National Radiation Laboratory

Fading of the latent image of neutron film

A Yeabsley

1978/4
NRL Report

MINISTRY OF HEALTH
MANATŪ HAUORA

FADING OF THE LATENT IMAGE

OF NEUTRON FILM

A. YEABSLEY

Report NRL 1978/4

Introduction

This project was initiated in an effort to provide information on the degree of fading of proton tracks in the emulsion of Kodak NTA type A neutron monitoring film under conditions encountered typically in establishments using these films in New Zealand.

Overseas studies of this phenomenon, using controlled conditions, have indicated that at above 90% relative humidity, the track count will regress to less than 40% in less than ten days.

In this study, sets of films were exposed, and developed after set time intervals had elapsed.

Exposure

Samples of 12 films were exposed round the circumference of a circle in an exposure jig to a 0.5 curie Am-Be neutron source. The exposure jig was made with fixed positions for each film and the source. This ensured constant exposure for the seven sets of films exposed. Two centimetres of lead were placed between the source and films to absorb x-radiation produced by the Am-241.

The neutron flux can be calculated as follows:

Total output of source	$= 1.3 \times 10^6 n\ sec^{-1}$
Radius of circle	$= 12$ cm
Surface area of sphere	$= 1810\ cm^2$
Neutron flux at 12 cm	$= \frac{1.3 \times 10^6}{1810}\ n\ sec^{-1}\ cm^{-2}$
	$= 7.2\ n\ sec^{-1}\ mm^{-2}$

The calibration factor used in this Laboratory for this film and neutrons above 3 MeV has been

$$14.4 \times 10^3 n\ mm^{-2} = 11.5\ tracks\ mm^{-2}$$
$$= 8.0 \times 10^{-4}\ tracks\ n^{-1}$$

When reading the films, a total area of $3.992\ mm^2$ was viewed, and for good statistics it was desired to obtain an initial count of approximately 500 tracks. This implied a track density of 125 tracks mm^{-2}. To obtain this track density, the required neutron density is

$$\frac{125}{8.0 \times 10^{-4}}\ n\ mm^{-2} = 1.57 \times 10^5 n\ mm^{-2},$$

and the time needed to produce the required track density is then

$$\frac{1.57 \times 10^5}{7.2} \text{ sec}$$

$$= 6.0 \text{ hours}$$

A trial sample of six films was exposed for 6.0 hours and a mean track count of 343 was obtained. The exposure time for the fading samples was therefore increased to 8.00 hours.

Development

All films were developed at 20° C in Kodak liquid x-ray developer Type 2 diluted 1:4 with water, for 6 minutes. The developer was agitated by gaseous burst of oxygen-free nitrogen at 25 second intervals for a period of 0.4 seconds. The films were then rinsed in water and fixed for 25 minutes in Kodak Liquid X-ray Fixer and Replenisher diluted 1:3 with water. After this they were washed for 30 minutes in running water, and soaked in Kodak Photo-Flo solution for 5 minutes. They were then dried in a cabinet drier.

Reading

Thirty three fields were viewed under a Leitz Ortholux microscope using a Pl 40/0.65 objective lens and a 10x eyepiece. The films were clipped in the same position on a glass slide, and the same thirty three fields were read on each film. Proton tracks were counted subjectively and the total for each film recorded. The criteria used for deciding whether a track should be counted or not was that it must be at least five grains long, although in some cases a judgement decision had to be made by the film reader. A total area of 3.992 mm^2 on each film was viewed.

Storage

Films were stored in ambient conditions in the Laboratory over the period October 1976 to January 1977. Atmospheric conditions over the period were assumed to be average.

Results

Seven sets of twelve films were exposed to the source. These were developed so that the period lapsing between exposure and development was increased by one week for each consecutive set of films starting with zero weeks and finishing with six weeks. These films were then read and a mean and standard deviation calculated.

Time from exposure to development (weeks)	Arithmetic mean ($\overline{x}$)	Standard deviation (sd)
Set 0	455.3	29.2
1	416.2	23.5
2	408.1	20.0
3	380.6	16.0
4	366.0	11.0
5	336.4	21.4
6	221.6	13.4

This data is depicted graphically in Figure 1.

