# ELECTRON ACCELERATORS FOR ELECTRON MICROSCOPY IN THE 1 MEV RANGE

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This paper describes the use of electron accelerators for electron microscopes of very high voltage. The 1.5 MeV electron accelerator for the worlds largest electron microscope at Toulouse, France is discussed as well as the 750 kV electron accelerator now under construction for the electron microscope at the Cavendish Laboratory of the University of Cambridge, England.

In this type of application a very high stability is demanded of the electron accelerator. The authors discuss how this stability is achieved and what the limitations are for obtaining even higher stabilities.

In recent years a new application for electron accelerators has come into existence. Electron microscopes for research were developed which could be operated at much higher voltages than the usual range of 50 kV to 100 kV. The largest electron microscope in the world, which was constructed by the Laboratory of Electron Optics of the French National Research Center at Toulouse, has a maximum accelerating voltage of 1.5 MV [1]. This high energy electron microscope is used for research work in the metallurgical field and for studying the behaviour of living microorganisms [2,3,4]. Another electron microscope with an energy of 750 keV is at present under construction at the Cavendish Laboratory of the University of Cambridge in England. Extremely high stabilized electron accelerators are required for the supply of the electron beam to these microscopes. It is expected that the enlarging power can be increased by using higher voltages. There is, however, another factor in electron microscopy that plays a most important part, namely the resolving power. The latter strongly depends on the mechanical tolerances of the microscope lenses, the stability of the lens supplies and the stability of the accelerating voltage. For this reason, electron microscopists are calling for an overall stability of 1 part in 100,000 during exposure times, i.e. up to three minutes.

The purpose of this paper is to describe the 1.5 MeV electron accelerator installed at Toulouse, the block diagram of which is shown in figure 1 [5]. The accelerating voltage of 1.5 MV is generated by a 10-stage cascade rectifier of the symmetrical design [6], discussed in detail in other papers published in these Proceedings. The high voltage terminal of the cascade generator is connected to a filter stack through a filter resistor. The dc voltage which has an extremely low ripple voltage of $\pm$ 3 volts at 1.5 MV is applied to the accelerating column through another filter resistor in order to make use of the filtering effect of the capacitive part of the measuring potentiometer. The measuring potentiometer is made of wire-wound resistors in parallel with capacitors, and is connected in parallel to the accelerating tube. The electron gun and the supply equipment are housed under the highly polished terminal of the accelerator structure. The high voltage terminal is resting on three insulating columns consisting of the measuring potentiometer, an insulating support containing some plastic tubes for the remote control of the equipment at 1.5 MV potential, and a third insulating column provided with a built-in grounding device for the complete installation.

Figure 1 also shows the block diagram of the stabilization circuit. Two stabilizations are provided : a coarse and a fine stabilization. The coarse stabilization is connected to the field excitation of the frequency converter set which supplies the 400 cps primary voltage to the pair of high voltage transformers. The principle of the fine stabilization is based upon a high voltage regulating triode directly inserted into the high voltage loop on ground potential. This triode acts as an additional variable resistor in the high voltage circuit. It is controlled by ac and dc amplifiers which amplify the error signals. The error signals are obtained by comparing the secondary voltage of the measuring potentiometer with an adjustable reference voltage source. It must be emphasized that the high voltage regulating triode can be used only because the installation is entirely symmetrical with respect to the electrical and geometrical lay-out. Otherwise reactive currents would be created and rectified by the triode, thus producing an undesirable ripple voltage which would upset the overall stability. Figure 2 is a view of the mechanical lay-out of the complete installation which is housed inside a spherical aluminum Faraday cage of 25 meters diameter. Figure 2 facilitates the understanding of figure 3 which is a photograph of the accelerator taken during the factory tests.

The electron gun, i.e. the cathode and the beam injection system, was supplied by the Department for Industrial Research of the Swiss Federal Institute of Technology, Zurich. The cathode is indirectly heated by electron bombardment; a system discovered and patented by E. B. Bas [7]. For the particular requirements of electron microscopy, the electron gun can be adjusted via remote controlled servomotors as far as its location and angle with respect to the optical axis of the accelerating tube are concerned.

The accelerator column was designed and constructed in close cooperation with the above mentioned laboratory [8]. It consists of porcelain insulators held together by metal flanges and double silicon rubber seals. The accelerator electrodes and the cylindric screens covering the accelerating gaps are made of highly polished mumetal. Entire screening of the electron beam is required in order to reduce the effect of the magnetic field of the earth which would otherwise strongly deflect the beam from the optical axis of the accelerating tube. The beam injection system and the accelerating tube are shown in figure 4.

