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ABSTRACT

This report discusses methods of obtaining the optimum processing from dental films, which will ensure that good quality radiographs are produced when using optimum exposure factors. It is demonstrated that the necessity for repeat exposures will be reduced as poor developer conditions are kept to a minimum.

A method of quality control of developing conditions for dental X-ray films has been developed. It does not require the use of Specialized instrumentation, is relatively easy to maintain and is sufficiently accurate for practical purposes.

INTRODUCTION

In dental radiography, bad developing techniques or poor developer condition may result in a radiograph which is unsatisfactory. If this occurs, the dentist may have to repeat the exposure and compensate for poor developing by adjusting the exposure factors. This procedure will result in the patient receiving unnecessary doses of radiation. In order to achieve optimum processing of dental films, there is a need to establish an inexpensive but suitable method of assessing the developing conditions, which can be readily used by dentists in their practices. Optimum processing of radiographs will help to ensure that the patient receives a minimal radiation dose.

Problems which can occur during manual or automatic film processing are varied, but most lead to an unsuitable film contrast and speed. If the film is underdeveloped, due to either a less active developer than normal or the temperature being below that which is recommended, the resultant contrast on the film is low and the image definition is poor. On the other hand, if overdevelopment occurs due to a higher than recommended temperature, the film will present a high contrast and a higher than normal base fog level. The consequences of bad developing techniques or poor developer condition are such that the information required from the film cannot be obtained and the dentist must repeat the exposures. This will result in the patient receiving unnecessary radiation doses to the eyes, thyroid or the mucosa of the mouth, which may result in somatic effects, or unnecessary radiation to the gonads causing genetic effects, which can become manifest in future generations.

In order to minimize the number of repeat exposures and to ensure that a uniform radiographic quality can be maintained, a quality control protocol must be set up to measure the effects of processing on the film emulsion. Existing protocols (e.g. McLemore 1981) require the use of instruments such as densitometers and sensitometers to determine the speed and contrast of the film but these instruments can prove to be rather expensive and their operation can be time consuming and tedious.

A suitably accurate method of quality control has been developed which is relatively easy to maintain and does not require the use of specialized instrumentation. This report outlines the methods used in the derivation of the protocol and also describes how it is to be used.

EXPERIMENTAL PROCEDURE

Over the useful life of X-ray film developer, the contrast and speed of the X-ray film will gradually change due to the aging of the developer. When the speed and contrast fall below an acceptable value, it is necessary to replace the exhausted developer with fresh developer. The speed and contrast can be determined by the use of a dental film which is exposed to Xrays in order to produce a step wedge. The dentist can follow the developer's deterioration by processing a step wedge at set intervals and comparing the step densities with the corresponding steps on a reference film which has been processed using fresh developer. Changes in the speed and contrast will give an immediate indication of the developer condition and whether or not a developer change is imminent.

The step wedge was produced by exposing an occlusal Dental X-ray film to Xrays under specified conditions. A Phillips Stanford Baratron 300, full wave rectified X-ray generator, with a Thermax C+ X-ray tube was used together with an RRD no. 2 dental cone. This cone had an added filtration of 1.5 mm Al. Exposures were made using 60 kV and 5 mA, with a focal spot to film distance of 90 cm to ensure a uniform film density. A lead sheet was placed on the exposure bench within the beam to minimize any back scattered radiation. The film to be exposed was marked into 7 areas and placed on the lead sheet directly under the beam. Another lead sheet was then placed over the film, leaving only one area of the film unprotected from Xrays. After an exposure was made, the lead sheet was repositioned so that the next area was also uncovered and the film once again exposed. This procedure was repeated for six of the seven areas. The seventh area was not exposed so that the base fog level could be measured. A schematic diagram of the experimental test set-up is shown in figure 1.

The resultant step wedge will have exposure steps with the following relationship:

Step number:	0	1	2	3	4	5	6
Relative Exposure (E)	0.00	1.00	2.00	3.00	4.00	5.00	6.00
Log(E)	-	0.00	0.30	0.48	0.60	0.70	0.78

Two standard exposures times of 0.6 seconds and 0.8 seconds were used so that a range of densities would be produced on the films and the most suitable step wedge could be obtained.

Once exposed, the films were left for at least 30 minutes and no longer than 8 hours before developing, as described in an International Standards Organization document ISO 5799 (ISO 1981), so that there was no significant latent image fading.

The films were processed using the procedures described in ISO 1981 with the temperature of the developer and fixer at 22.0°C and by using the following processing conditions:

Development: 4 minutes with agitation for the first 15 seconds then 5 seconds each minute thereafter.

Fixation: 10 minutes with initial rapid agitation for the first 30 seconds.

Washing: For at least 30 minutes. The temperature of the mains water was approximately 20°C.

Drying: At not greater than 40°C.

Note: All dental film and developing solutions were obtained from Kodak. These were:

1.	Dental film	DF-58
		DF-50
2.	Developer	Cat. no 405-8400
3.	Fixer	Cat. no 405-8418

After fresh developer and fixer had been prepared, a set of step wedges were exposed and developed in order to obtain the speed and contrast of the film under optimum developing conditions. The photographic density of the steps were measured using a densitometer and a graph of density versus step number (i.e. relative exposure) was plotted (see fig. 2).

Due to the limited range of densities produced on the step wedge, the standard ISO method for obtaining the films contrast was not suitable. For these tests, the contrast was taken to be the difference in density between step 6 and step 3 as both of these steps were on the straight line portion of the density vs log exposure graph. The speed was taken to be the inverse of the log of the relative exposure which would be produced by an optical density of 1.00 above the base fog density.

