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SCANNING ELECTRON BEAM PROFILE MONITOR*

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Abstract

A scanning beam profile monitor is described that was developed for use along the Stanford two-mile linear accelerator. The maximum beam loss due to scattering caused by this monitor can be made to be a small fraction of that which would be caused by a Cerenkov radiator or scintillating screen.

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I. INTRODUCTION

A scintillating screen or Cerenkov radiator can cause sufficient scattering of the electron beam in most places along the Stanford two-mile accelerator to deflect much of the beam into the inner walls of the accelerator structure. In the normal course of events, the resulting intense radiation would cause some safety device immediately to shut off the beam. If the safety system were to be disabled, sudden and severe, possibly catastrophic, heating of the accelerator structure would become possible. To permit measurement of the beam profile with minimum risk of damage and minimum disturbance of the electron beam, the scanning monitor illustrated in Fig. 1 was developed. When its target is inserted into the electron beam, at most only a few percent of the beam, depending on target size and beam spot size, will be scattered into the inner walls of the accelerator pipe.

II. MECHANICAL ARRANGEMENT

The active element of the scanning monitor is at present a 1 mm × 1 mm cylindrical Mo target which is hung by a 0.05-mm W wire stretched on a fork. The fork is rigidly fixed to a plate which caps the bellows. The plate in turn is fixed to a scanning mechanism. The bellows flexes back and forth when the target is moved by the horizontal drive motor, crank, and levers. It compresses and stretches to accommodate the much slower motion produced by the vertical drive motor. When both motors are running, the target traces out an approximate Lissajous figure, scanning an area about 2.5 cm square. When the target is inserted into the beam, part of the beam is disturbed, being scattered by a few milliradians.[1] The scattered beam then produces an electromagnetic shower in the accelerator structure downstream. The shower is measured with an air ion chamber mounted nearby.

III. DATA DISPLAY

It is anticipated that the electron beam will ordinarily be focused to approximately 0.5 cm diameter. The desired resolving power of the monitor was somewhat arbitrarily set at 1 mm. Since the data from a scan will consist of at most a few hundred pulse heights, it is practical to display them directly on an oscilloscope screen. In this way, the profile can be read directly to an accuracy on the order of 10%. A storage oscilloscope record of the signal resulting from part of a scan, using the prototype unit, is shown in Fig. 2. The oscilloscope vertical signal represents the sum of the voltage pulse produced by the ion chamber and a position signal voltage produced by the linear motion potentiometer linked to the vertical motion drive mechanism. The horizontal signal is produced by the potentiometer linked to the horizontal drive mechanism. The potentiometers are supplied with about $\pm$ 5 volts dc. In the production units, the position transducer linkages and other levers were made long enough so that indicated relative positions would be accurate to better than 0.5 mm.

The pulses at the ends of the traces represent background, partly due to the beam striking the wire which supports the target, and partly due to stray beam striking the inner wall of the accelerator pipe. Corrected for background, the pulses indicate beam intensity as a function of the position specified by the "baseline" trace position. The scan was taken at 60 pps. The interesting part, shown in Fig. 2, required about eight seconds to make. The full scan required about 20 seconds to complete. The scan was made during preliminary beam operation, while the first two 100-meter sections of the accelerator were being tested. The monitor was mounted at the 100-meter point, where the energy was near 650 MeV. The beam current was about 10 mA peak, 1 μA average.

With a sufficiently small target, the space resolution is governed by the vertical and horizontal motor speeds. For Fig. 2, the speeds were adjusted to be ≈1.5 and 50 rpm, respectively, so that at 60 pps the target advanced horizontally by at most 1 mm per pulse, and vertically by at most 1 mm for each horizontal trace. The pulse amplitude accuracy will depend upon the pulse-to-pulse stability of the beam profile, which has not yet been well measured, and possibly upon saturation effects in the detector, which were estimated to be less than 10%. Saturation effects can, of course, be reduced by shielding or moving the detector.