The electrical equipment at 1.5 MV potential can be energized from batteries or from a frequency converter set with an insulating drive shaft.

The stability of the accelerating voltage was determined by two different methods. Before the completion of the electron microscope, it was measured in a bridge circuit connected to the secondary terminal of the measuring potentiometer and including a Weston element and a sensitive recorder. Later the stability was computed from the resolving power of the electron microscope. Both methods proved that the short-time stability over three minutes is $0.8 \times 10^{-5}$ in the voltage range between 500 kV and 1500 kV for beam currents up to 200 μA. The beam current is stabilized at 1 percent and is normally in the range of 5 μA to 50 μA which is sufficiently powerful for taking micrographs.

In 1964 another 750 keV electron accelerator was built for the Cavendish Laboratory of the University of Cambridge in England. While the accelerator structure corresponds to the Toulouse installation, having only half the number of stages, the high voltage dc power supply is of the Cockcroft-Walton type. The cascade rectifier is energized from a driver chain which supplies a 10 kcps ac voltage to the input transformer. Because of the non-symmetrical design of the standard cascade rectifier circuit, considerable reactive currents are created, so that the high voltage regulating triode cannot be used any more. The use of the driver chain offers the possibility of modulating the amplitude of the ac supply voltage in accordance with the fluctuations of the accelerating voltage. This stabilizing method provides the same high degree of stability and fast response which was obtained with the 1.5 MeV accelerator.

References

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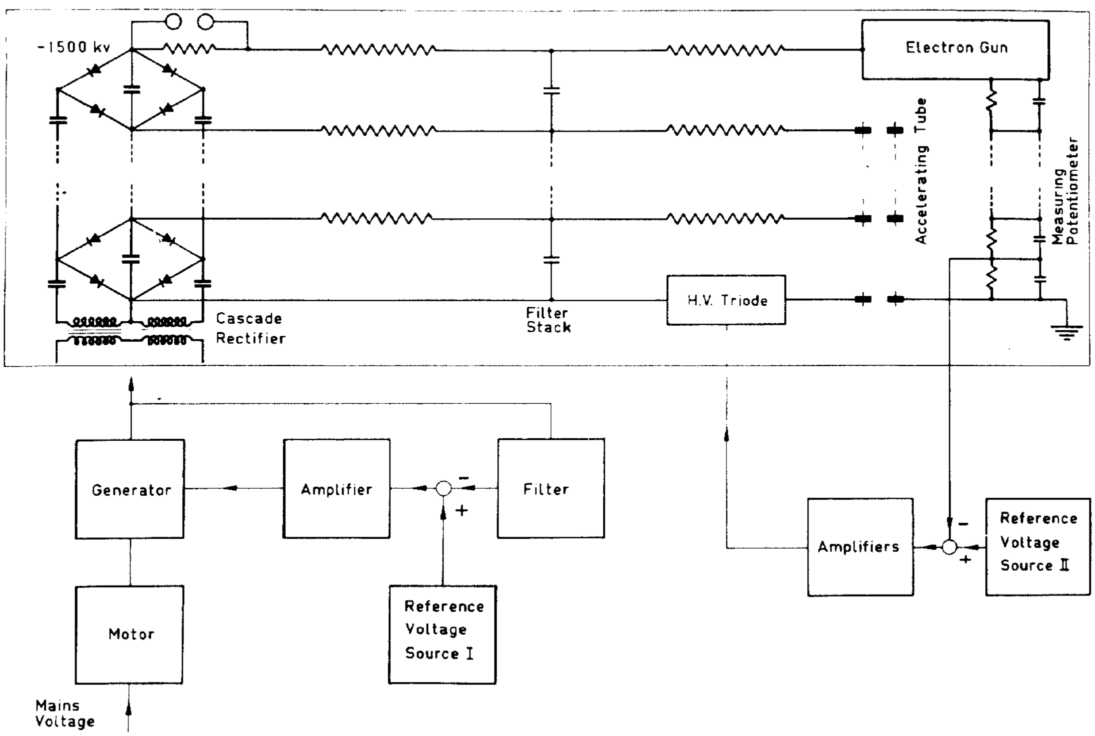


Fig. 1. Flock diagram of the 1.5 electron accelerator.

