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THERMAL FOGGING OF PERSONNEL MONITORING FILM

Livermore, California

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November 12, 1964

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THERMAL FOGGING OF PERSONNEL MONITORING FILM*

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November 12, 1964

Abstract - Thermal fogging did not occur in personnel monitoring films held at temperatures below 50° C for up to 216 hours. Films maintained at temperatures above 50° C were fogged nonuniformly, with peak fogging occurring at relative humidities of 40-60%. The hypothesis stating that competing reactions from radiolytic products of water cause the humidity dependence of response to gamma radiation is disproved.

Unexpected or untoward darkening of personnel monitoring film is often attributed to excessive heat rather than to exposure to ionizing radiation. Although this explanation is convenient, doubt as to its validity may be expressed, since the thermal fogging phenomenon has not yet been well characterized.

A few studies, however, have been made that touch on this effect. Ehrlich,⁽¹⁾ in a brief examination of film storage temperatures, found that unexposed personnel monitoring and spectroscopic film would fog when maintained at temperatures of 65 or 75° C for a few hours. Pre-dosed film was found to fog in one case and to fade in the other.

In another study, Ehrlich⁽²⁾ examined the effects of heat and moisture on the response of dosimetric film to gamma rays. The films were held

and exposed at temperatures of 5.5, 19.8, and 32.5° C and at several different humidities. In this study, she noted what appeared to be excessive darkening of film exposed at 32.5° C and high humidity. From this, she concluded that fogging was enhanced at high temperatures by high relative humidity.

More recently, Brodsky and Kathren⁽³⁾ and Kathren and Brodsky⁽⁴⁾ examined the combined effects of temperature and humidity on the sensitivity and response of personnel monitoring film to gamma radiation. Film response was found to be a function of humidity (Fig. 1). Temperature dependence was also noted, and was seen to be lessened by low humidity. Although some unexposed films were maintained for as long as three months at temperatures of 48.9° C and relative humidities approaching 100%, little or no fogging was observed. These data differ from the conclusions reached by Ehrlich.⁽²⁾

In a very recent report, McCarthy and Mejdahl⁽⁵⁾ studied the effect of 60 and 80° C temperatures on Kodak PM2 films. Little or no temperature dependence was noted at 60° C; after 240 hr the density of the sensitive emulsion had increased by 15% while that of the insensitive emulsion had increased 30%. At 80° C large density increases were noted after about 30 hr.

EXPERIMENTAL METHOD

The Du Pont 558 film packet was selected for study. This packet contains two dental-sized films; a dual-coated 508 and a single-coated 1290. The former is a sensitive personnel monitoring film, useful for dosimetry in the range of 0.01 to 10 rad referenced to electromagnetic radiation from Co^{60} . The 1290 film is a less sensitive emulsion, useful for quantifying exposures of 5 to 1000 rad. These two film types are representative of most β - γ personnel monitoring film used in the United States.

Groups of film packets were maintained under constant temperature and humidity conditions in exposure chambers similar to those described by Brodsky and Kathren.⁽³⁾ Temperatures were held constant to within $\pm 1^\circ\text{C}$ by a heat source connected in series to a thermoregulator switch. Relative humidities of $\leq 2\%$ were achieved by placing a desiccant (anhydrous CaSO_4) in the chambers. Higher relative humidities were obtained and maintained by shallow pans of saturated salt solutions in equilibrium with the solid phase. Air movement within the chambers was provided by a 1-cfm blower at one end of the chamber.

Films were held at temperatures of 30 to 70°C for periods of 24 to 216 hr. Within 4 hr after removal from the chamber, films were developed in Kodak Liquid X-Ray Developer for 5 min at 20°C . Processed films were read on a Photovolt Model 501R densitometer.

RESULTS AND DISCUSSION

At temperatures below 50°C , fogging was absent or minimal (Fig. 2). Above 50°C , fogging was noted and was seen to be a function of time (Fig. 3). Heat-fogged films had nonuniform optical density across their surfaces, being darker at the outer edges (Fig. 4). Density readings were therefore taken near the center of the film.

The effect of relative humidity on thermal fogging was marked, and followed closely the humidity dependence curve for response to gamma radiation established by Kathren and Brodsky⁽⁴⁾ (Fig. 1). Peak thermal fogging occurred at a relative humidity of approximately 50%; thermal fogging at relative humidities exceeding 75% was markedly reduced. The toe of the response curves shown in Fig. 2 was not appreciably altered by a change in relative humidity; however, the steepness of the slope was increased with

increasing relative humidity up to about 40%, while decreasing with increasing relative humidity beyond about 60%. This can be inferred from Fig. 1.

The above results are not inconsistent with the data of Ehrlich,^(1,2) Brodsky and Kathren,⁽³⁾ and Kathren and Brodsky.⁽⁴⁾ They do, however, disagree with the conclusion reached by Ehrlich,⁽²⁾ namely, that at high temperatures, high relative humidity enhances thermal fogging.⁽⁶⁾

In a prior study, Kathren and Brodsky⁽⁴⁾ suggested that relative humidity effects upon film response to gamma radiation were caused by competing reactions within the sensitive portion of the emulsion. The reactants were thought to be various radiolytic products of water, produced in greater or lesser degree as a function of temperature. The fact that thermal fogging shows a similar humidity dependence negates in part this hypothesis, for radiolytic products of water were not present in the thermal fogging experiments. The suggestion of two competitive reactions still appears valid, however, particularly in view of the curve shown in Fig. 1, which can readily be resolved into two smooth equilibrium-type curves.

The implications in personnel monitoring are apparent. Unless films are heated to temperatures above 50° C, thermal fogging will not occur. Hence, unusually high optical densities should not be ascribed to thermal fogging unless it is reasonable to assume that the film was subjected to temperatures of > 50° C. Proximity to a radiator of thermal energy may result in more efficient fogging.

CONCLUSIONS

- (1) Thermal fogging of personnel monitoring film is absent or minimal at temperatures below 50° C for holding times of up to 216 hr. Films held at temperatures above 50° C were fogged nonuniformly, with fogging being a function of both temperature and time. These data are referred to the Du Pont 558 pocket.
- (2) Thermal fogging depends on relative humidity, being maximal at relative humidities of 40-60% and markedly reduced at relative humidities above 75%.
- (3) Humidity dependence of the photographic response to gamma radiation is not caused by radiolytic products of water produced in the sensitive portion of the emulsion. The effect does appear to be a combination of two or more competing reactions.

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- * Work performed under the auspices of the U.S. Atomic Energy Commission.
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Fig. 1. Humidity dependence of personnel monitoring films. Curve 1, redrawn from Kathren and Brodsky, ⁽⁴⁾ shows sensitivity to gamma radiation. Films (Du Pont 555) were held in environment 125 1/3 hr. Curve 2 shows humidity dependence of thermal fogging mechanism, and was obtained with Du Pont 508 film held for 216 hr at 70° C.

Fig. 2. Fog density as a function of temperature for Du Pont 508 and 1290 films. Data were obtained at $\leq 2\%$ relative humidity.

Fig. 3. Fog density as a function of time for Du Pont 508 and 1290 films. Data were obtained at $\leq 2\%$ relative humidity.

Fig. 4. Appearance of a thermally fogged film. Note that fogging occurs at the edges first.

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