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## DESCRIPTION OF HSRI HIGH-SPEED X-RAY CINERADIOGRAPHY SYSTEM

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A versatile high-speed cineradiographic system developed in the Biomechanics Department of the University of Michigan's Highway Safety Research Institute has recently been completed, for application to human injury tolerance and occupant protection research. This system consists of a high-speed motion picture camera which views a 2-inch diameter output phosphor of a high gain 4-stage, magnetically focussed image intensifier tube which is gated on and off synchronously with shutter pulses from the motion picture camera. The input photocathode of the image intensifier tube is optically coupled by a fast lens to x-ray shadowgraphs produced on a fluorescent screen by an x-ray generator. This system is adaptable to a wide variety of experimental configurations because: 1) screen size can be easily and inexpensively changed, and can be larger than the largest x-ray intensification tubes made; 2) the image intensifier tube is readily switchable over a wide range of pulse repetition rates and pulse widths, allowing motion picture frame rates closely matched to dynamic events under study; and 3) the system is not limited to a particular x-ray generator, and even not limited only to x-rays. The system is shown schematically in Figure 1.

Two x-ray generators are presently used with this system, a portable 110 KVP, 10 mA, self-rectified Picker Industrial

radiographic unit, which produces 60 x-ray pulses per second, and a 140 KVP, 300 mA, full-wave rectified Picker medical-type unit, which gives 120 x-ray pulses per second. Motion picture framing is synchronous with these two frequencies, for use with live human subjects. A third x-ray generator for high-speed cineradiography up to 3000 frames per second will become available in April 1976. This is a 125 KVP, 300 mA, constant potential machine which is movable, to enable set-ups in a variety of experimental configurations. It also has sufficient power for dual x-ray head operation for eventual biaxial cineradiography. Use of three screen sizes is anticipated to meet the needs of various investigators who will use the system. There are two categories of experiments: 1) primate and human cadaver, in which events will occur in time durations between 4 to 250 milliseconds, requiring high-speed frame rates of 1000 to 3000 frames per second, and will require sufficient screen area to observe displacement of the subject across the screen; three screen sizes will be used in this category, 9, 12, and 17 inches diameter; 2) the second category will involve live human subjects in which motion of structures of interest will occur over longer time intervals, from 250 milliseconds to 1.5 seconds, at most, requiring lower speed frame rates, ranging from 30 to 400 frames per second; subjects will be relatively static, so that 9 and 12 inch diameter viewing areas are expected to be adequate. It is expected that exposure danger to human subjects will be no greater than that already encountered in clinical conditions.

Limiting resolution in this system is determined by the reduction ratios from the input screen dimension to the photocathode diameter and from the output phosphor diameter to the dimensions of a motion picture frame, and by the resolving capability of a particular camera-film combination. For a 12-inch diameter screen, with a 16-mm Milliken camera, the minimum resolvable dimension is 0.33-mm; with a Hycam, for the same size screen, the minimum resolvable dimension is 0.5-mm. For a 17-inch screen, with a Millikan, minimum resolvable dimension is 0.5-mm, and with a Hycam, 0.7-mm. Screen sizes up to several feet in size can be used in special situations where required, but with corresponding decrease in resolution. In this case, a screen of three feet in diameter would have a minimum resolvable dimension of approximately 4-mm, or 5/32-inch.

In view of the variability of screen size, frame rates, x-ray exposure levels appropriate for live human use, camera adaptations, and set-up flexibility, it is expected that the HSRI cineradiographic system will meet objectives in a wide range of biomechanics research.

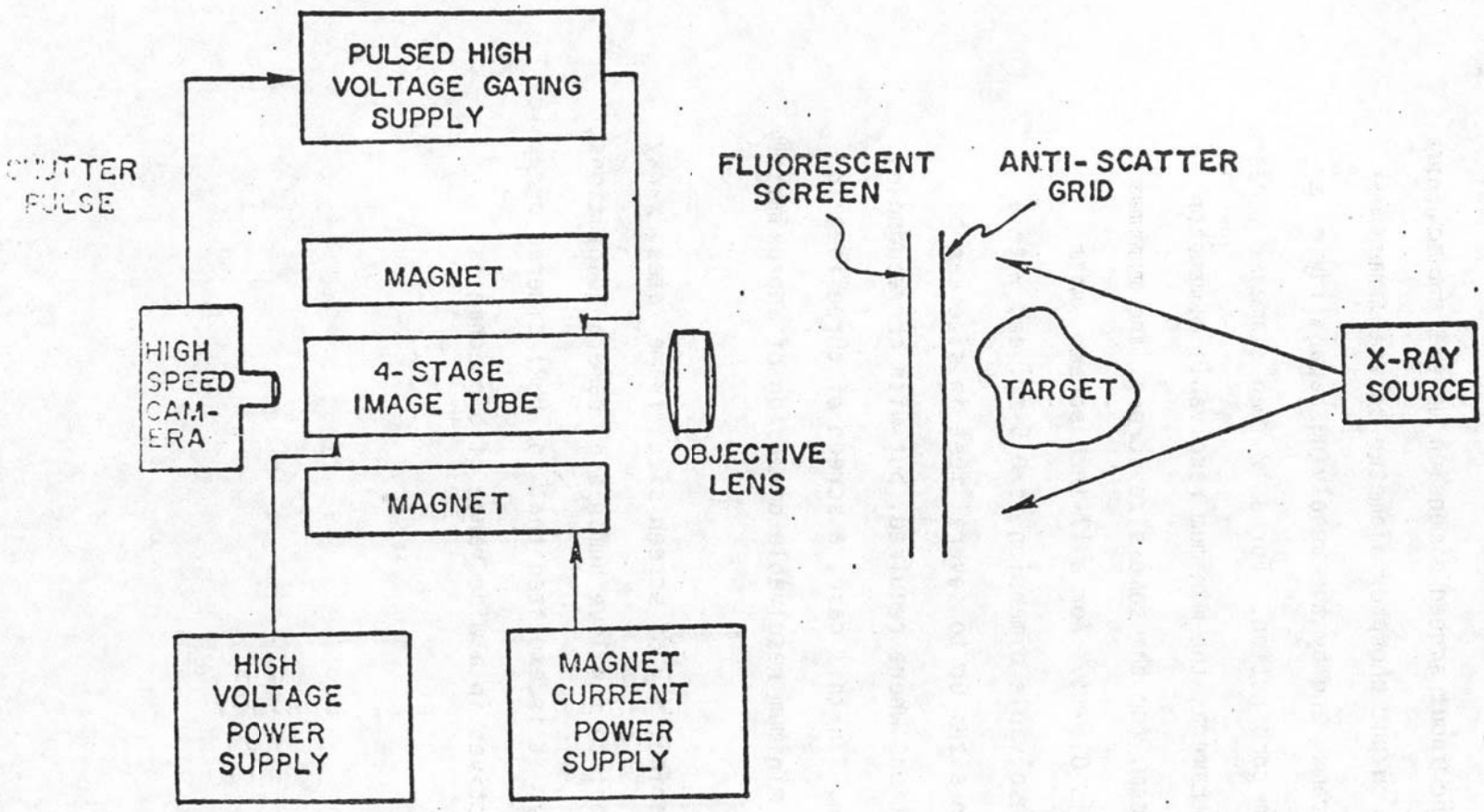


Figure 1.

Synchronously Gated High-Speed Cineradiography System