MAGNETIC ELECTRON DEFLECTION TUBE*


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Summary

The deflection tube described here is used to harden the electron output spectrum of the Febetron 705 Flash X-ray (FXR) machine. The deflection tube is intended for use when performing electron-beam transient radiation effects on electronics (TREE) experiments. High-energy-electron dose rates in silicon are variable from $10^9$ to $3 \times 10^{10}$ rads(Si)/sec. A magnet is used to deflect all low-energy ($E < 0.5$ Mev) electrons out of the horizontal electron beam. The remaining high-energy electron spectrum can be used to irradiate test samples with more uniform dose-depth profiles in the test sample. More than 99.9 percent of the electrons are returned to the FXR machine via the deflection tube walls, thereby satisfying an operational requirement of the Febetron.

Electron-beam Testing

The main disadvantage of electron-beam testing is that the sample and exposed wiring collect low-energy electrons which are not energetic enough to pass through these materials. This leads to negative pulses on signal leads, charge trapping in insulators, and nonuniform dose-depth profiles in the test sample. These problems can be eliminated if only high-energy electrons are used to irradiate the test sample.

Magnetic Deflection

The deflection tube uses a magnetic field to remove all low-energy electrons from the electron beam.

The deflection geometry for small-angle ($\theta < 10^\circ$) deflections in air is illustrated in Fig. 1. The deflection is

$$z = \frac{b^2}{2\rho}$$

where $b$ is the length of the electron trajectory through a uniform magnetic field, and $\rho = \frac{mv}{Be}$ is the radius of curvature. The electromagnet which was designed for this deflection tube can develop 400 gauss (IMAG = 1A) over a pole face area large enough ($b = 1.38$ cm) to deflect all low-energy electrons ($E < 0.5$ Mev) out of the beam.

![Deflection geometry for small-angle deflections in air.](image)

Fig. 1 - Deflection geometry for small-angle deflections in air.

Physical Characteristics of Deflection Tube

Fig. 2 shows the deflection tube geometry. The undeflected (high-energy) electrons escape through the exit port. By changing the magnet current polarity, the low-energy electrons can be deflected either upward or downward to be absorbed in the tube wall.

The tube walls, diffuser support ring, collimation shield, and end cap are constructed from 4-inch aluminum. This shield

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*This work supported by Office of Naval Research Contract ONR N00014-68-A-0158.

**Detailed deflection tube operational characteristics and construction details are given in a report to be published by The University of New Mexico. Requests for this report may be directed to the authors of this paper.
thickness is considerably greater than the range of the most energetic electron which can be produced by the Febetron.

The diffuser causes the electron beam at the collimation shield to be more symmetrical. The 1/8-inch mu-metal annular magnetic shield, located behind the collimation shield to prevent bremsstrahlung production, minimizes interaction between the focusing magnet in the FXR machine and the deflection magnet in the deflection tube. BNC type connectors are mounted in the tube wall for electrical access to the charge collection monitor, the beam current monitor coil, and the deflection magnet coil.

Fig. 3 shows the deflection tube mounted to the Febetron. Fig. 4 shows the collimation shield, the magnetic shield, the electron guide tube, and the deflection magnet.

![Deflection tube mounted on Febetron 2-Mev FXR machine.](image)

Fig. 5 - Radiation output as a function of deflection magnet current and pulser charging voltage.

The shot-to-shot repeatability is worse for electron beams which are rich with low-energy electrons. This is observed in Fig. 5 for measurements made with magnet currents of less than ½ ampere. The repeatability is very good for deflection magnet currents greater than ½ ampere.

The manner in which the Faraday cup pulse shape changes with pulser charging voltage is shown in Fig. 6. The radiation pulse shape is independent of the deflection magnet current. The changing structure of the electron beam pulse is characteristic of the Febetron. At any given charging voltage, the pulse shape is highly repeatable, but the change in pulse shape with a change in pulser charging voltage is always observed, even when the Febetron is operated in the X-ray mode.

![Faraday cup pulse shapes as a function of pulser charging voltage.](image)

Fig. 6 - Faraday cup pulse shapes as a function of pulser charging voltage.

**Radiation Output**

Fig. 5 shows the radiation output as a function of deflection magnet current for pulser charging voltages of 20, 25, 30, and 35 KV. The maximum electron flux is measured for zero deflection magnet current. As the magnet current is increased, lower energy electrons are deflected out of the beam and the electron flux decreases.

**Acknowledgments**

We wish to acknowledge the support of Capt. C. L. Schroeder, Lt. D. R. Alexander, and Messrs C. D. Bussell, J. L. Teale, C. J. Day, C. R. Church, R. D. Lillard, and G. J. Kuhlmann, during the development of this deflection tube.