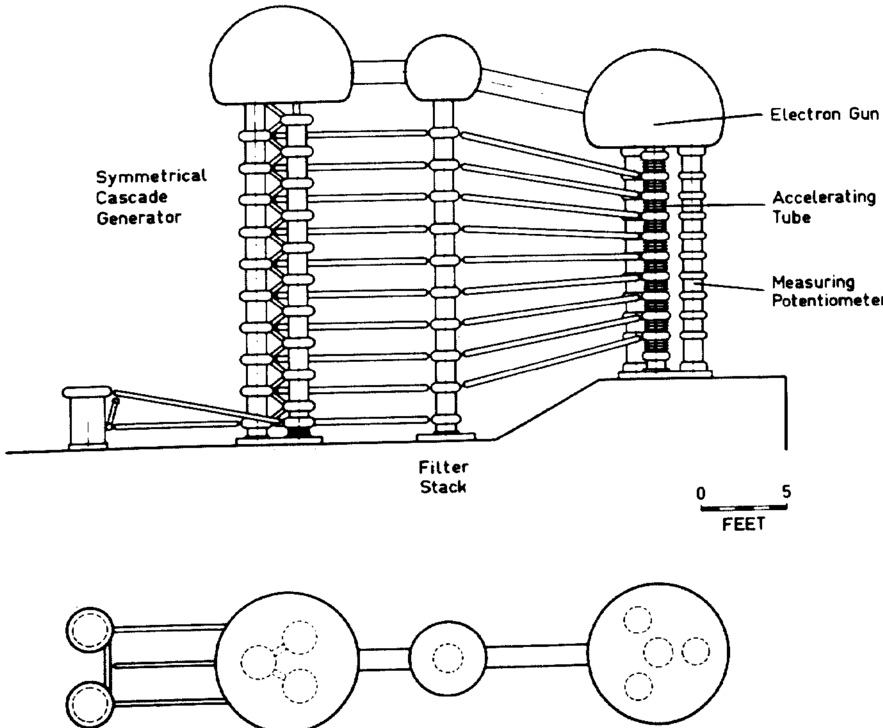


Fig. 2. Mechanical layout of the 1.5 electron accelerator.

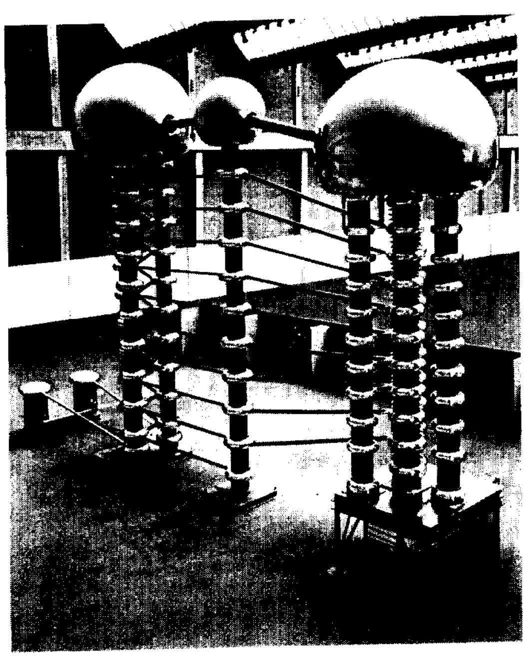

Fig. 3. 1.5 MeV electron accelerator during factory tests.

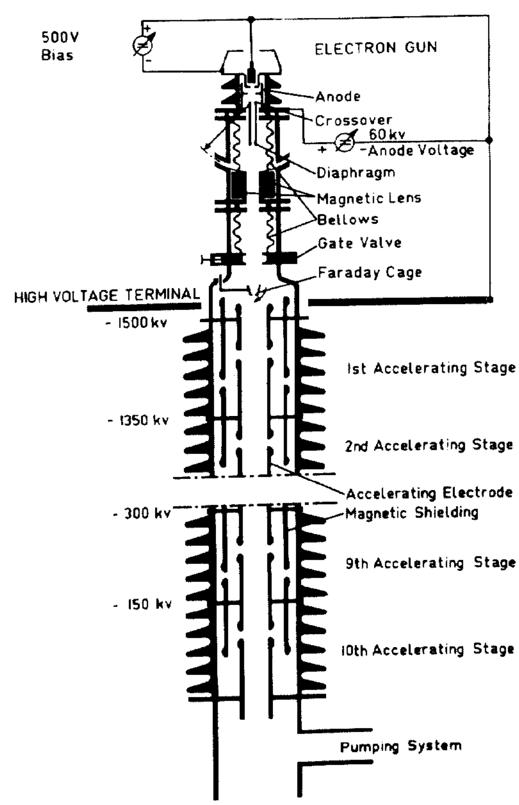


Fig. 4. Electron gun, injection system and accelerating tube of the 1.5 MeV electron accelerator.