

# Accelerator and Pulsed Power Development in BARC

– P. H. Ron

---

8.1	At Technical Physics Division (TIFR Campus)	66
8.1.1	Electron Beam Technology	66
8.1.2	Exploding Wire (EW)	66
8.2	At Technical Physics Division (Trombay Campus)	66
8.3	At Plasma Physics Division (BARC Campus)	67
8.3.1	Pulsed Power Technology	67
8.3.2	Pulsed e-beams & Applications	67
8.3.3	Pulsed High Magnetic Fields	67
8.3.4	EMI/EMC Technology	67
8.4	At Neutron Physics Division (BARC Campus)	68
8.5	At APPD (BARC Campus)	68

---

APPD was formed in 1992, with Dr. P. H. Ron as its Head. The mandate of APPD was indigenous development of devices and applications of: (1) Industrial Electron Accelerators and (2) Pulsed Power. As we take a stock at APPD in 2020 with Dr. Archana Sharma as its Head, it has been making significant impact in multi-disciplinary research fields, industry, defence and nuclear power programs. The present day numerous activities of APPD owe their origin to the past innovative programs carried out at different divisions of BARC by highly talented scientists. A brief resume follows.

## 8.1 At Technical Physics Division (TIFR Campus)

### 8.1.1 Electron Beam Technology

At the initiative of Shri C. Ambasankaran, former Head TPD & Director E&I Group BARC, the program for development of DC high power electron beam was started in 1959 at TPD (Technical Physics Division), part of which was then located at the TIFR Colaba campus. The program was implemented by Shri S. K. Iyyengar, a 2nd batch physics trainee and later joined by Dr. P. H. Ron, a 5th batch engineering trainee. Shri C. K. Shah, a mechanical engineer who had just returned from US, headed this section later and brought professional quality to the programs & devices. The DC e-beam applications were oriented to meet the future needs of melting and welding of special materials not amenable for conventional processes.

### 8.1.2 Exploding Wire (EW)

These studies, just beginning to appear in international research, were started out of curiosity by Dr. P. H. Ron at the TPD, in the hutment of TIFR complex in 1963. A small energy storage capacitor bank with spark gap as a high voltage closing switch was developed for the purpose. The studies were conducted on the fascinating phenomenon of EW plasma. Expertise was gained in the recording of low-level fast signals, stepped down from extremely short pulses of high voltage and current, in highly interfering environment. This experience was to later evolve into a major program on EMI/EMC at APPD.

To support both the above activities, there was an extremely shy but skilled Diploma holder in Shri S. T. Iyengar, who in a very short time mastered the art of vacuum technology as well as building high voltage supplies.

## 8.2 At Technical Physics Division (Trombay Campus)

Some time in late 60s, the TPD activities at TIFR complex got shifted to BARC campus at Trombay, and were allotted PRIP shed at north site located behind Engg. Hall-1. It was here that brilliant engineers like Shri A. V. Thakur, Dr. A. K. Ray, Shri A. K. Sinha after graduating from BARC Training School joined the program of DC e-beam program. Many interesting applications of EW such as pulsed high temperature dense plasma generation, shock waves under water and its applications to metal forming were effectively demonstrated. This program of EW pulsed plasma later became so evolved and expanded at APPD, that it lead to deep investigations with new findings into the electrical breakdown phenomenon in vacuum resulting in a large number of high quality international publications and as well earned a PhD degree for Dr. P. H. Ron.

## 8.3 At Plasma Physics Division (BARC Campus)

The TPD had grown to a very big size, with numerous highly specialized activities. With a view for optimum functioning, some of the programs were taken out of TPD and included in a newly created Plasma Physics Division (PPD) in late 70s with Dr. V. K. Rohatgi, who had just returned from US, taking over as its Head. The major programs of the Division were MHD, Plasma Torch Technology, DC e-beam technology and pulsed power facilities. Due to nonavailability of localised single large space at BARC, the PPD activities were carried out at south site shed of Electronics Division and north site PRIP shed. At the PPD, the program of DC e-beam reached high standards and made big impacts. Advanced high power DC e-beam equipment were later supplied to SMP/NFC at Hyderabad and other defence labs. It was at PPD that a pulsed relativistic electron beam technology was demonstrated with field emission from cold cathode driven by a Marx impulse generator. Simultaneously, a pulsed high magnetic field (10 Tesla) with a simple 25 kJ capacitor bank and its capability to cold welding of copper-Aluminum was demonstrated at the south site ED shed. A large number of re-charging and de-charging of permanent magnets were carried out for indigenous and defence applications. Based on the confidence obtained in these indigenous developments and rapidly progressing international developments in pulsed power with its great potential for strategic applications, very ambitious pulsed power programs were proposed at PPD and accepted. However, it was not possible to implement such huge programs without the availability of a Building of high ceiling with crane facility. In a highly contested competition for space by many priority programs, Engg. Hall-4 was allotted to pulsed power activities. The accelerated development of the following programs happened at Hall-4.