To compare one sample with another, statistical analysis may be used. The standard error of difference is

$$\sqrt{\frac{sd_i{}^2}{n_1} + \frac{sd_j{}^2}{n_2}} ,$$

where sd_i is the standard deviation of the ith sample, sd_j is the standard deviation of the jth sample, and n_i and n_j are the numbers of items in each sample respectively.

In this case the sample size is always 12 and the standard error of difference becomes

$$\frac{1}{\sqrt{12}} \sqrt{sd_i{}^2 + sd_j{}^2} .$$

The significance of difference is given by Υ where $(\overline{x}_i - \overline{x}_j) = \Upsilon$ x the standard error of difference. If $3>\Upsilon>2$ there is a significant difference between Set i and Set j. If $\Upsilon>3$ the difference is considered highly significant.

Set	Υ	% Age fading
0-1	3.61	8.6
1-2	0.91	2.0
2-3	0.83	6.8
3-4	2.60	3.8
4-5	4.26	8.1
5-6	15.75	34.1
0-6	25.20	51.3

These figures show that there is a definite degeneration of latent tracks within the undeveloped emulsion. The tendency is for regression to be linear up to set 6 where a definite fall-off occurs. There are not only fewer tracks observed, but they are harder to distinguish as tracks. This is due to a drop in contrast between background density and track density from set 0 to set 6.

Discussion of Results

These results show that routinely-worn films must be processed within six weeks of the beginning of the wearing period. This could be facilitated by reducing the wearing period.

Correction factors derived from the ratio of the mean track count for set 0 and the mean track counts for the other sets could be applied to increase the accuracy of the reported doses.

Assuming all exposure was received in the middle of the wearing period, correction factors applied can be obtained from the table below.

Time from middle of wearing period to development	Correction Factor
1 week	1.06
2 weeks	1.13
3 weeks	1.19
4 weeks	1.28
5 weeks	1.43
6 weeks	1.81

If all exposure was received at the beginning of a 4-week wearing period, and development was 6 weeks after this, with the subsequent fading correction made to the middle of the wearing period, the assessed dose would be

$$\frac{1.28}{1.81} \times 100\% \text{ true dose}$$

$$= 71\% \text{ true dose}$$

Without correction applied, the assessed dose would be

$$\frac{1.00}{1.81} \times 100\% \text{ true dose}$$

$$= 55\% \text{ true dose}$$

If all exposure was received at the end of a 4-weekly wearing period, and development 2 weeks after this, with the subsequent fading correction made to the middle of the wearing period, the assessed dose would be

$$\frac{1.23}{1.13} \times 100\% \text{ true dose}$$

$$= 109\% \text{ true dose}$$

Without correction factor applied, the assessed dose would be

$$\frac{1.00}{1.13} \times 100\% \text{ true dose}$$

$$= 88\% \text{ true dose}$$

Figure 2 is included to compare the fading curve determined in this study (dotted line) with fading curves produced by K. Becker (solid lines). Becker's figures were produced using controlled conditions of relative humidity, these being 92.2%, 75.5%, 33.5% and 12.5%.

Neutron calibration factor

The exposure test casts doubt on the correctness of the calibration factor for converting neutron density to track density. Conflicting information is available for the number of tracks produced per neutron and some published data is tabulated below.

Kodak NTA type A emulsion

Author	Neutron Energy	No of tracks per Neutron
Piesch (1964)[2]	Fission Spectrum	3.8×10^{-4}
	Po/Be (approx 4 MeV)	6.2×10^{-4}
	14 MeV	6.5×10^{-4}
Lehman[3]	4 MeV	$5.0 \pm 0.02 \times 10^{-4}$
Watson[3]	4 MeV	6.9×10^{-4}
Hart and Hale[3]	4 MeV	6.9×10^{-4}
Factor used at the National Radiation Laboratory at present.		8.0×10^{-4}
This Study	Am/Be (approx 4 MeV)	6.0×10^{-4}

