A HIGH VOLTAGE THIN X-RAY BEAM SCANNER FOR COMPUTER CONTROLLED RADIOGRAPHY

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A high voltage flying-spot thin X-ray beam generator for computer controlled radiography has been constructed.* An experiment on automatic tracking of pellets placed on the tongue is being undertaken. In this report, operational features of the X-ray system will be described with special reference to its capability in the pellet-tracking experiment. The basic principles of the experimental system are the same as those described in our previous reports (Fujimura, Kiritani, and Ishida, 1969, 1973).

X-ray Generator

In order to obtain a dense X-ray beam, the present X-ray generator adopts relatively high acceleration voltage, 150kV maximum. Stabilized DC high voltage is used to achieve stable positioning and focusing of the electron beam. Electron beam current effectively focused on the X-ray generating target is approximately 1mA maximum. A fast random-access type deflector of the electron beam is constructed by using an electromagnetic deflector which is ordinarily used in the fast precision oscilloscope display unit. For small deflections, the bandwidth of the deflector is 1MHz and, for the largest deflections on the target, settling time to within 0.2% of the destination point is about 10μsec. The X-ray detector consists of a Na-I scintillation counter with an effective surface of 20cm in diameter. Intensity of the X-ray beam is measured by integrating the output signal from the photo-multiplier tube over a time interval.

The size of a pin-hole that is used to form a thin X-ray beam and also the distance between the target and the pin-hole, can be varied according to the desired resolution and size of the image field. The arrangement of the pin-hole scan system for the pellet tracking experiment is as follows. A pin-hole of 250μ in diameter is located at a distance of 15cm from the target. The object plane is 52 cm apart from the pin-hole and the usable image field is a square of $14cm^2$. Resolution on the object plane is approximately 1 mm.

Intensity of the X-ray Beam

Under the operating conditions of 150kV-1mA and the arrangement of the pin-hole scan system as stated above, the number of effective X-ray photons emitted through the pin-hole is estimated to be approximately 10^7 per second. The attenuation of X-rays in the tissues around the tongue may be approximated by that in the water layer, 10-15cm in thickness. With a Cu filter of 0.6mm in thickness and the X-ray absorber of a

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12cm-thick water layer, X-ray photons of about 10^6 per second reach the detector. In the present system, it is assured that, for practical conditions of exposures that will be met in the pellet-tracking experiment, fluctuations in the measured X-ray intensity are exclusively due to inherent statistical fluctuations caused by the quantum effect (Fig. 1). The noise component due to noise currents in the photo-multiplier tube is estimated at about 1% in r. m. s. amplitude at a photon density of 10^6 per second. Short time fluctuations in the intensity of the X-ray source is measured at less than 1%.

Figure 2 shows an example of the position measurement accuracy for a metallic object with high opacity to X-rays. A narrow rectangular Pb sheet of 2mm in width is placed in the middle of the 12cm-thick water layer. Exposures are given to contiguous sample points on a single line along the direction of its width. A point of minimum X-ray intensity is determined as the center of the Pb sheet. Fluctuations in the detected positions over 100 time measurements are examined as a function of exposure time. Accuracy of $\pm$ 0. 5mm is obtained with an exposure time of 50μsec per sample point. In the measurement of the position of the pellet on the tongue, total exposure time for one frame-time measurement will be a few milliseconds. [1)]

Controls

In the computer, sample points on the object plane are located by 9bit x- and y-coordinates. Coordinate values are transferred to the D/A converter as parallel 18bit data. For measuring the intensity of the X-rays, the computer sends out a CLEAR pulse which resets the integrator to zero and initiates the integration. After a selected time interval, the output signal of the integrator is sampled and converted to a digital signal of 6-8bits through the A/D converter.

