# RADIOGRAPHICAL DUPLICATION OF RADIOGRAPHS.

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# CHAPTER 1.

Reason for the research.

Known methods of copying radiographs.

Radiographic contact printing.

Method of presentation.

# CHAPTER 1.

## FOREWORD.

The present research was prompted by the need to acquire radiographs of oral and facial conditions which are rarely seen in a purely dental school. Good radiographs are essential for teaching and should always be available to augment the clinical cases which present themselves during the period of a systematic course in radiology, dental surgery, pathology and oral surgery.

The duplication of radiographs has always been a tedious and unsatisfactory procedure involving the photographic department, necessitating a series of processes, and producing a copy which is generally inferior to the original.

Confronted by the shortcomings and difficulties of former techniques for radiograph duplication, it seemed desirable to find a simple and efficient method of producing a duplicate radiograph comparable with the original and one which would require no photographic equipment for its production. It was considered necessary to have the process completed entirely in the Radiology Department by the radiographers, using a standardised technique and one which should give uniform results. The normal routine of the department would not be unduly disturbed by additional duties.

The evolution of such a technique and the possible achievement of producing an enhanced duplicate radiograph from the original, with its obvious advantages to diagnosis and teaching, was the goal which provided the incentive for this work.

## KNOWN METHODS OF COPYING RADIOGRAPHS.

The known methods of copying radiographs by intermediate transparencies, reversal development, solorization and photography were considered but found unsuitable for the following reasons:-

1. Intermediate Transparencies.

This method requires the use of the photographic department which generally is not available nor convenient.

2. Reversal Development.

Although this process uses the minimum of photographic equipment, the length of time and the numerous solutions required render it unsuitable.

3. Solorization.

Solorization makes use of a printing frame and exposure for approximately 20 minutes with photoflood lamps; or, as an alternative, the use of direct sunlight for a similar period. This long prefogging period is a definite objection and the resultant copies are dependent upon the high density values of the originals which vary considerably on a cross-section of X-ray negatives, with corresponding adverse effect on the duplicate.

4. Photographing the illuminated original.

Photography was discarded. It not only required considerable time but also involved the use of additional equipment, and was dependent upon the radiographer being a competent photographer.

One other method remained for experimentation, namely that of using X-rays as a light source, and by employing intensifying screens to fluoresce and intensify the source of light. This method appealed most as it required no photographic equipment and could be done within the confines of the radiographic department. This technique has few references but is mentioned in Longmore's Medical Photography (1), where it is not recommended because of a resultant lack of detail and excessive contrast. X-ray film, and not photographic film, was used in Longmore's experiment and this was probably the main cause of the failure to produce satisfactory duplicates.

E.O. Goss, (2), in the Society of Radiographers' Magazine, draws attention to fluorescent contact printing by the use of X-rays, but found its usefulness limited.

C. J. MacKay, (3), in the Journal of Radiography, discusses this radiographic contact method more fully, and he follows a technique on lines similar in purpose to that which is contemplated and desired in the present thesis. Paterson High Speed Screens (Series II) and Kodak Blue Brand X-ray film were used in MacKay's experiment. The results proved that quite satisfactory copies could be made from film of medium or low density, but that the solorization method was more satisfactory than the intensifying screen method with films of high density. MacKay's paper evinced a modicum of hope that it might be possible to obtain satisfactory copies of X-ray negatives, using a simple technique within the confines of the X-ray department and using no photographic equipment.

## METHOD OF PRESENTATION.

In a treatise such as the present, the results were dependent upon the comparison of radiographs obtained from various methods employed. The principle involved was to make a positive copy of an original X-ray, and to make a duplicate or negative X-ray film from the positive copy. The primary effect was purely visual or subjective, and scientific proof was required to decide if the copy was inferior, equal to, or better than the original. Confirmation or proof could only be given by means of a densitometer test. This necessitated taking an X-ray negative of an optical density stepwedge, an apparatus with a graduated series of metal density steps of known increment, covering a range from first perceptible density to apparent complete opacity. Throughout the investigation the same stepwedge was used, with a thickness of 1 millimetre for the first step and graduated to reach 6 millimetres in the sixth step. This assured a standardised method of assessing the varying densities of the different experiments.