Films were subsequently exposed and developed every three to four days. Once a noticeable change in either the speed or contrast became apparent, films were exposed and developed daily so that the change in the activity of the developer could be observed in greater detail.

When either the contrast or speed had reached a level where the exhaustion of the developer was indicated, a graph of the speed and contrast versus days elapsed was plotted for each set of films (fig. 3a and 3b). It can be seen from this graph that there are small fluctuations of the speed and contrast from day to day until there is a sudden change due to the onset of developer exhaustion. A comparison between the initial films developed with fresh chemicals and the films developed immediately prior to the onset of developer exhaustion showed that the matching densities on the two films differed by several step numbers.

A step wedge which could be used to check the deterioration of the developer should give a change of one step number between a wedge processed with near exhausted developer. The change in density must also be large enough to be observable with the naked eye. By using the data derived from the tests, with the two different exposure times, it was concluded that a wedge with four steps, with the second step having an approximate optical density of 1.0, would give the most suitable results. The four steps should have relative exposures in the ratio of 1:2:3:4 for steps 1 to 4 respectively.

As a comparison of optical densities is to be made rather than the calculation of the speed and contrast, it is not necessary to include a base fog level on the test wedge.

EXPOSURE OF THE TEST STEP WEDGE

In order for a Dentist to expose the Test Step Wedge, it is first necessary to set up a reproducible exposure system. It is important that the distance of the film to the X-ray tube is always the same each time step wedges are exposed. The uniformity of the X-ray field must be sufficient to ensure that the film would receive the same dose over the whole area. Consequently, the film to X-ray distance must be large enough to permit this to occur. A radiograph, using a large film, should be taken so that the most suitable distance can be determined. The surface on which the film is placed should give an even backscatter and it may be preferable to place the film on a lead sheet or a lead apron. Any size Dental X-ray film may be used for the Test Step Wedge provided that it is large enough for four different areas to be exposed on it. The test films must be taken from a fresh supply so that there is no significant increase in the background fog of the film due to any aging effects.

Step 2 should have a density of approximately 1.0 and some experimentation using different exposure factors will be necessary. An optical density of 1.0 can be estimated without the aid of a densitometer by firstly exposing a film to Xrays using the previously determined exposure set-up and then placing the developed film on a piece of white, printed paper. In a well illuminated room, the printed letters should be just legible. If they are easily recognizable, the density is below 1.0 and if they cannot be seen, then the density is above 1.0 (Herz 1969). Once a density of 1.0 has been obtained, the standard exposure factors which will be used to produce the Test Step Wedge are the same as those used to obtain the density of 1.0, but the exposure time should be reduced to ONE HALF or the nearest obtainable time to this value. It is recommended that the exposure time should not be less than approximately 0.5 seconds as the X-ray output may not be reproducible for lesser times. It may be necessary to increase the film to X-ray tube distance in order to obtain long enough exposure times.

Once a reproducible exposure system has been set up and standard exposure factors determined, the Test Step Wedges can be exposed by using the same method as described previously (i.e. covering three quarters of the film with a sheet of lead, making an exposure, then progressively uncovering a quarter of the film and repeating the exposure until the whole film has been exposed).

LATENT IMAGE FADING

A series of Test Step Wedges were exposed each day over a period of one month and then processed simultaneously in fresh developer in order to determine the latent image fading of the films. The optical density for each step was then plotted as a function of elapsed time between exposure and development. The results are given in figure 4. The graph shows that there was an insignificant variation between film densities for the same given exposures over the period of test and consequently, the latent image fading is insignificant. It is therefore possible for the dentist to expose a number of Test Step Wedges at one time and provided that they are stored in a suitable place away from Xrays and chemical contamination (preferably in a refrigerator), they can be used up to a maximum period of one month after exposure. Apart from the convenience of exposing the wedges at one time, there is the added advantage that the films will be exposed under identical conditions.

EFFECTS OF VARIATIONS IN DEVELOPING CONDITIONS

Variations in the step densities as a function of temperature were investigated in order to determine the sensitivity of the Test Step Wedges to the developer temperature. All processing conditions of the dental films were kept constant except for temperature. For the Kodak films tested (DF-50, DF-58), the recommended development temperature was 22°C for a development time of four minutes. Films were processed with the temperature of the developer varying from 10°C to 32°C in 2 degree steps, paying strict attention that all other development factors were kept constant. A graph of the optical density of each step number versus temperature is shown in figure 5.

It can be seen from the graph that the density of the steps is highly dependent on the developer temperature. A temperature of as low as 10°C or as high as 27°C would result in a change in the density equivalent to one step. Unless the temperature is kept at the same value each time films are processed, changes due to temperature could be mistaken for developer exhaustion. For example, a change of half a step due to the aging of the developer together with a temperature of 17°C instead of 22°C would suggest that the developer needs changing. On the other hand, if the developer needs changing and the developer temperature is 25°C, the Test Step Wedge would incorrectly indicate that the developer is satisfactory. However, at this higher temperature, there would be a change in contrast which would produce a radiographic image of unsuitable quality.

CONCLUSION AND DISCUSSION

A relatively simple and readily usable system of quality control for dental X-ray film processing has been set up. By exposing Test Step Wedges to Xrays and developing one prior to processing normal dental X-ray films, the deterioration of the developer can be observed and an indication of when the chemistry needs changing can be ascertained. A step by step procedure for the exposure and use of the Test Step Wedge is given in the Appendix.

Sufficient Test Step Wedges should be exposed at a given time, so that one wedge can be developed each day that normal dental films are to be processed, to ensure that the processing chemicals are not exhausted.