The computer controls the start and stop of X-ray exposures by three control pulses. Fast interruptions of X-ray exposures are achieved by the OVERDEFLECTION control. When this is turned on by the control pulse, the electron beam is deflected far out of the target so that radiation of X-rays through the pin-hole does not take place. Complete cessation of X-ray generation is achieved by the FILAMENT-OFF control, which stops the supply of the filament current to the electron gun. The time constant for this control is about 0. 2sec. Both of these controls are disabled by the RESET pulse.

In order to detect unwanted halting of the electron beam on the target, a circuit is adopted which watches the change in the currents through the deflection yoke. When the amplitude of deflection change does not exceed a prespecified threshhold level for a 0. 1sec time interval, X-ray exposure is automatically stopped by turning on the OVERDEFLECTION and FILAMENT-OFF controls. This facility is provided to prevent an overheating of a point on the target and/or unintended exposures of the subject that may be causes by the wrong functions in the deflector unit or improper controls to the deflector. Status of the control settings such as a selection in the high voltages are stored in the 18bit register and can be read into the computer.

For the purpose of off-line observations, the X-ray image can be displayed on a monitor oscilloscope by using a hardware scan signal generator. Brightness of the displayed points are modulated directly by the output signal from the photo-multiplier tube.

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References

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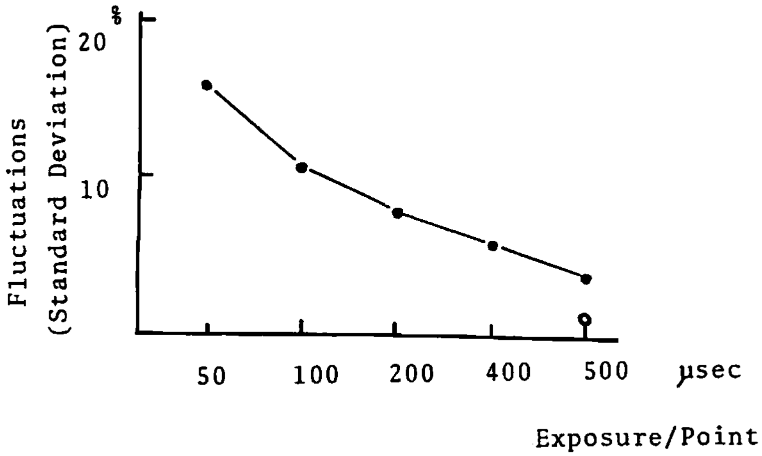

Figure 1. Fluctuations in the measured X-ray intensity transmitted through a 12cm-thick water layer. Open circle, direct exposure without water layer.

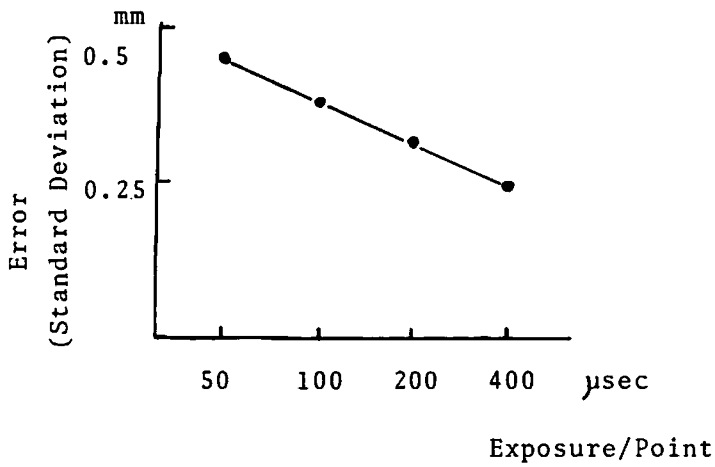

Figure 2. Fluctuations in the measured positions of the 2mm wide Pb sheet placed in the 12cm-thick water layer. Fifteen sample points on a line along the direction of its width are exposed and the point of minimum X-ray intensity is detected. Fluctuations over 100 measurements are plotted as a function of exposure time per sample point. Step of scan, 0.25mm.