### 8.3.1 Pulsed Power Technology

Multigigawatt pulsed power systems based on drivers (Marx or Tesla transformer) pulsed charging a PFL (water or oil insulated) and switched into a matched load by a fast spark gap switch were developed. Pulsed power systems based on magnetic pulse compression and LTD were also developed. LTD is a wonderful concept of combined capacitive and inductive energy storage.

### 8.3.2 Pulsed e-beams & Applications

The multigigawatt pulsed e-beams produced in single cavity or accelerated in multiple cavities were suitably configured to produce flash X-ray, high power microwaves, high power laser excitation, plasma heating, material irradiation, and many such applications. A flash X-ray system was commissioned in a defence lab for ballistics research. Detailed investigations were carried out to study the effects of HPM on electronic systems.

### 8.3.3 Pulsed High Magnetic Fields

A high magnetic field device energised by an advanced capacitor bank was successfully used in nuclear reactors at Narora and Kakrapar for garter spring repositioning. Feasibility studies based on pulsed high magnetic fields have demonstrated effective magnetoforming.

### 8.3.4 EMI/EMC Technology

Electromagnetic Compatibility is important because of intense electromagnetic fields produced by the operation of pulsed power systems. This radiation in addition to causing possible damage to sensitive electronics will also result in faulty measurements. Expertise has been developed for effective shielding and protection.

## 8.4 At Neutron Physics Division (BARC Campus)

When Dr. V. K. Rohatgi retired, the pulsed power and pulsed e-beam activities along with staff were taken out of PPD and transferred to NtPD. Head, NtPD, Shri M. Srinivasan was a great & good scientist and gave full freedom and needed resources for pulsed power activities to be continued as before at Hall-4.

## 8.5 At APPD (BARC Campus)

As mentioned at the beginning, APPD was formed in Feb.1993 with Dr. P. H. Ron as its Head. The following is a resume of the APPD activities.

- (1) The design of conversion of 5.5 MV Van-de-Graff into a 7 MV Folded Tandem Ion Accelerator (FOTIA) was earlier conceived by Shri Hattangadi, who was in charge of PELLETRON. An Engineering Design Committee was formed under the chairmanship of Dr. P. H. Ron. The implementation was done by a team comprised of Dr. P. H. Ron, Shri R. Mazumder, Dr. Bhagwat, and Dr. Pitamber Singh. The successful commissioning of FOTIA was considered a great contribution for furthering nuclear research at BARC campus.
- (2) Garter Spring Repositioning (GSR) in the nuclear power plants at Narora (NAPP) and Kakrapar (KAPP) was implemented by a team comprised of APPD, RED and AFD. After successful repositioning at many channels, an accident happened and the high field coil burst while inside the K19 channel. The coil was badly damaged. The diagnostics team of NAPP swung into action and came to the conclusion that the inside surface of the K19 channel had suffered damage. However, the work on GSR continued and the remaining channels were handled successfully. A hard decision was taken by NAPP to commission the reactor without fuel in K19. However, a detailed diagnostics carried out later by a very competent AFD team, headed by Shri P. G. Kulkarni, concluded that there was no damage to the interior surface of K19 channel, and that it was only a simple sticking of insulation tape on the channel surface. In retrospect, NAPP had made a faulty decision and it was a big relief that an undeserved blot on APPD was removed.

Garter Spring Repositioning at KAPP was implemented very successfully. Thus APPD's pulsed high magnetic field program resulted in an immense breakthrough contribution to the nation development. In a recent conversation with Dr. P. H. Ron, Dr. Anil Kakodkar, former Chairman DAE, expressed that if GSR was not successfully done, there was a danger of discontinuation of PHWRs in India. The APPD team of engineers was comprised of Dr. P. H. Ron, Shri R. K. Rajawat, Dr. K. V. Nagesh, Shri R. S. Kalghatgi, Shri K. Nanu, Shri S. T. Iyengar, Shri Fernandis and Shri Narvekar.

- (3) Dr. A. P. J. Abdul Kalam (former Advisor Defence Ministry and later honourable President of India) was deeply interested in the Pulsed High Power Microwave (HPM) effects on electronic systems and had visited APPD facilities in Hall-4. A meeting called by Dr. A. P. J. Abdul Kalam, which was attended by Dr. P. H. Ron and Directors of LRDE and MTRDC. A review was done of the results of HPM collaborative work done by APPD jointly with DRDO labs of LRDE & MTRDC. As a result, an operating pulsed power e-beam facility KALI-200 developed at APPD was commissioned at LRDE, Bengaluru for furthering the HPM studies.
- (4) APPD had developed powerful programs of pulsed power technology of international standard. In these programs, energy storage systems were designed & implemented by a team comprised of Dr. P. H. Ron, Shri R. S. Kalghatgi, Dr. K. V. Nagesh, Shri R.