II. VARIABLE SPEED DRIVE

The electron beam pulse repetition rate of the two-mile accelerator can be varied over a wide range, from single pulses to 360 pps. It is desired to be able to scan a profile at any regular rate between 60 and 360 pps. The highest rate will permit rapid scanning, about 3 seconds for a complete raster. Lower rates will be useful to limit heating of accelerator components at high peak beam power levels, for the investigation of possible 60-Hz ac hum effects upon the beam parameters, and in connection with multiple beam operation.

As a simple and economical solution to the problem of changing speeds, series-wound gear motors are used with SCR speed controllers. The largest force to be dealt with is the atmospheric force on the bellows cap, about 30 kg. This force is roughly balanced by the adjustable coil spring and by the average spring force of the bellows, which is approximately 2 kg. The maximum torque required from the vertical drive motor is probably less than 3 kg cm. This motor, a Dayton 4K869, is rated at 187 kg cm at 6.7 rpm and 115 volts ac. The horizontal drive motor, a Bodine HSE12RH, is rated at 12.9 kg cm at 120 rpm and 115 volts ac. In spite of the high torque ratings of the motors, it is necessary to supply both motors from half-wave SCR motor controllers, rather than variable autotransformers, in order to get satisfactory low speed operation. Achievement of the highest desirable speeds, ≈9 and 300 rpm, is easily accomplished under the light loads.

V. UTILITY

In addition to reducing the radiation hazard to the accelerator, a scanning monitor makes beam profile measurements possible, in some circumstances, without interrupting experiments. In the future, a scanning profile monitor may facilitate experimental studies of beam optics. A scanning target, upstream, can cast a shadow, the relative position of which may be observable downstream, after the beam has passed through a system of focusing and deflecting magnets. The present radiation detector, being a slow response device, gives a pulse which is proportional to an integral over the beam pulse period, which is 2.5 μsec or less. If desired, a faster detector could be used, as an aid in investigating possible dynamic beam instability effects.

Acknowledgements

The prototype and production units were built by W. Schaetzle. He and R. Iwao have been responsible for a number of improvements.

REFERENCE

1. Rossi, B., High Energy Particles (Prentice-Hall, Inc., New York, 1952), p. 68.

FIGURE CAPTIONS

1. Scanning mechanism, fork, and target. The target is shown in the position corresponding to the location of the beam centerline when the mechanism is mounted in the accelerator structure.
2. Storage oscilloscope record of the electron beam profile at the 100 meter point of the Stanford two-mile accelerator. The horizontal scan extends over 2.6 cm. Only the central 1.5 cm of the vertical scan is shown. The pip heights are approximately proportional to beam intensity at the position indicated.

