

Development of Thermal Electron Beams in BARC

– A. K. Ray

Seed for the development of Electron Beam Technology was sown in early-fifties at TIFR, Colaba under Prof. D. Y. Phadke, a professor of Physics. He had a very strong background on Vacuum Tubes, particularly Microwave Tube development. A group was formed under him for development of indigenous vacuum tubes. In mid-fifties, Shri C. Ambasankaran, working in Edwards Vacuum, UK and Shri Sitaram also from UK with experience in vacuum tube development joined the group. Shri Sitaram started development of sealed vacuum devices. Shri Ambasankaran took up development of vacuum pumps, diagnostics and vacuum systems, this group was later named Technical Physics Section with Shri Ambasankaran as its head. Shri Sitaram took up development of microwave tubes that culminated into SAMEER.

A number of young and enthusiastic scientists and engineers from IIT and BARC Training school joined the Technical Physics Section. That gave a boost to the Vacuum Science and Engineering activities aimed at developing vacuum pumps, vacuum instruments and systems. By late 1950s and early 1960s, Shri S. K. Iyyengar, a physicist, from second batch of training school, Shri S. T. Iyyengar, Shri P. T. Raju and Shri S. Ramaswamy were inducted and the group that was named as High Temperature Technology (HTT) Group. It started developing electron beam furnaces. Subsequently, Shri C. K. Shah, a mechanical engineer, after completing his MS in USA, Shri P. M. Varghese, Dr. A. K. Ray, an electronics engineer, from fifth batch of training school and another electronics engineer Shri S. C. Kumar from sixth batch of training school joined the group. During mid-1960s Technical Physics Section was designated as Technical Physics Division (TPD) and HTT Group was designated as HTT Section.

Internationally the first Electron Beam Melting furnace was reported around late 1950s. Shri S. K. Iyyengar, at that time, was already developing 7.5 kW melting furnace. It was developed in 1962 and performed very reliably. In the next few years a number of similar furnaces were supplied to Metallurgy Division of BARC, National Metallurgical Laboratory Jamshedpur and National Aeronautical Laboratory, Bangalore. By 1966, Dr. P. H. Ron developed one 6 kW Electron Beam Welder. These furnaces were extensively used for melting and welding of reactive and refractory metals. In 1968, Dr. A. K. Ray and Shri A. K. Sinha two electronics engineers from 11th batch training school joined the team. Dr. A. K. Ray was given the responsibility of developing electron gun and related optics while Shri A. K. Sinha was responsible for developing high voltage DC power sources. Shri S. C. Kumar was already working in developing DC power sources and the control system.

In 1972, newly formed Nuclear Fuel Complex (NFC) at Hyderabad wanted one 15 kW EB melting furnace. It was commissioned at NFC site during January 1974. The machine was extensively used to melt Tantalum that was supplied to ECIL for fabrication of tantalum capacitors.

With an aim to boost up plasma activities and to develop Magneto Hydro-Dynamic (MHD)

Generators with Russian collaboration, Dr. V. K. Rohatgi, an expert in Plasma Physics from Princeton University, USA, joined the division in 1970 and a new section named Plasma Physics Section which included Plasma and Electron Beam activities was formed in early seventies. By late 1970s the section was converted into a division named Plasma Physics Division (PPD), under Electronics and Instrumentation (E&I) Group. The division had three sections namely MHD Project headed by Dr. N. Venkatramani, Pulsed Power Section headed by Dr. P. H. Ron and HTT group was renamed as Electron Beam Technology (EBT) Section headed by Shri A. V. Thakur, a mechanical engineer from seventh batch of training school transferred from TPD.

During 1969-70 a need was felt to develop Pulsed Power Sources for industrial applications. First high current pulsed power source was developed by Dr. P. H. Ron. It could generate 100s of kA current pulses across a copper rod and was used to magnetise soft iron pieces. By mid 1970s it was decided to take up pulsed power activity in a big way. Mainly to develop high pulsed current and high pulsed voltage sources. A new section named Pulsed Power Section, under Dr. P. H. Ron and Shri S. K. Iyyengar, was formed. It shifted to a new location as they needed a large hall to develop High Voltage Pulsed Power Sources. This team, also, took up development of DC and RF accelerators and later named Pulsed Power Division.