K. Rajawat, Dr. Archana Sharma, Shri K. Nanu, Shri R. Majumder and others. The pulsed e-beam generation and transport were handled by a team of physicists comprised of Shri S. K. Iyyengar, Shri A. S. Paithankar, Dr. K. C. Mittal, Shri S. N. Acharya and others. Shri R. K. Rajawat was strong in theory and possessed an analytical mind. Dr. K. V. Nagesh was excellent in the design of Tesla transformers. He earned PhD for his work on low pressure spark gap operating in a burst mode. Dr. Archana Sharma was very hard working, extremely sincere person and excellent team manager. From IISc, Bangalore; She earned her MSc (Engg) and PhD for her work on LTD and magnetic saturation switches which led the milestone of repetitive pulsed power system. Shri K. Nanu was shy, intelligent, helping nature, practical and possessed ability to fix up trouble spots in any system.

- (5) Another powerful program at APPD, in parallel to pulsed power technology, was development of Industrial Electron Accelerators. The fore-runner for these programs was a 500 keV accelerator, designed by APPD and commissioned at BRIT facility at Vashi, Navi Mumbai. In all the industrial electron accelerators, the e-beam is generated, propagated and scanned in vacuum. The e-beam is brought out into atmosphere through a thin foil and impinges on products on a moving conveyor belt for irradiation. The product conveyor needs to be installed in a radiation shielded vault. The inaugural commissioning of the 500 keV accelerator was done by honourable former Prime Minister of India, Shri. Atal Bihari Vajpayee in 1998. Based on the expertise developed on this first accelerator, a very ambitious program of indigenous development of industrial accelerators was proposed and accepted. A steering committee was constituted under the chairmanship of Dr. P. H. Ron to plan for a dedicated ELECTRON BEAM CENTER (EBC). The result of this was construction of a huge EBC Building at Kharghar. Two accelerators: one based on Cockcroft- Walton Multiplier (CWM) and the other a LINAC, were proposed & designed. The design team for EBC accelerators was comprised of Dr. P. H. Ron, Dr. R. C. Sethi, Shri R. S. Kalghatgi, Dr. Kavita Dixit, Shri K. Nanu, Shri C. Vishwanadham, Shri R. Majumder, Dr. B. N. Karkera, Shri R. I. Bakhtsingh, Shri S. K. Iyyengar, Shri A. S. Paithankar, Dr. K. C. Mittal, Shri S. N. Acharya and others. The radiation shielding was handled by RSSD. The coordinators were: Dr. P. H. Ron for the CWM; Dr. R. C. Sethi for LINAC; Dr. B. N. Karkera for EBC Building layout, conveyors and computer controls; Shri S.K Iyyengar for beam generation & transport; Shri Vishwanadham for vacuum systems and Shri Majumder for mechanical engineering design & fabrications. Dr. P. H. Ron was thoughtful with focused attention and tough when necessary. Dr. R. C. Sethi was brilliant, task master and totally result oriented. With his experience on setting up RFQ facility at NPD, and having developed a talent pool of scientists, he handled the LINAC facility efficiently. Dr. B. N. Karkera was very energetic, hard working, good coordinator and excellent in computer controls. Dr. K. C. Mittal a cool performer.
- (6) Development of pulsed power technology was complicated because it was heavily dependent on importing of numerous components. For this purpose, a close collaboration was established with industry for indigenous development. The major partners in this respect were: YASHA Electricals at Baroda for energy storage capacitors, LENZOHM at Deonar, Mumbai for high strength high magnetic field components, ZEONICS at Bangalore for specific cables & diagnostic facilities.
- (7) APPD had established close association with teaching institutions for APPD staff to give lectures and conduct semester courses on pulsed power technology. A collaboration was established with IISc, Bangalore to allow external registration and submission of thesis of work done at BARC, subsequently leading to the award of academic degrees to outstanding work done at APPD. This was a deeply appreciated incentive for dedicated

scientists and lead to enhanced quality of research results.

- (8) The continuing growth and evolution of APPD owes its origin to the support, freedom and love given by Shri C. Ambashankaran; Dr. R. Chidambaram and Dr. Anil Kakodkar, former chair persons of DAE.

It remains relevant till date with sustainable support of all seniors and sincere efforts of all BTDG team.