The developer exhaustion period cannot be stipulated due to the influence of many variables. e.g. environmental conditions and the number of films processed. During the test procedures the temperature was maintained at 20°C and as the developing tank used for the processing of the films presented only a small surface area, oxidation would be minimized. As only a small number of films were processed during this period, the fact that the developer became exhausted after approximately one month, would infer that, in practice, one month would be a maximum period before exhaustion occurs.

It is emphasized that there should be, at all times, strict adherence to the film manufacturers processing specifications. This will minimize the possibility of adverse processing affecting the developed films.

If optimum processing of dental X-ray films is maintained, the resultant radiographs will be of a sufficient quality such that the optimum exposure factors can be used and that the number of repeat exposures is reduced. This procedure will ensure that the radiation doses to the patients are kept to a minimum.

ACKNOWLEDGEMENTS

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ISO (1981) Photography - Direct-Exposure medical and dental radiographic film/process combinations - Determination of ISO speed and average gradient. International Organization for Standardization ISO 5799 1981-10-01.

McLemore, Joy M., (1981). Quality assurance in diagnostic radiology. Chicago: Year Book Medical Publishers.

Figure 1: THE EXPERIMENTAL TEST SET UP FOR THE STEP WEDGE.

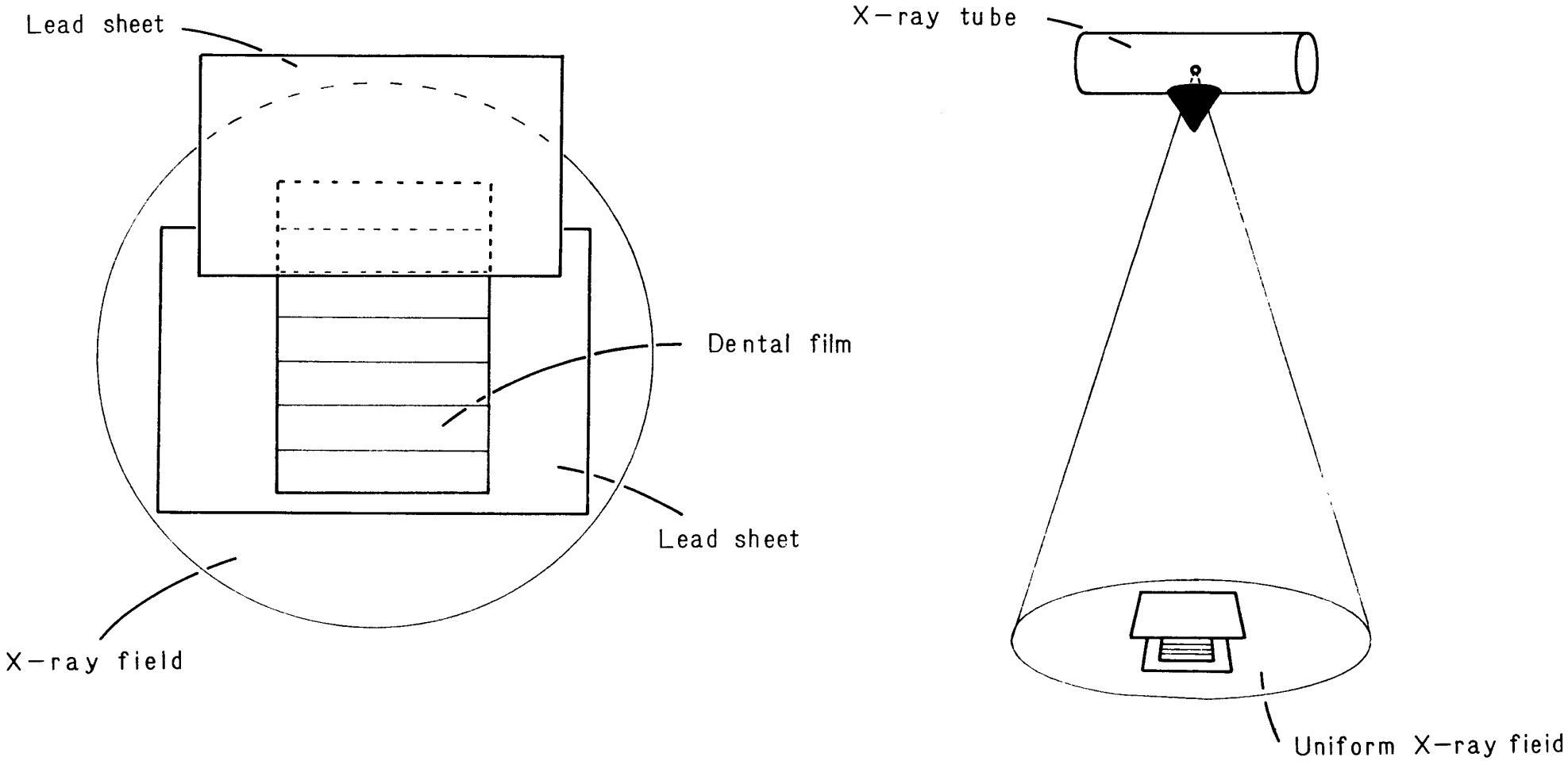
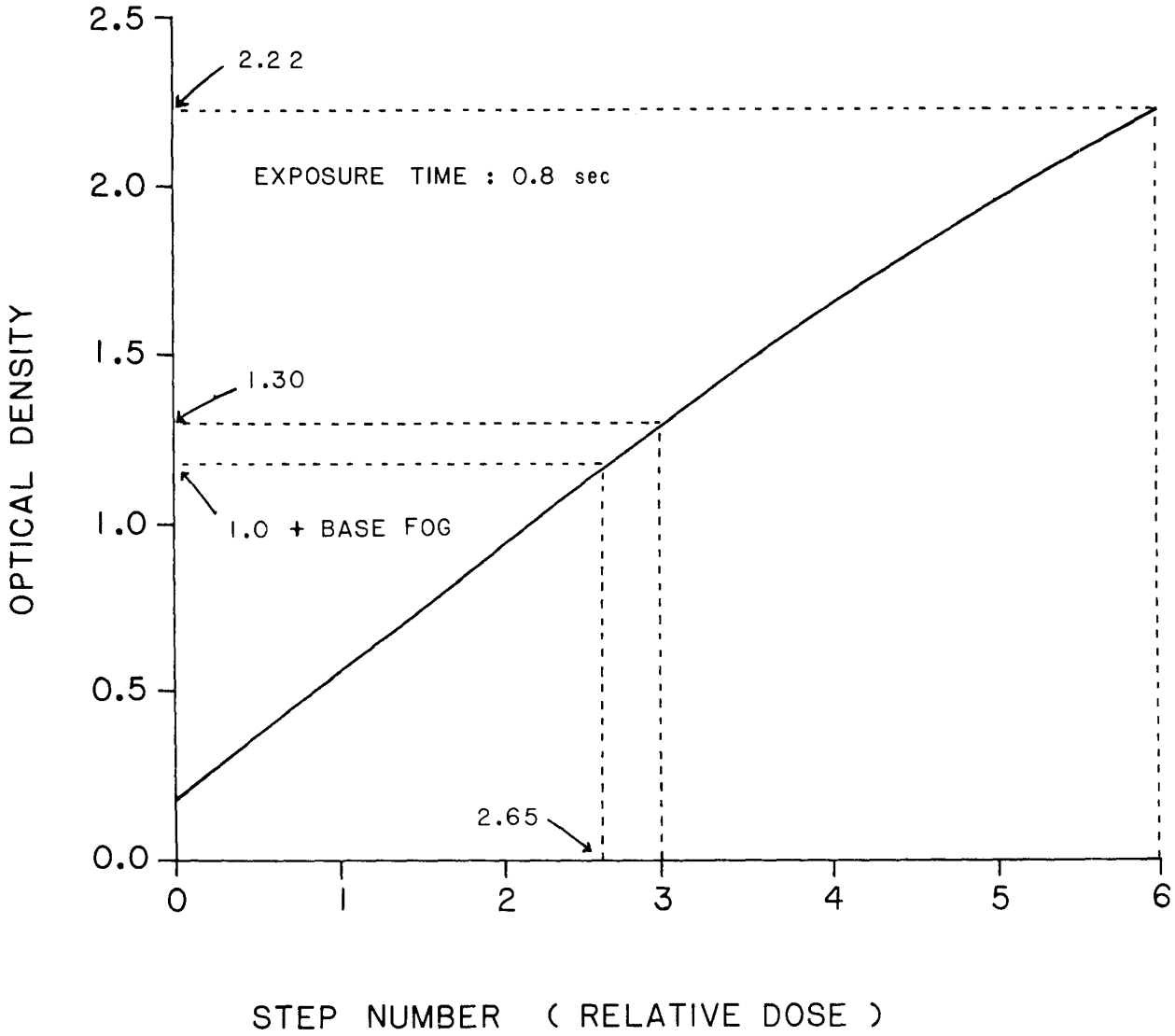


