# OPERATING EXPERIENCE OF 10MeV INDUSTRIAL LINAC

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*Abstract*

For the past three years, an Industrial 10MeV RF Electron linac has been in operation at Electron Beam Centre, Navi Mumbai. This pulsed linac has an on-axis coupled cavity bi-periodic π/2 structure and operates at frequency of 2856MHz. The linac has been tested up to a maximum beam power of 5kW and is being used for industrial applications. A successful 24-hour continuous run, at 3kW, established the long term stability of all the linac parameters.

This paper describes the high power operating experience of the 10MeV linac. Details of RF conditioning and performance of the linac during long term tests is presented. Effect of various linac parameters, including injection voltage, RF input power, PRF, gun filament heating power, on the output beam power and energy has been discussed.

## LINAC DESCRIPTION

A 10MeV RF Industrial Electron LINAC [1] is in operation at EBC, Kharghar. Specification of LINAC is given in Table 1 and the system layout is given in Fig. 1. As the beam power requirement is 10kW, a Klystron based RF source of 6MW peak & 25kW average power rating is used. This is a Multi-beam Russian klystron (Toriy make) having beam perveance of 21μPerv. For this, a line type Klystron Modulator of rating 55kV, 270A, 10μsec, 400Hz is designed & developed by SAMEER. Microwave components like directional couplers, circulator with matched loads, bends with arc detectors and RF window are used for transmission of microwave power from Klystron to LINAC. Pulsed driver amplifier of 110W was used to give low RF power to Klystron input cavity.

Table 1: - 10MeV LINAC Specifications

| | |
|---|---|
| Operating Frequency | 2856 ± 2 MHz |
| Output Beam Energy | 10 MeV |
| Peak Beam Current | 250 mA |
| Beam Pulse Width | 10 μsec |
| Pulse Repetition Frequency | 400 Hz |
| Average Output Beam Power | 10 kW |
| Microwave I/P Power to LINAC | 6 MW peak, 25 kW average |
| Electron source | 50 – 70 keV, 1 A (peak); $LaB_6$ based |
| Length of Accelerator section | 871 mm (33 cells) |

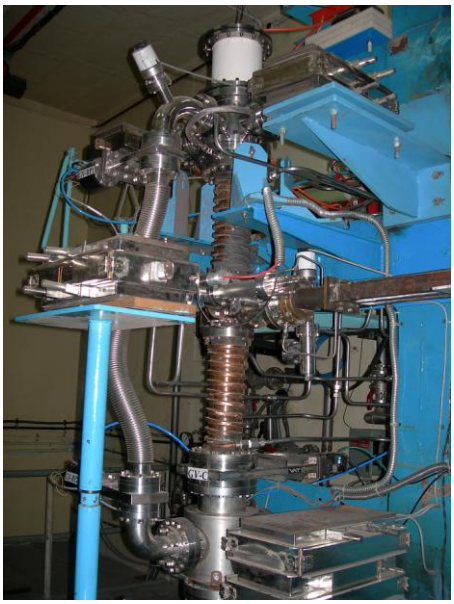


Figure 1: 10 MeV Linac system layout.

A 70kV, 1A thermionic indirectly heated cathode ($LaB_6$ Pellet), Triode Electron Gun [2] was designed and developed by APPD, BARC. The line-type Electron gun modulator is designed to produce 10 μs pulses at a negative voltage of 70 kV max. The Grid is biased at typically 1kV (negative w.r.t. the cathode).

For scanning the products, C- shaped Magnetic Sweep Scanner (MSS) made from silicon steel laminations is used. A maximum magnetic field of ~1.5 kgauss is maintained between the pole pieces, which are separated by a gap of 50 mm. The scan horn chamber, made of SS304, has the overall dimensions as 1005 mm × 1200 mm × 279 mm.

Vacuum to air interface is taken care of by a 50 μ thick Titanium foil. A vacuum level in the range of $10^{-07}$ Torr is required to be generated and sustained for holding an electric field of about 60 MV/m inside the cavity, thereby minimizing the arcing and related problems.

The Vacuum system of 10MeV linac comprises of 5 no's of SIPs (operated continuously) maintain the required vacuum (in range of $10^{-7}$ Torr). 2 no's of 70 l/s SIPs at the Gun, 1 no of 70 l/s at the Linac RF feed, 2 no's of 140l/s in the drift and scan-horn region post acceleration. A 400l/s TMP is used for the initial pumping during maintenance only.