Positive and duplicate radiographs were then made and the densitometer readings taken of the original and copy. A graph shows the relative increase or loss of intensification between the original and the copy. This graph varied with different experiments and confirmed the improved technique. Densitometer readings were taken only for the final results of each experiment on the different methods employed; but not for individual films in each experiment. Comments and conclusions on each experiment were then made.

It must be appreciated that the delicate relationship of contrast and definition between the original and the duplicate radiographs was difficult to produce in photographic prints.

For this reason separate files of all X-rays in the various experiments were numbered consecutively, and only one example pertaining to each experiment was enclosed in a separate envelope, and incorporated within the text of the thesis in order to ensure accuracy of subjective comparison.

# REFERENCES.


1. Longmore, T.A. (1949).

   "Medical Photography."

   4th Edition, London. The Focal Press.

2. Goss, E.O. (1941).

   "Fluorescent Contact Printing."

   Radiography Vol. VII, No. 79, July 1941.

3. MacKay, C.J. (1951).

   "An investigation of a simple method of copying radiographs."

   Radiography Vol. XVII, No. 200, August 1951.

4. Marshall, S.H.J. (1952).

   "Reproduction of radiographs by reversal process."

   Radiography Vol. XVIII, No. 214, October 1952.

5. Roberts, Edmund P.

   Davidson, James B. (1953).

   Lambuck, Charles.

   "Composite film prints from dental radiographs."

   Dental Radiography & Photography, Vol. 26, November, 1953.

6. Kodak. (April 1954).

   "Copying radiographs and other transparencies."

   Kodak Data Sheet G.M.2.

# CHAPTER 2.

## Photographic Terminology.

# CHAPTER 2.

## PHOTOGRAPHIC TERMINOLOGY.

Unfortunately it is essential to define and explain a number of technical terms before proceeding to the actual work of the thesis. These established photographic and radiological terms are used in relation to the factors influencing the final radiographic results. Consequently there is no claim to originality in the explanation of the terminology employed, as this is collated from the various sources to which reference is made at the end of the chapter; and when diagrams are used, their origin is acknowledged.

### DENSITY.

The image of a radiograph is built up of grains of metallic silver distributed throughout the two emulsion layers of an X-ray film. When the image is inspected in front of a viewing box, the relative transparency of the various areas in the radiograph depends on the distribution of the black silver grains and it is the quantity and variation of light transmitted which makes up the image. Seen by the eye, the "blackness" is usually described as 'density' and we therefore speak of a greater or smaller density according to whether more or less light is absorbed by the film.

Lambert's law states that "when the thickness of an absorbing medium, (whether it be a single layer or superimposed layers) increases in arithmetical progression, the light transmitted decreases in geometrical progression."

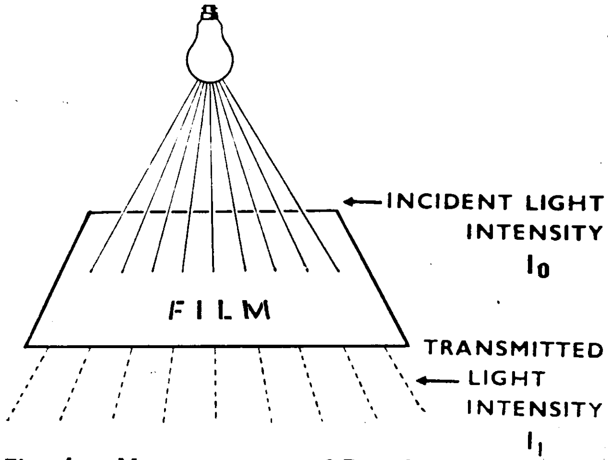



**Fig. 1. Measurement of Density**

Copied from "Photographic Aspects of Radiography".