FIGURE 2 :

DERIVATION OF SPEED AND CONTRAST FROM OPTICAL DENSITY VERSUS STEP NUMBER (RELATIVE DOSE)



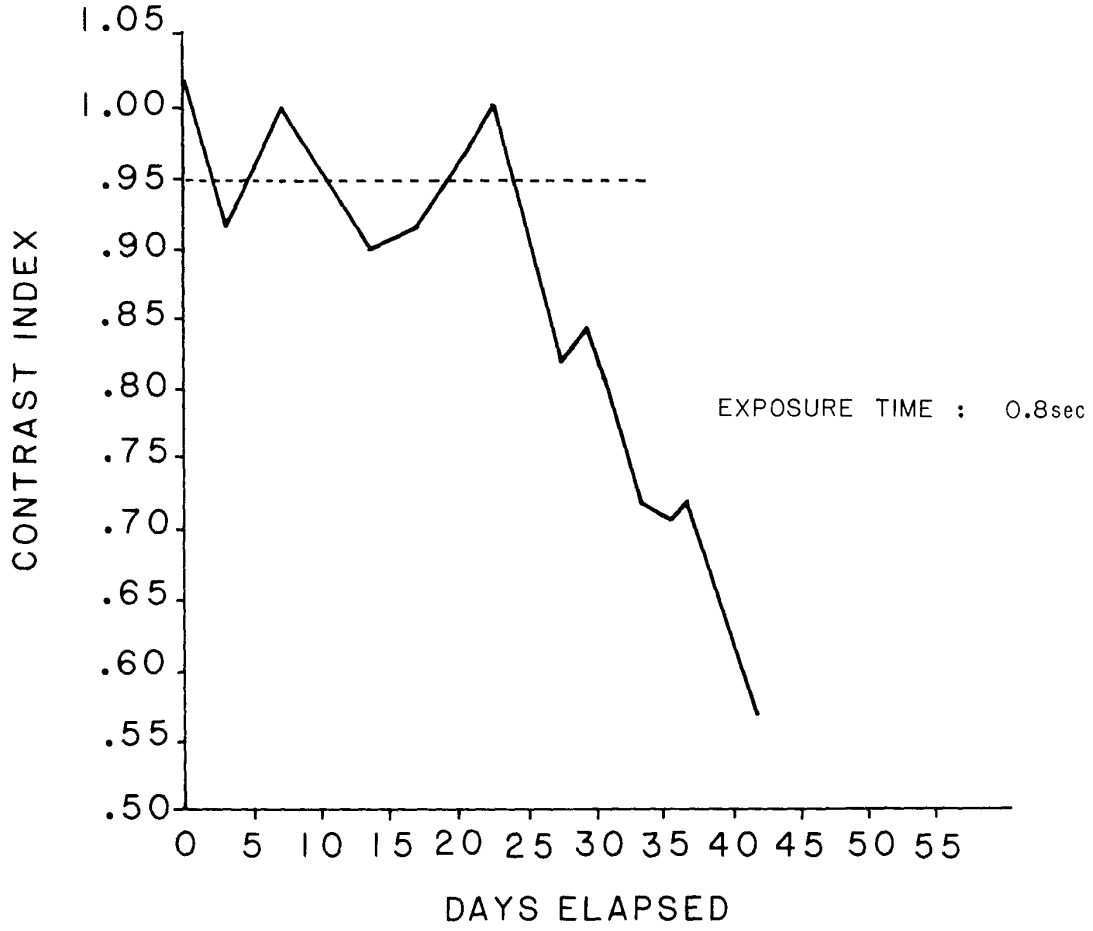
CONTRAST : (STEPS 6-3): 2.22-1.3 = 0.92

