination Division, BARC, and Mr B.K. Pathak, TT&CD, BARC

Mr N.D. Sharma, Head, TCD, BARC, handing over the working model of Domestic Water Purifier to Mr I.B. Rao, Managing Director, M/s Power-one Micro Systems Pvt. Ltd., Bangalore, after signing the agreement. Others seen from left to right are : Mr G.M. Prasanna, Executive, M/s Power-one Micro Systems Pvt. Ltd., Bangalore, Mr M.R. Rajesh, Director-Marketing, M/s Power-one Micro Systems Pvt. Ltd., Bangalore, Dr B.M. Misra, Head, Desalination Division, BARC, Mr A.M. Patankar, Head, TT&CD, BARC, Mr V.K. Upadhyay, TT&CD, BARC, Mr M.S. Hanra, Head, STS, Desalination Division, BARC

The know-how of "On-line domestic water purifier based on ultrafiltration polysulfone membrane" was transferred to the following parties :

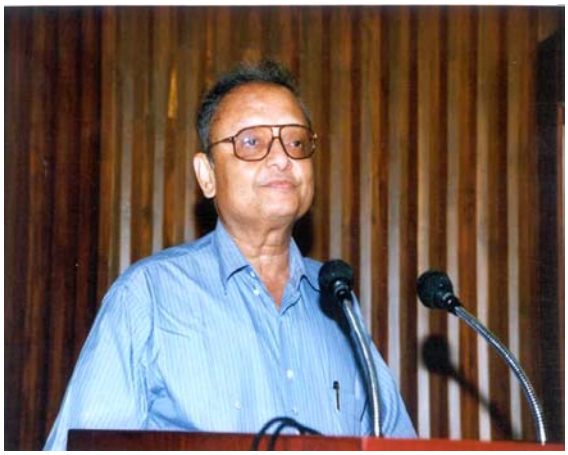
1. M/s Ardee Hi-Tech Pvt. Ltd., Visakhapatanam, A.P., on December 19, 2002.
2. M/s Filfab Corporation, Jaipur, Rajasthan, on December 26, 2002.
3. M/s Natural Appliances, Neemuch, M.P., on January 3, 2003.
4. M/s Alfatech Fabricators, Thane, Maharashtra, on January 8, 2003.
5. M/s Aakar Technocrats, Nasik, Maharashtra, on February 26, 2003.
6. M/s Aquamall Water Solutions, Hyderabad, A.P., on February 26, 2003.
7. M/s Power-one Micro Systems Pvt. Ltd.,Bangalore, Karnataka, on April 21, 2003.

TRAINING WORKSHOP ON RADIATION EMERGENCY PREPAREDNESS

The XIII Training Workshop on Planning, Preparedness and Response to Radiation Emergencies for Medical Officers was held under the aegis of Local Working Committee for Radiation Emergency Medical Response (REMR) of BARC at Niyamak Bhavan, AERB, during April 2-25, 2003 and was inaugurated by Mr B. Bhattacharjee, Director, BARC .

At the outset, Dr P.R. Bongirwar, Medical Officer-in-Charge of Trombay Dispensary and Chief Coordinator of the Workshop, welcomed the distinguished invitees, guests and delegates and said that though it was the thirteenth workshop in the series, it was on the second occasion that it was being held under the auspices of the Local Working Committee for REMR, BARC. He added that the workshop had attracted the maximum number (47) of delegates among the workshops held so far and that the delegates included top ranking medical specialists and super specialists from Mumbai's major hospitals, armed forces medical hospitals and medical officers from various constituent units of DAE.

Dr P.T.V. Nair, Head, Medical Division, BARC, and Chairman of Local Working Committee of Radiation Emergency Medical Response (REMR), greeted the delegates and said in his welcome address, that ionising radiation was increasingly being used in various fields and hence it was very crucial for doctors to know how to handle radiation emergencies and radiation injuries particularly in view of the fact that there is hardly any teaching done on this subject either at undergraduate or at postgraduate level in medical colleges and hence the imperative need for hosting this workshop. This would certainly help in filling the knowledge gap by dissemination of information and bringing clinical awareness about handling radiation injuries among the physicians. He also added that the workshop would help in creating a pool of trained physicians and help in developing further the integrated medical network system among different medical institutions as a matter of radiation emergency medical preparedness.



