A Grid Diaphragm Image Diffuser For Secondary Radiation Control

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Introduction

In the years since the introduction of the roentgen ray, refinement of radiographic techniques to facilitate production of increasingly superior images has taken many forms. The preponderance of experimentation and investigation in this area has been centered around modification of the method of production of the x-ray beam proper. Thus, increasingly efficient and effective x-ray tubes, incorporating such innovations as rotating anodes, have evolved. Similarly receiving investigative attention, with the same end in mind, has been the development of finer quality film emulsions and more precise and dependable film processing techniques. In a third area, exploration has been directed toward control of the effects of secondary radiation on image quality. Various auxiliary devices have been introduced which either decrease production of secondary radiation or minimize exposure of the film emulsion to that secondary radiation which is produced.

The most significant contribution in the latter category was the introduction, in 1913, by Gustav Bucky[1] of a grid diaphragm designed to absorb scatter radiation resulting from thick-body roentgenography. Modification of Bucky's grid design and introduction of a mechanism for diffusing the film image of the grid laminations by Potter[2] enhanced the possibilities of using such a diaphragm system routinely in diagnostic roentgenography. However, the cumbersome nature of commercially available Potter-Bucky mechanisms limits their use with modern, adjustable roentgenographic cephalometers. This paper introduces a lightweight grid diffusion assembly designed specifically for adaptation to roentgenographic cephalometric systems.

Nature of Secondary Radiation

Secondary, or scatter, radiation is generated as a result of the incidence of primary radiation on any body tissue. While the primary and remnant roentgen rays describe a path that is only slightly divergent from the "central beam" path, the electrons emitted from the exposed tissues as secondary rays are randomly directed (Fig. 1). Exposure of the film emulsion to these secondary rays results in a decrease in definition of the structures being radiographed.[3]

The amount of secondary radiation produced is dependent upon the cross-sectional area, the thickness, and the density of the exposed tissues as well as the kilovoltage of the primary x-ray beam. Since the interrelationships of these variables are complex and a complete discussion of them is not within the scope of this paper, the reader is referred to Fuchs[1] for a detailed review.

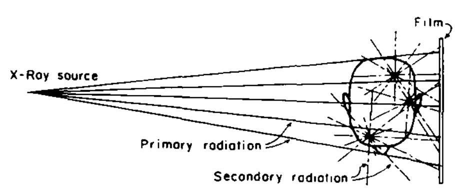

Fig. 1 Production of secondary radiation in cephalometric roentgenography.

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It is sufficient to say here that total secondary radiation emission varies directly with tissue exposure area, tissue thickness, kilovoltage, and inversely with tissue density.

Elimination of unnecessary tissue exposure area and lowering of kilovoltage, then, provide convenient means for minimizing the production of secondary rays. Obviously, scatter radiation cannot be completely eliminated by control of these two variables since both have unassailable lower limits. Reduction of tissue exposure area is limited by the size of the organ to be examined and reduction of kilovoltage is limited by the necessity to provide sufficient radiation for production of a satisfactory image. However, further secondary radiation attenuation can be realized by interposition of a grid diaphragm assembly between the secondary radiation source and the x-ray film.

Grid Absorption of Secondary Radiation

Although the details of grid fabrication vary from one manufacturer to another, the basic principles of design presented by Bucky[3] and modified by Potter[2] prevail. The grid is composed of parallel, alternate, thin strips of radiopaque lead foil and a relatively radiolucent material such as aluminum or wood. These strips are oriented in such a manner that the planes of the slots created by the radiolucent material are either parallel to the central beam path (unfocused grid) or converge toward a point in space which corresponds to the anode target (focused grid). In either case, remnant rays, which enter the grid system approximately parallel to the plane of the slots, will be allowed to pass through unhindered, while secondary rays, which strike the grid with random directionality, will be absorbed by the radiopaque strips (Fig. 2). The efficacy of grid diaphragms in attenuating secondary radiation has been substantiated experimentally by Wilsey.[4]

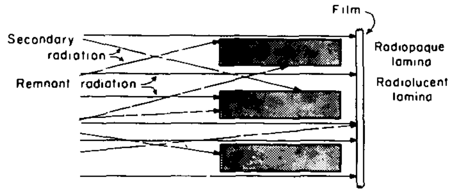

Fig. 2 Diagrammatic representation of grid absorption of secondary radiation.