SPEED : 1.0/RELATIVE DOSE FOR DENSITY OF 1.0 ABOVE BASE FOG :

1.0/2.65 = 0.38

FIGURE 3(a).

SPEED & CONTRAST VERSUS DAYS ELAPSED.



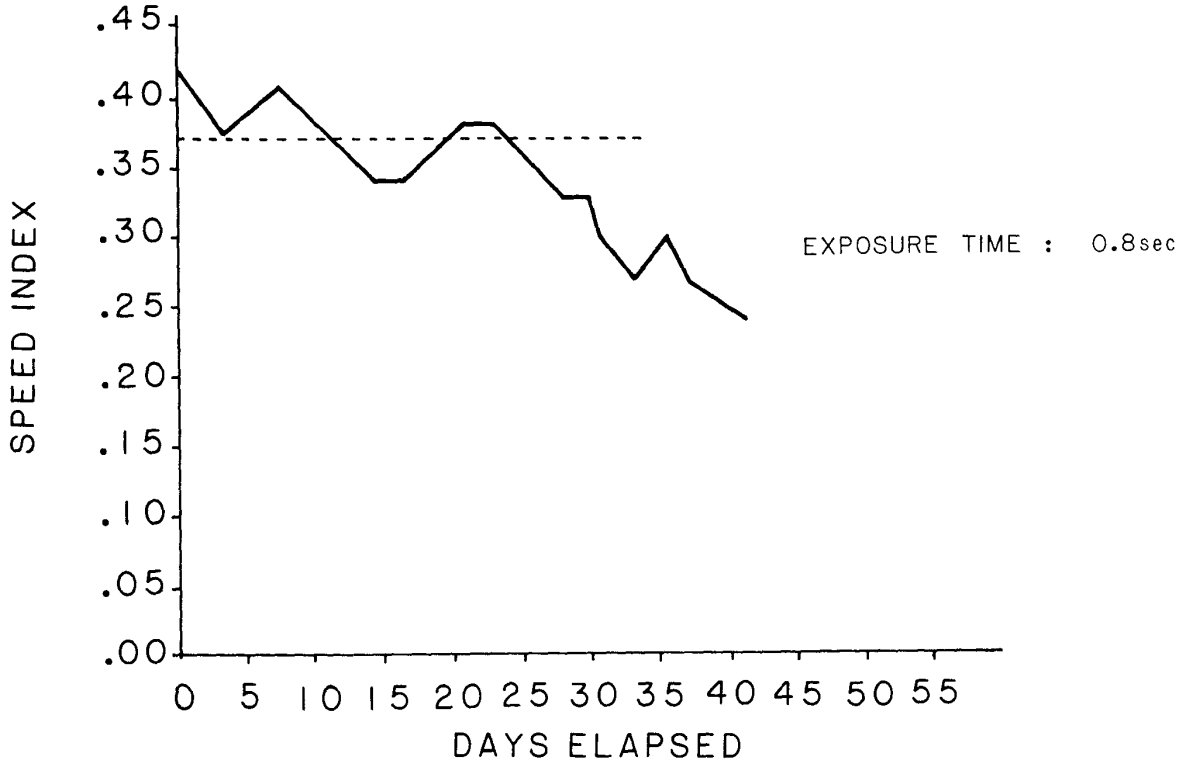
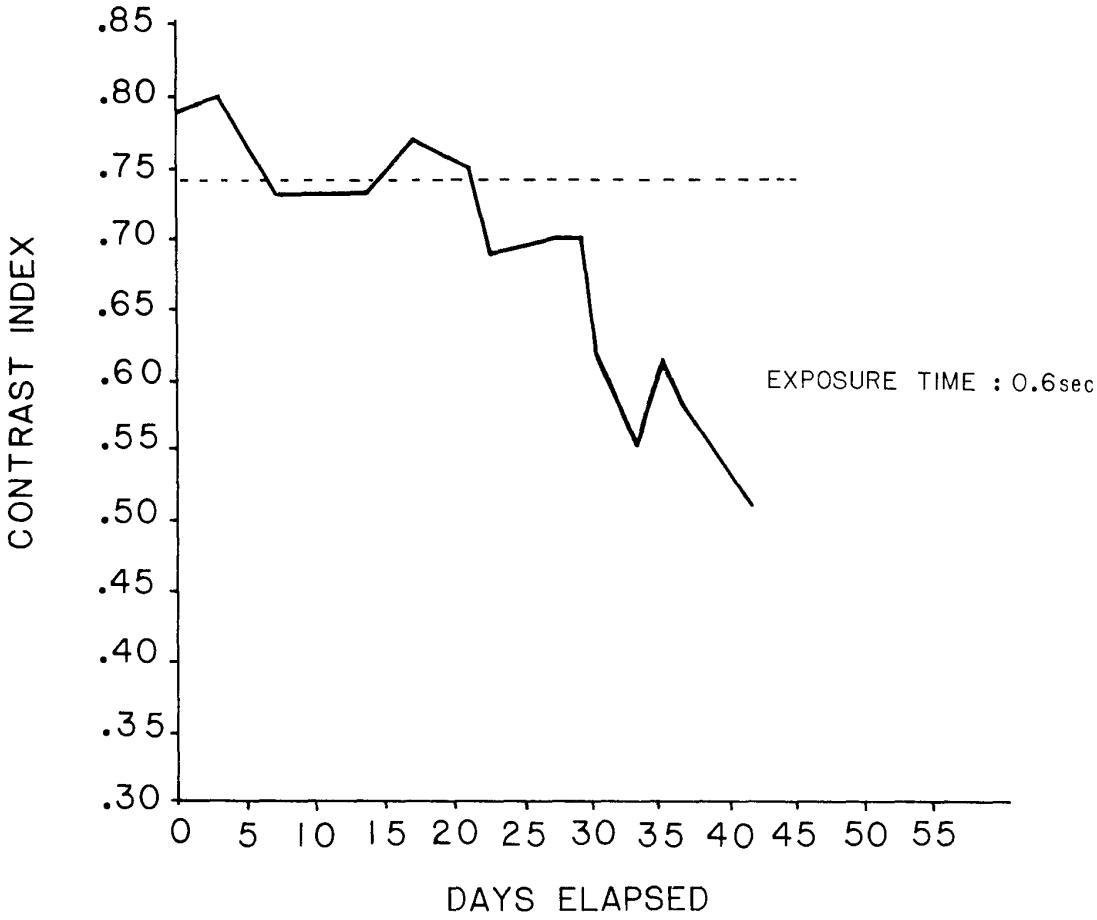