Mr B. Bhattacharajee, Director, BARC, delivering the inaugural address at the workshop

In his presidential address, Dr B.J. Shankar, Associate Director, Medical Group, BARC, and Chairman of DAE Steering Committee of Radiation Emergency Medical Response System (REMRS) said that it was necessary to go beyond the DAE family to spread the knowledge in the medical community. He stressed the fact that most cases of radiation injuries emerged from the practice of industrial radiography and hence the need for awareness among physicians for handling such cases of radiation burns. He further said that in the field of therapeutic and diagnostic radiology, the physicians also need to learn a lot about radiation protection measures and need to adopt and comply with the same stringently.

Photograph of the inaugural function. Seated on dais from left to right are: Dr P.R. Bongirwar, Medical Officer-in-Charge, Trombay Dispensary, BARC, Dr P.T.V. Nair, Head, Medical Division, BARC, Mr B. Bhattacharjee, Director, BARC, and Dr B.J. Shankar, Associate Director, Medical Group, BARC

Mr B. Bhattacharjee, Director, BARC, in his inaugural address, said that he always assigned a very high priority to training workshops, and complimented the Local Working Committee, REMR, for conducting the training workshop. He outlined the pressing need for increased production of electricity in India and said that use of nuclear energy was one of the best options available to us for eco-friendly power production. He gave a comprehensive overview of different radiation accidents that have occurred at global level and the lessons learnt therefrom. He also referred to the possibility of accidents during transportation of radioactive materials, inadvertent handling of orphan sources and the possibility of their misuse for nuclear terrorism. He reiterated the need for medical emergency preparedness to handle radiation emergencies in an integrated network system among medical institutions to effectively encounter radiation emergencies should they ever occur.

The valedictory function of the workshop was held in the afternoon of April 25, 2003. Dr S.S. Galinde welcomed the chief guest. Prof. S.P. Sukhatme, Chairman, AERB and other invitees.

Prof. Sukhatme distributed the certificates to the participating delegates and said in his Valedictory address that he appreciated the hosting of training workshop for bringing awareness about how to handle radiation injuries among medical fraternity at large. He referred to the excellent safety record in the operations of our nuclear power stations and the crucial role played by Atomic Energy Regulatory Board in regulatory functions.

Dr Ravi Jammihal and Dr Hemant Haldavnekar proposed the vote of thanks on the occasions of inaugural & valedictory functions, respectively.

भा.प. अ. केंद्र के वैज्ञानिक को सम्मान / BARC SCIENTIST HONOURED

• डॉ. के. पी. मिश्रा, अध्यक्ष, विकिरण जीव विज्ञान तथा स्वास्थ्य विज्ञान प्रभाग, भाभा परमाणु अनुसंधान केंद्र को फरवरी 2003 में लखनऊ में आयोजित सामान्य जन सम्मेलन में सोसाइटी ऑफ फ्री रेडिकल रिसर्च इन्डिया का उपाध्यक्ष निर्वाचित किया गया है। SFRR भारत को फ्री रेडिकल रिसर्च संस्था -एशिया तथा अन्तर्राष्ट्रीय फ्री रेडिकल रिसर्च संस्था के साथ सहबद्ध किया गया है। डॉ. मिश्रा ने भाभा परमाणु अनुसंधान केंद्र के प्रशिक्षण केंद्र से 12 वें बैच के द्वारा 1969 में भाभा परमाणु अनुसंधान केंद्र में कार्यभार ग्रहण किया, तथा जीव विकिरण उत्प्रेरित क्षतिग्रस्त आयनों में परिवर्तित क्रियाविधि में विस्तृत रूप से काम किया। कुछ वर्षो में ही इन्होंने जीव विकिरण अनुनादी इलेक्ट्रानिक चक्रण तथा प्रदीप्ति तकनीक का प्रयोग करते हुए जीव-विकिरण तथा मूल अनुसंधान के क्षेत्र में महत्वपूर्ण योगदान दिया। इस योगदान को मान्यता देने के लिये डॉ. मिश्रा को राष्ट्रीय वैज्ञानिक अकादमी, भारत का सम्मानित स्नातक चुना गया है।

Dr K.P. Mishra, Head, Radiation Biology and Health Sciences Division, BARC, has been elected Vice-President of Society of Free Radical Research-India in the meeting of the general body of the Society held at Lucknow in February 2003. SFRR-India is affiliated to Society of Free Radical Research-Asia and also to International Free Radical Research Society. Dr Mishra joined BARC in 1969 from the 12th batch of BARC Training School and has extensively worked on radiation-induced mechanisms of ionizing radiation induced damage in biological systems involving free radicals. Over the years, he has made significant contributions in the area of radiation biology and free radical research using Electron Spin Resonance and Fluorescence techniques. In recognition of his work on radiation and free radical biology, he has been elected a Fellow of National Academy of Sciences, India.