Activities on development of EB melting, welding and evaporation continued under Shri A.V. Thakur. Sometime in mid-seventies, a requirement of one portable, local vacuum welder capable of 25 mm deep penetration in stainless steel, was felt. By 1978, the machine was developed and demonstration welds carried out successfully. Subsequently, the machine passed all the rigorous qualification tests set by the user division.

Shri S. C. Kumar, in the meantime, had developed one 150 kV, 6 kW DC power source. Shri S. K. Iyyengar took up the responsibility of building a graded vacuum chamber in mid-1970s so that electron beam generated by an electron gun could be brought to atmosphere to carry out welding. Here the scattering of electrons at higher pressures results drastic loss of electron energy thus welding of very thin stainless steel sheets was demonstrated. It was then decided to use the same power source to build a partial vacuum chamber welder so that the chamber evacuation time is much reduced and recycling time reduces. T. Vijayan, working with Iyngar, was pursuing his PhD under Dr. Rohatgi on electron optics and electron guns, joined the group and helped in developing the 150 kV, 6 kW electron gun. Shri A. K. Sinha made a number of improvements in the design, layout and component assembly of 150 kV, 6 kW power source. He changed the vacuum rectifiers to solid state rectifiers. The welder was developed by 1983 and a large number of welds for various agencies were carried out. It served as a work horse for next one and a half decade. Shri T. K. Saha, joined the division in early 1980s, was entrusted with the responsibility of operating and maintaining the welder and improving the work handling and optics of the welder. With able assistance and guidance he did an excellent job and became an indispensable member of the team. Shri P. T. Raju and Shri P. M. Varghese, since the TIFR days have been very important part of the team. Shri Varghese was a vacuum expert. In those early days his expertise was not only sought by scientists and engineers from within BARC but also from out side BARC like Tarapur Atomic Power Station and Tata Thermal Power Station, Trombay. Since early 1970s, it was felt that a number of equipment and techniques developed in Technical physics Division, like fabrication of diffusion pumps, freeze drying equipment, electron beam melting furnaces and mass spectrometers developed in house should be transferred to an industry which has a some experience in vacuum science and engineering. After a rigorous search it was found that Engineering Division of Indo-Burmah Petroleum (IBP) Co, a government of India undertaking was a suitable agency. An MoU was signed with them in mid-1970s. Under the MoU Shri A. K. Gupta, an eighth batch training school physicist, working in the field of vacuum Physics and Engineering was deputed to IBP in 1976. Shri P. T. Raju from

our section was deputed to IBP in early 1980s for technology transfer on EB melting. There were demands for a number of EB melting unit from National Laboratories, this technology was transferred first. The first EB melting unit that was developed under this MoU was a 15 kV, 15 kW unit for Metallurgy Division, BARC. Two more units were supplied by IBP to Nation Physical Laboratory, New Delhi and IGCAR, Kalpakkam.

As mentioned above, the 150 kV partial vacuum welder was being regularly used for welding of jobs from different organisations, public as well as private. In late eighties Machine tool Prototype Factory (MTPF) at Ambernath, under Ordnance Factories Board came with the proposal for welding of maraging steel coronets, for cluster bomb development. In next couple of years thousands of such components were welded. Shri Saha played a major role in this. Observing the excellent performance of the welder, MTPF put up a request to develop a welder for them but with a larger work chamber and higher vacuum system. The welder at BARC had a 1 m x 1 m x 1.5 m size chamber operated at a vacuum of 10^{-3} mbar. They asked for a 2 m x 2 m x 2.5 m chamber operating at a vacuum of 10^{-5} mbar. Under the BARC – IBP MoU the order was placed with IBP and BARC provided the consultancy. Two of our brilliant engineers Dr. Namita Maiti, electrical engineer from 30th batch of training school joined in 1987 and Shri Martin Mascarenhas, electronics engineer from 33rd batch of training school joined in 1990 along with Shri Varghese, Shri Raju, Shri Saha, Shri Sinha and Dr. Ray comprised of BARC team. The collaboration worked very well and the welder was commissioned at MTPF in late 1990s. During late 1980s thin film coating by EB evaporation and DC magnetron sputtering was taken up to investigate hard coating for industrial applications. As magnetron sputtering activity was new to us it was taken up first. It was built with the available components and hard coatings of TiN were generated. Test results as carried out by Metallurgy Division were encouraging. It was then decided to go deeper into the mechanism and try newer compounds. A number of studies on hard coatings were carried out that resulted in one PhD from IIT Bombay.