FIGURE 3(b).

SPEED & CONTRAST VERSUS DAYS ELAPSED.



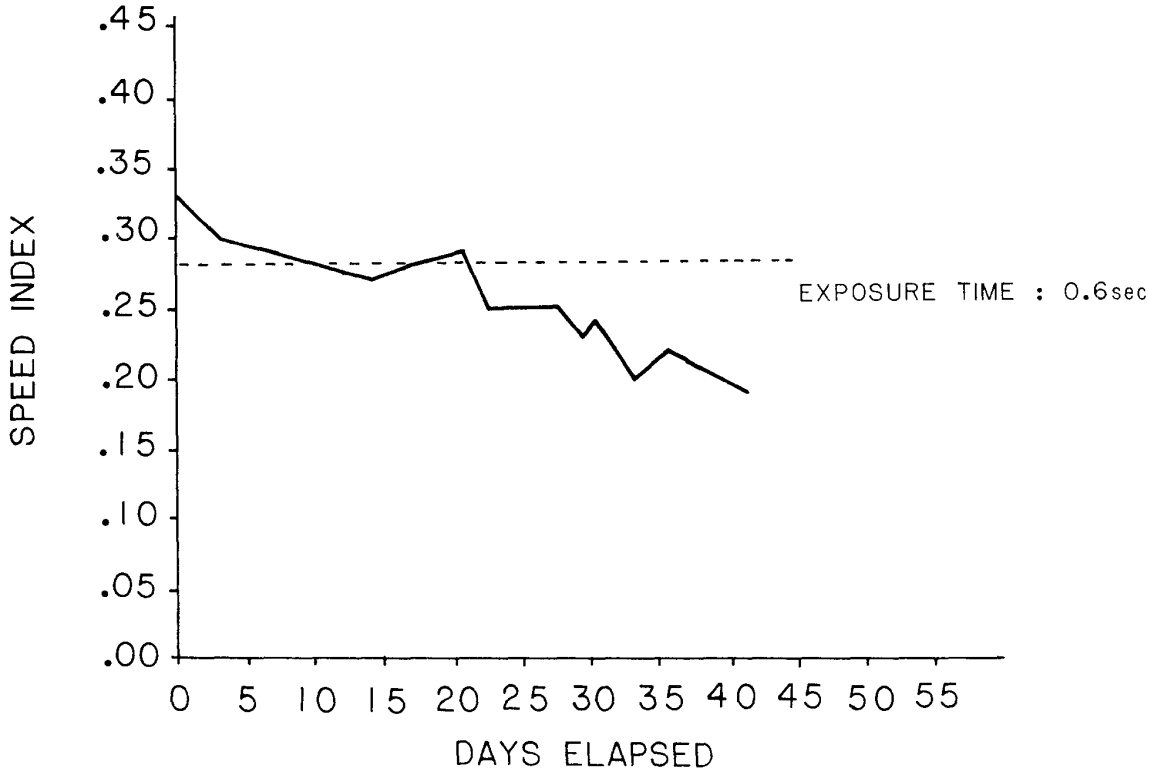