There are two characteristics of a grid which determine its absorption efficiency: the grid ratio, and the number of radiopaque strips per inch. The grid ratio describes the relationship between height of the radiopaque strips and width of the radiolucent slots. As the ratio is increased (i.e., as height is increased relative to width), secondary radiation passage is correspondingly decreased.[5] Although grids with a wide range of ratios are available, an 8:1 ratio is applicable to the technique to be described here. Increasing the number of strips per inch by making them thinner and by decreasing the interval between them allows the fabrication of a less bulky grid without modification of the grid ratio. An additional advantage of the ultra-thin strips is reduction of the prominence of the grid-line images.

The Grid Image Diffusion Assembly

As noted previously, Potter designed a mechanism for diffusion of the grid lamination images in 1920. This device consisted of a Bucky grid mounted on rollers and driven along a path at right angles to the length of the grid strips by a hydraulically counterbalanced weight.[2] Subsequent commercial models embodied the basic design advocated by Potter and later included such improvements as variable speed and time controls, interchangeable grids, electromagnetic releases, and electronic drive mechanisms.[5] The primary application

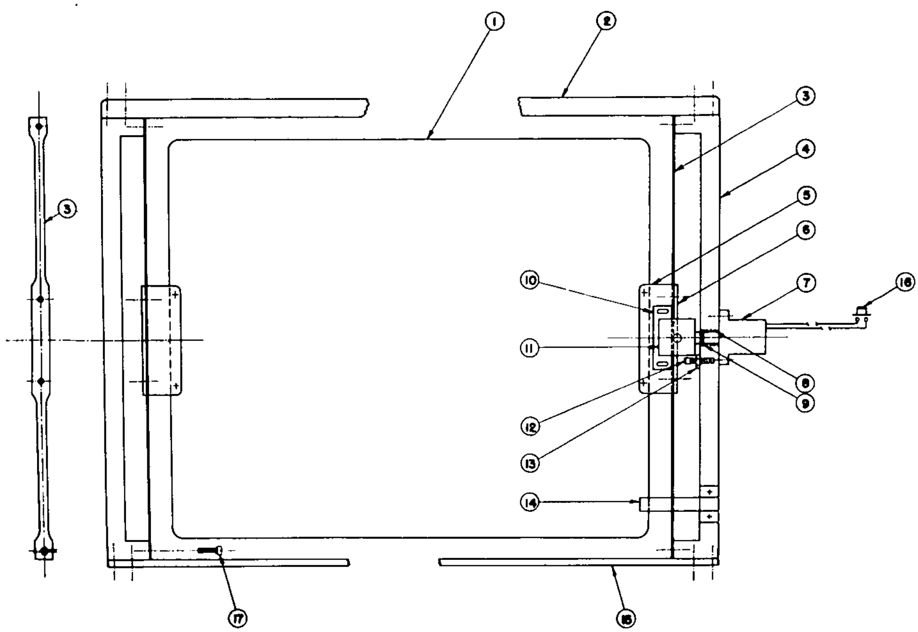

Fig. 3 Line drawing of the grid image diffusion assembly. 1. Lysholm grid, 10" x 12", 8:1 ratio, 100 lines per inch. 2. Frame, top (2024-T4 Aluminum alloy) 3. Leaf spring (.020" phosphor-bronze) 4. Frame, right and left 5. Grid bracket 6. Spring bracket 7. Solenoid 8. Coil spring 9. Solenoid plunger 10. Magnet bracket 11. Magnet 12. Adjustable stop (cushion head) 13. Stop lock nut 14. Cassette stop 15. Frame bottom 16. X-ray timer circuit 17. Shoulder screw.

of these devices has been for medical roentgenographic systems in which the entire assembly is housed in the x-ray table. Hence design has not been limited by demands for compactness and lightness.

