H and D curves of screen–film systems: factors affecting their dependence on x-ray energy

Carl J. Vyborny

Kurt Rossmann Laboratories for Radiologic Image Research, The Department of Radiology and The Franklin McLean Memorial Research Institute, The University of Chicago, Chicago, Illinois 60637

(Received 22 August 1977; accepted for publication 7 November 1978)

The sensitometric properties of radiographic screen–film systems are investigated with regard to their dependence on x-ray energy. Sensitometric measurements and a heuristic model for density formation are used to show that variation in the relative amount of light emitted by front and back screens may be the most important factor influencing the change in system H and D curves with x-ray energy.

I. INTRODUCTION

The density obtained on a radiographic film exposed to x rays either directly or in a screen–film system is related to the agent responsible for its formation through the sensitometric or H and D curve. It has been supposed that the shape taken by the H and D curve of a screen–film system is independent of the energy of the exposing x rays.[1] Such independence would be a useful property because it would allow prediction of the density response of screen–film systems to broad x-ray spectra containing many energies.[2,3] The study of the energy dependence of sensitometric curves in screen–film systems has been very limited, however. Recent experimental measurements have confirmed independence of curve shape for several calcium tungstate systems with diagnostic spectra ranging from 60 to 150 kVp[4,5] but, in general, this problem has not been studied in detail.

We have examined the factors which could produce changes in the shape of screen–film system H and D curves as the energy of the incident x rays is varied. Sensitometric measurements and a heuristic model for density formation are used to study these factors and to identify circumstances under which changes in H and D curve shape may be expected.

II. FACTORS AFFECTING H AND D CURVE SHAPE

It is necessary at the outset to distinguish between the sensitometric curve of a screen–film system and the sensitometric curve of the film alone. We will confine our discussion to typical screen–film systems having a double-emulsion film placed between two radiographic screens. The sensitometric curve of such a system depends on the x-ray absorption properties of the screens, the relative sensitivity of the film to light and x rays, and other factors which would not affect the H and D curve of the film exposed either directly to light or to x rays. It is therefore possible that the H and D curve of a screen–film system will differ from that of the film alone, even if the film is exposed to a light spectrum which is the same as that emitted by the screens.

An extensive literature exists on the sensitometric properties of film. Sophisticated experiments and theoretical models have been used for examination of the actual shape of film sensitometric curves exposed either to light[6–11] or to x rays.[12,13] Such and more would be required to explain the observed shape of the sensitometric curves of screen–film systems. We are, however, not interested in the shape of sensitometric curves *per se*, rather only in their variation with x-ray energy. This will allow us to concentrate on the properties of screen–film system response which change with x-ray energy and to avoid dealing in great detail with the intricate workings of the film emulsions.

The first aspects of screen–film system behavior not encountered in the study of single-film emulsions are that the film is exposed by two sources of light (the two screens) and that the film has two emulsions. Light from the front screen can "cross over" to expose the back emulsion and vice versa. This effect can be described by a system crossover fraction f, defined as the number of quantum hits caused in the far emulsion by light from a screen divided by the number of quantum hits caused in the near emulsion by light from the same screen. The term "quantum hits" is used here to refer to interactions between light quanta and film grains, which have the potential to render film grains developable. The concept of quantum interactions between light and film grains is common to all models of film developability.[7,8,11]

The amount of light coming from the front and back intensifying screens during an x-ray exposure is usually not the same; to describe this, one can define a relative screen contribution fraction g: g is the number of quantum hits caused in the back emulsion by light from the back screen divided by the number of quantum hits caused in the front emulsion by light from the front screen. Since the energy of the incident x rays determines their relative absorption by the front and back screens, g is a function of x-ray energy.

The most important factors determining the shape of the H and D curve of a screen–film system, especially in regard to its dependence on x-ray energy, include: (1) the intrinsic properties of the film emulsion, such as the quantum hit requirement and size distributions of the film grains; (2) the system crossover fraction f; (3) the system relative screen-contribution fraction g; (4) the fraction of film grains made developable by direct interactions with x rays; (5) the fraction of film grains made developable by means other than

 0094-2405/79/010039-06$01.20