FIGURE 4: LATENT IMAGE FADING TEST

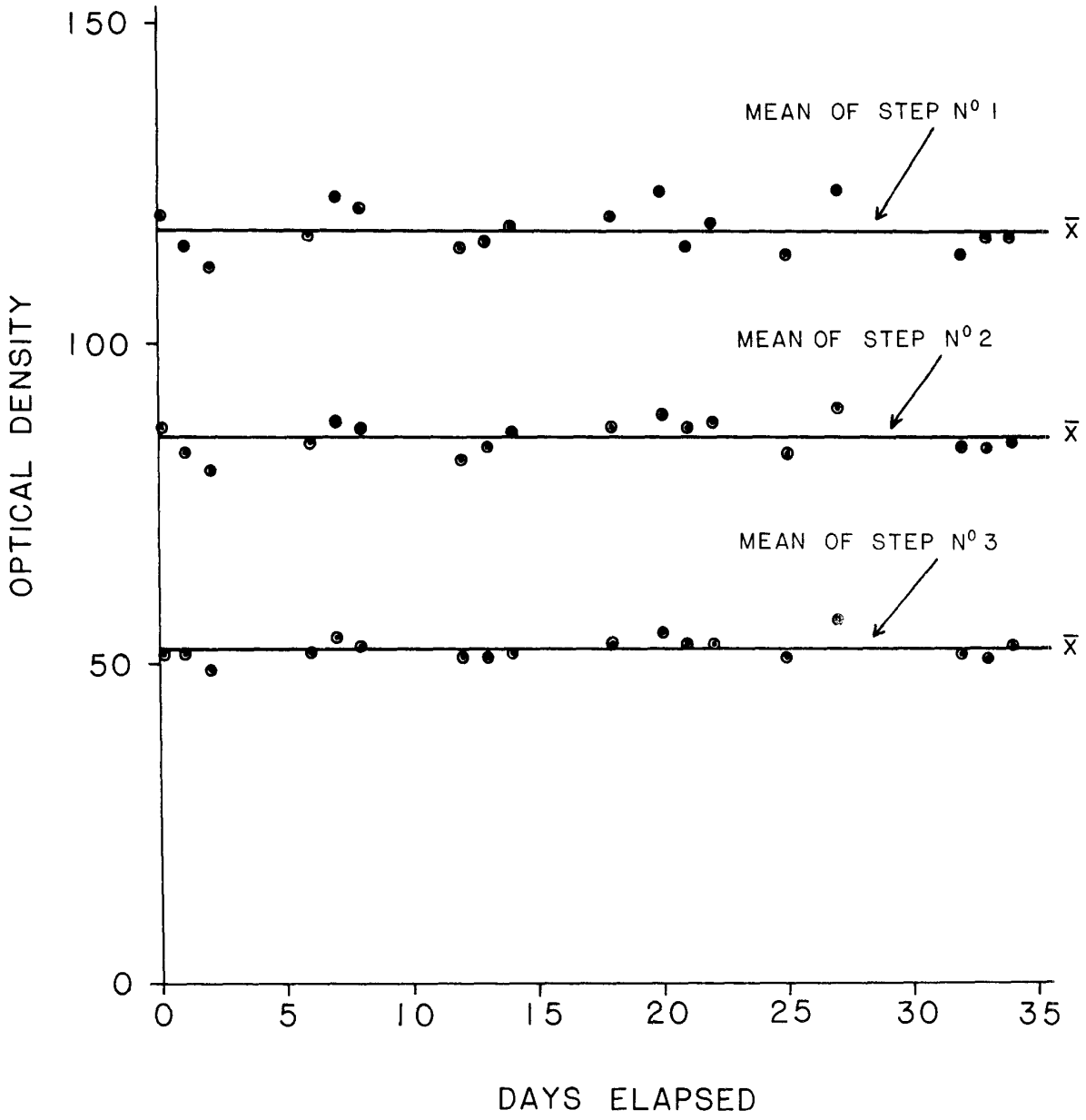
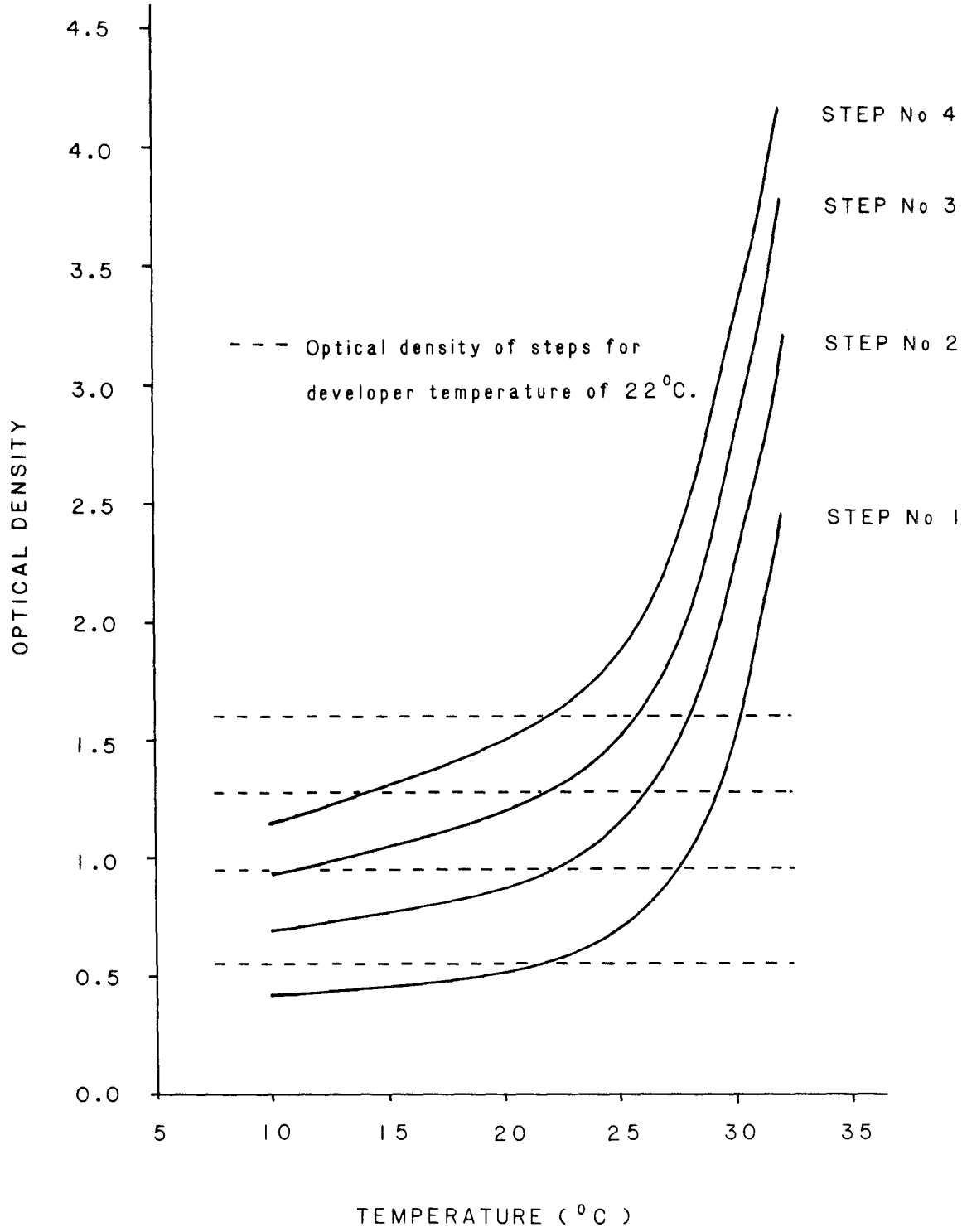