In order to be adaptable to a roentgenographic cephalometric system a grid image diffusion assembly must:

a. provide satisfactory diffusion of the grid lamination images,

b. not transmit vibration to the cassette holder,

c. be sufficiently light that it will not interfere with operation of the adjustable cephalometer,

d. be sufficiently compact that it will not increase the object-film distance to a significant degree.

The following design* is proposed as fulfilling these requirements.

Figure 3 shows the grid diaphragm suspended in a lightweight aluminum alloy framework by leaf springs which permit diaphragm movement in only one plane, i.e., perpendicular to the central beam path. Diaphragm movement is initiated by activation of the solenoid plunger (Fig. 4, No. 9) through the x-ray timer circuit. Since the plunger is in contact with a magnet (Fig. 4, No. 11) attached to the diaphragm suspension block, the diaphragm is pulled in the same direction as the plunger (to the right in Figs. 3

* Technical assistance in design and fabrication by Donald Russell and Vernon Mueller, Medical Instruments Facility, University of Washington, Seattle, Washington.

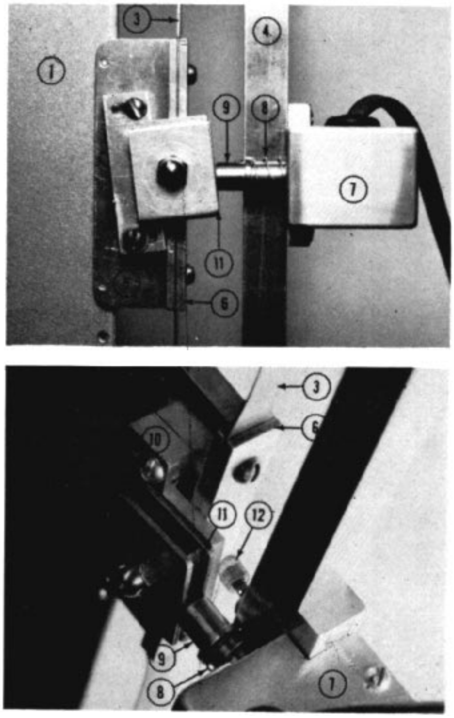

Fig. 4 Photographs of grid image diffusion activation mechanism. Identifying numbers correspond to those in Fig. 3.

and 4) until it contacts the adjustable stop (Fig. 4, No. 12). This contact overcomes the plunger-magnet union allowing the spring suspension to move the diaphragm in the opposite direction. The diaphragm is then free to describe oscillations of decreasing magnitude until the solenoid circuit is broken. At that time the solenoid plunger is returned to its resting position by the coil spring (Fig. 4, No. 8) thus reestablishing contact with the magnet and arresting diaphragm movement.

Timing of diaphragm movement relative to exposure interval is simplified by energizing the solenoid via the x-ray tube anode motor circuit. This circuit provides for anode acceleration by activation of the anode motor prior to emission of energy from the cathode. By utilization of this circuit for the grid diffusion device, diaphragm movement is initiated prior to x-ray emission and continues for a short interval thereafter, thus assuring oscillation during the entire exposure interval. The time-lag between solenoid activation and incidence of x-radiation on the grid diaphragm also permits dampening of the small amount of vibration produced by the diaphragm-stop contact.

The mode of attachment of this assembly to the cephalometric cassette holder is not presented here since it is dependent upon the type of cephalostat used. The object-film distance is increased by only slightly more than the grid diaphragm thickness (2.7 mm) so that increase of image magnification is negligible.

This design represents a major departure from most conventional commercially available grid image diffusion assemblies since the diaphragm motion is oscillatory rather than unidirectional.* Since no reference was given the source could not be traced. Oscillatory movement does not provide satisfactory diffusion if successive oscillations are of identical magnitude. However, the continually decreasing magnitude of oscillation provided by the spring suspension system results in a degree of grid lamination diffusion comparable to that produced by unidirectional grid movement.

*Sante[6] alluded to the design of an oscillatory grid image diffusion mechanism by Morgan.

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