Recommendations

A. Films should be desiccated and sealed in a water vapour proof package before issue.

B. A new calibration in the new package, preferably using a variety of neutron sources, would be necessary.

C. An extended fading check using the new package would provide correction factors for fading that occurs.

References

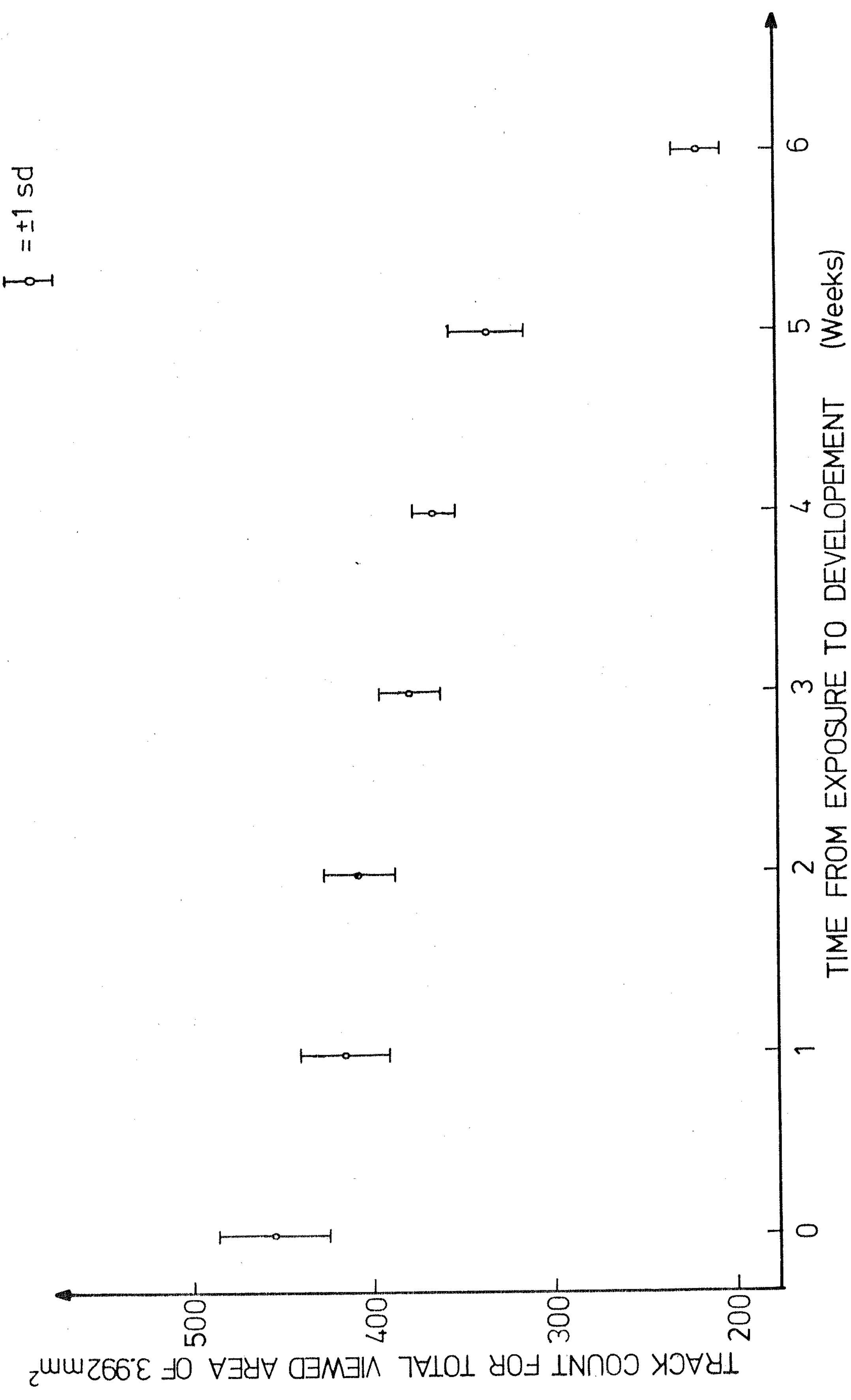
1. David T. Bartlett and F.L. Creasy, Nuclear Instruments and Methods, 127 (1975) 149.