Figure 5.

OPTICAL DENSITY VERSUS TEMPERATURE.



APPENDIX

Procedure for the Exposure of a Test Step Wedge.

NOTE: 1. Any size dental film can be used to produce a step wedge provided that it is large enough that four areas can be exposed on it. When a batch of Test Step Wedges is to be exposed, all of the films are to be from a fresh supply and of the same manufactured emulsion number and preferably from the same box of films.

2. Prior to the preparation of the Test Step Wedge, mix up fresh chemicals and allow a suitable time period for temperature stablization. Ensure that the temperature of the developer complies with that specified by the manufacturer.

The following procedure must be followed in order to produce a Test Step Wedge:

A. Check of the Field Size and Uniformity.

1. Set up the X-ray tube so that later exposures may be easily reproduced.

2.. Place a large dental film on a flat surface within the X-ray field.

3. Using appropriate exposure factors, expose and develop the film. The developed film should have an optical density that can be visually assessed. Check to see that the field is uniform and that the field size is large enough to cover the whole film. If the field is not uniform or if the field size is not large enough, increase the X-ray tube to film distance and place the film in the most uniform region of the field. Repeat this procedure until a satisfactory result is obtained.

B. Determination of exposure factors for the Test Step Wedge.

The film must be exposed so that the developed film has an approximate optical density of 1.0. A density of 1.0 can be estimated by the following procedure:

Place the developed film on a white piece of printed paper in a well illuminated room. With a density of 1.0 the printed letters should be just legible.

1. With field size and uniformity established, place a dental film in the beam.

2. Expose the film using known exposure factors and check to see if the developed film has an optical density of approximately 1.0.

3. If the optical density is greater than 1.0, decrease the exposure time or increase the X-ray tube to film distance. If the density is less than 1.0, increase the exposure time or decrease the X-ray tube to film distance making sure that the X-ray field remains uniform and the heat loading of the X-ray tube is not exceeded.

4. Once an approximate density of 1.0 is established, HALVE the exposure time. Where this is not possible, an exposure time as close to half the original will suffice. This will give the exposure time to be used for the Test Step Wedge.

5. Note the exposure set up distances, etc. and the exposure factors, including the test wedge exposure time, so that the system can be reproduced for the future.

C. Exposure of the Test Step Wedge.

The film is exposed in strips so that after processing the resulting image will be of four strips of differing densities. The first strip will receive four exposures, the second three exposures, the third two exposures and the fourth, one exposure.

1. With the film in the X-ray field place a lead sheet over three quarters of the film so that the first strip may be exposed.

2. Once exposed, reposition the lead sheet so that half the film is uncovered. Repeat the exposure.

3. Repeat the procedure until all four (strip) quarters have been exposed.

4. Expose enough films using the above procedure so that there are sufficient films available to develop one film for each day that normal films are to be processed up to a maximum period of one month.

5. Once exposed the films must be stored in a suitable place away from Xrays and chemical contamination (preferably in a refrigerator). It is recommended that the films, stored in a container, be clearly marked as having been exposed to Xrays.

D. Use of the Test Step Wedges.

1. After fresh developer has been made up, develop one test step wedge. This wedge is to be used as a reference film to which subsequent developed Test Step Wedges will be compared for the active life of this developer.

2. Each day that normal dental films are to be processed, develop one of the Test Step Wedges.

3. Compare the Test Step Wedge with the reference film by placing the films on a light box. If the density of the steps on the Test Step Wedge correspond with a different step number on the reference film, the developer needs changing.