DM water or Low Conductivity water (LCW) is desired for cooling of the accelerator components. Two cooling lines of 90 psi & 45 psi are installed for various linac components. Total flow capacity of LCW plant is 400 litres/min. An air blower system for ventilation and ozone removal has been installed

## LINAC TEST RESULTS

Klystron based RF source was first tested on water load. Klystron was first operated in the diode mode and its V-I characteristics were measured. Beam perveance of 21µPerveance was measured. Klystron was tested up to peak forward power of 5.5MW at modulator parameters of 50kV, 235A. Reflected power was less than 1%. All these tests were done at PRF of 50Hz.

### *RF Conditioning of LINAC Cavity*

Initially frequent arcing was observed at RF peak powers as low as 0.5MW. The arcing was accompanied with heavy out-gassing in the linac region, and total power reflection. Subsequently frequent arcing reduced after the RF conditioning of cavity. It took ~250 hours for conditioning of the linac to 4MW at 400 pps. During the RF conditioning of the linac cavity, a vacuum of $3.0 \times 10^{-7}$ mbar was maintained throughout the complete linac system. The reflected power was <10% of the forward power at resonance, for all the forward power levels.

### *High power beam results*

After conditioning the LINAC cavity with RF power, electron beam was injected into the LINAC cavity. LINAC was operated for ≥5hours at each beam power of 1kW to 4kW without any breakdown. The curves of E-Gun injection voltage, Klystron current & Output beam current is shown in Fig2.

Dependence of Beam energy on beam current & RF power (Theoretical analysis) is shown in Fig. 3.

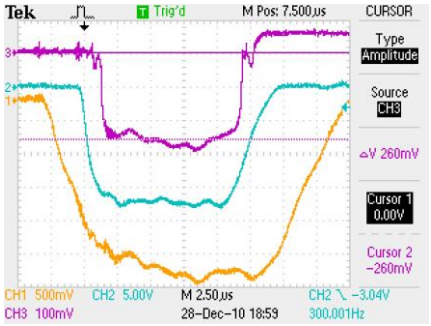
With increase in E-Gun injection voltage up to 67kV, output beam current of 165mA was measured. LINAC System was operated at maximum beam parameters of 10MeV, 5.6kW for ~1hour.

A 24hour test run of the LINAC was done to verify its stable and safe operation. The LINAC was operated at beam energy of 10MeV & beam power of 3kW. The beam current was 100mA, PRF was 300Hz, and microwave power was set at 3.25 MW. The system operated successfully for 24 hours.

Now, system is routinely being operated at 3kW for various Industrial and R&D experiments.

### *Experimental Analysis*

Various experiments were to done to check the effect of various RF & beam parameters. Beam current increase is ~25% with increase in RF power from 1.5MW to 3MW. Beam current increase is ~50% with increase in E-Gun injection voltage from 25kV to 50kV.Beam current increase is ~65% with increase in Gun Filament power from 200W to 250W. With PRF increase from 50Hz to 250Hz, Beam current increases by 30%.




CH1: E-Gun Injection Voltage; 50kV

CH2: Klystron current; 174A

CH3: Output beam current; 100mA.

Figure 2: Envelops of E-Gun voltage, Klystron current & Output beam current

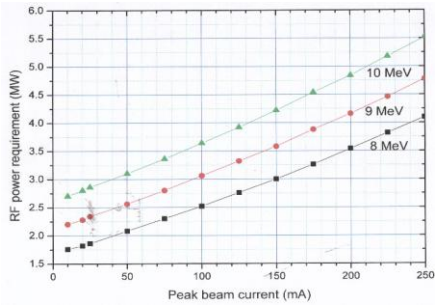



Figure 3: Beam Energy Relation with Beam current & RF Power

### *X-Ray Mode Operation*

A 1.8mm thick tantalum sheet was placed at a distance of 150mm from the titanium window to produce X-rays. X-ray measurement was done at different electron beam energies. X-ray energies from 3.0 MeV to 3.8MeV were measured by varying the Klystron forward power at different beam currents.

### *Dosimetry Experiments*

Dosimetry experiments were done using B3 films at 10MeV, 3kW linac parameters for full 1m of beam scan width. This was done at 460mm from Ti exit window at various conveyer speeds. For 0.1m/min of conveyer speed dose rate of 21kGy/min was measured. This dose was linearly dependent on the conveyer speed.

## CONCLUSION

The 10MeV LINAC system is reliably being used for industrial applications at 3kW beam power.

## REFERENCES

[1] K.C. Mittal, “Accelerators at Electron Beam Centre, Kharghar,” Proc. InPAC 2006, page 98-101.

[2] Dhruva B, et al, "Operational Experience and modifications in Electron Gun for the 10 MeV RF linacs ", these proceedings