2. K. Becker, Photographic Film Dosimetry.

3. IAEA Technical Report Series, No. 109.

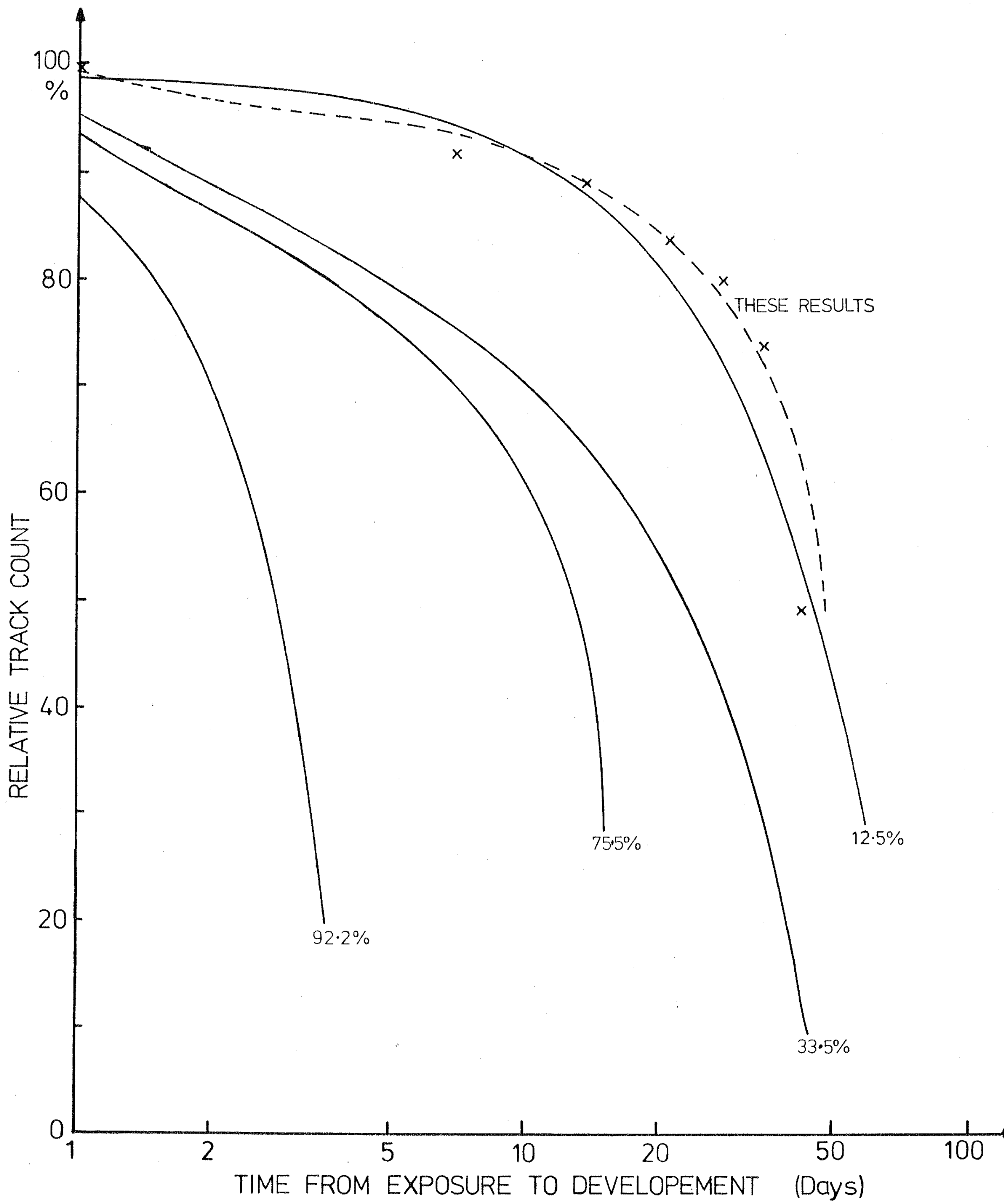
4. M.J. Moroney, Facts from Figures, Pelican.

FIG 1.



= ±1 sd
0
1
2
3
4
5
6
TIME FROM EXPOSURE TO DEVELOPEMENT (Weeks)
500
400
300
200
TRACK COUNT FOR TOTAL VIEWED AREA OF 3.992mm²

FIG 2


100 %
80
60
40
20
0
RELATIVE TRACK COUNT
THESE RESULTS
92·2%
75·5%
33·5%
12·5%
1
2
5
10
20
50
100
TIME FROM EXPOSURE TO DEVELOPEMENT (Days)