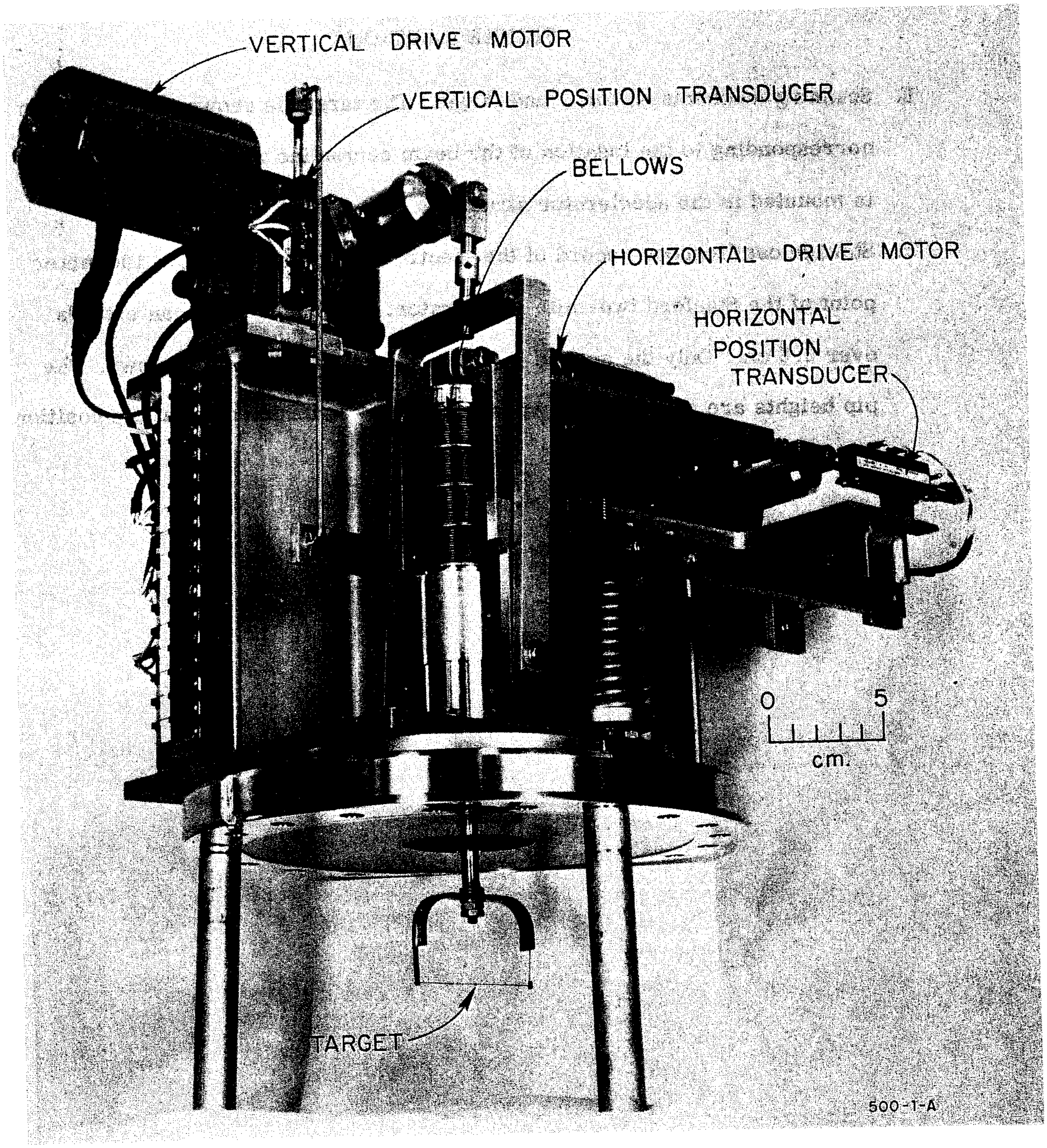
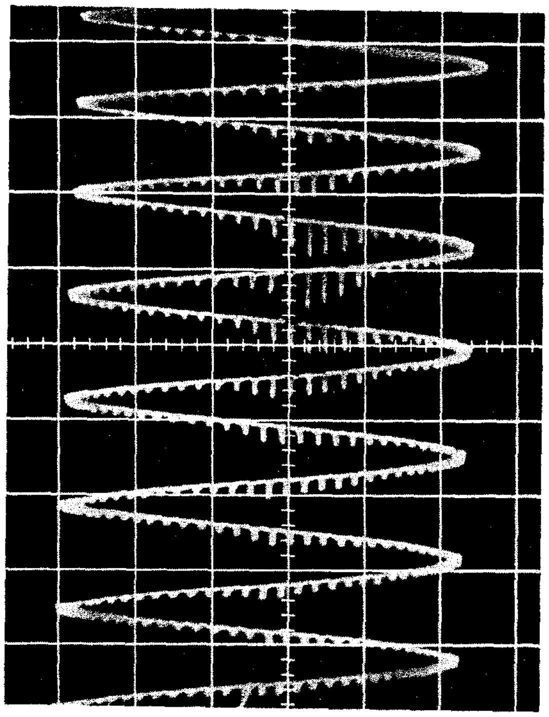

VERTICAL DRIVE MOTOR
VERTICAL POSITION TRANSDUCER
BELLOWS
HORIZONTAL DRIVE MOTOR
HORIZONTAL POSITION TRANSDUCER
0 5
cm.
TARGET
500-1-A

Fig. 1



500-2-A

Fig. 2