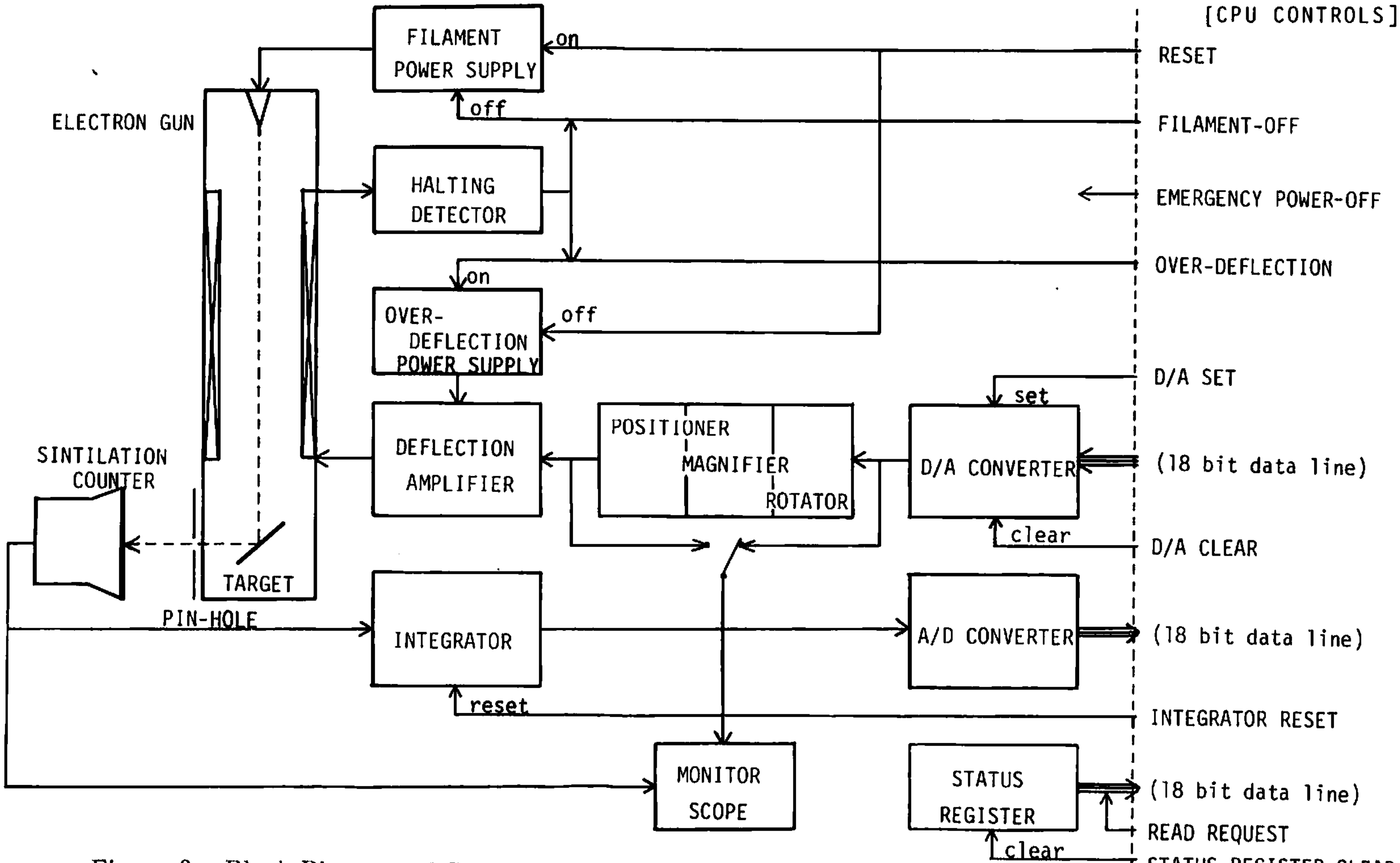

Figure 3. Block Diagram of Controls

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