Dr. Namita Maiti, joined IIT Bombay for her MTech degree. After that she took up EB evaporation work and built a 10 kV, 15 kW EB evaporator for high rate evaporation. The beam shape generally was elliptical. It was then felt that as for various experiments sheet type vapour are needed for wide area deposition, we should develop strip type electron guns to generate strip beams. Dr. D. Das and Dr. K. B. Thakur two very good scientists from Training School, 18th and 21st batch respectively were interested in development of strip beam for their studies and collaborated with electron beam group. They met with very good success and carried on their studies on metal vapour during early 1990s. It was then decided to build 60 kV 200 kW evaporation system. Dr. A. V. Bapat after his MTech in Mechanical Engineering from IISc, Bangalore joined MHD project of Plasma Physics Division in 1976. In early 1980s he completed his PhD from IISc After successful completion of the MHD Project he joined the Electron Beam Technology Section in 1988. Dr. Bapat took the responsibility of building the vacuum and work handling system for the evaporator project. Gradually he built a very strong team of that catered to the requirement of the whole of Plasma Physics Division.

Shri E. Kandaswamy, MTech in Electrical Engineering joined in 1996, Shri R. L. Bharadwaj, MTech in Power Engineering joined in 1998, both of them were Post graduate Trainees from Training School. Smt. Ranjana, electronics engineer, from Training School joined the section in early 2002. All of these young engineers were involved with the various sub systems of the 200 kW evaporator and have contributed immensely.

During mid-2000s, it was decided to park one EB welder in the old Training School Building at South Site, BARC which could cater to the industry requirements. One 60 kV, 12 kW welder was developed by Shri Sinha, Dr. Bapat, Shri Martin, and Shri Kandaswamy. Dr. Maha Nand Jha a mechanical engineer from training school joined the team in 1998. The welder was commissioned within a short time. The parameters of the welder were computer

controlled. It was used to carry out jobs for various institutions. IIT, Kharagpur wanted to procure such a welder. One welder was built for them and delivered during early 2010s, it was installed at the Department of Metallurgy. Dr. Maha Nand Jha took interest in EB welding and did his PhD on EB welding from IIT, Kharagpur. The machine has been extensively used by the students for their research and generated a large number of papers in reputed journals.

Shri Pravanjan Malik, MTech in Power Engineering from training school, joined in 2010 and started working with Shri Martin in developing high voltage Power sources and controls. Shri Sachin an electronics engineer joined the team from training school in 2011 and started working on electron gun development with Shri Kandaswamy. Shri Baibhaw Prakash, a mechanical engineer, from 2015 batch of training school joined the group under Dr. Jha. One 6 kW, table top EB melting unit was developed for Atomic Fuel Division, BARC and commissioned at their Laboratory. The machine is working satisfactorily.

NFC, Hyderabad had put a requirement for one 300 kW EB Melter. The design was finalized by mid-2010s. Dr. Jha, Shri Prabhaanjan and Shri Sachin were involved in this development and incorporated a number of improved features that made the operation very reliable. It was supplied in mid-2010s and is working to the satisfaction of the user. Subsequently, one small EB welder for use in a glove box was built and is working very satisfactorily.

The thermal Electron Beam Group has been consistently developing different types of welding, melting and evaporation equipment of high performance to the satisfaction of users. It has a number of new projects lined up for implementation and persistent efforts are being made to improve the quality and reliability of the smallest of components of the EB systems. The road ahead has many challenges and the team is ready to overcome them.