(Kodak Ltd.,) Ref: 1.

Accurate measurement of density is carried out by a special instrument called a densitometer. This measures the amount of transmitted light intensity passed by a certain area of uniform blackness in the film, the incident light intensity being known and of constant value. (See Fig. I - opposite page.)

$$D = \text{Log.} \frac{I_o}{I_1} = \text{Log.} \frac{\text{Incident Light Intensity}}{\text{Transmitted Light Intensity.}}$$

Suppose the incident light intensity $I_o$ on a film is 1000 units and the transmitted light intensity $I_1$ is 100 units, that is 1/10th of the incident intensity, the density is then

$$\text{Log.} \frac{I_o}{I_1} = \text{Log.} \frac{1000}{100} = \text{Log. } 1000 - \text{Log. } 100 = 3-2 = 1.$$

If the transmitted light intensity is 1/10th of the incident light intensity, then D = 1. If 1/100th D = 2, and if 1/1000th, then D = 3.

An average radiograph of a chest is usually built up of densities ranging in diagnostic value from about D = 0.3 to 1.5. Densities above D = 2 or 3 are so opaque that the Threshold Difference is reached and the difference between them can hardly be recognised when the film is viewed in ordinary illumination.

**TRANSPARENCY.**

The proportion of incident light transmitted by a silver deposit is called transparency.

**OPACITY.**

The reciprocal of transparency is termed opacity and the density is the common logarithm of the opacity.

## CONTRAST.

When inspecting a radiograph in front of a viewing box, the eyes are affected by the various brightnesses of light transmitted through the different densities of the film. The smaller or greater variation of brightness between these two adjacent areas is called the contrast.

## SUBJECTIVE OR INDIVIDUAL CONTRAST.

The value of the contrast perceived by the eye depends on the observer, the size of the field, and on conditions of illumination. This is called subjective or individual contrast and cannot be determined by measuring methods as it differs for each individual.

The subjective contrast can be modified by variation of the light intensity. Small differences in density, at low densities, can best be distinguished by weak illumination, when light reaching the eye is of low intensity, whereas large densities in the order of D = 2 to 3 can only be differentiated under strong illumination. Subjective contrast can also be improved by masking the film in front of the viewing box. This is usually carried out by covering the brighter portion of the radiograph with suitable masks of paper or cardboard and thus eliminating dazzle.

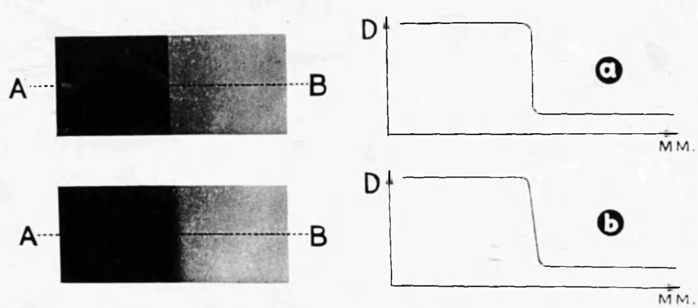



Fig. 2. Measurement of Definition.

(a) Sharp definition. (b) Poor definition.

Copied from "Photographic Aspects of Radiography".

(Kodak Ltd.)

OBJECTIVE CONTRAST.

Objective contrast is the contrast reached by measuring the light intensities transmitted through the two areas, and can only be measured by an instrument such as a densitometer.

THRESHOLD DIFFERENCE.

Threshold difference is the limit at which the eye is able to perceive a difference between two neighbouring brightness fields.

DEFINITION.

Ideal definition in a radiograph would be attained when every point of the object is reproduced in the image as a point. In practice this is not possible as there is always an element of blurring, due to factors influencing contrast and definition, as shown in Tables I & II (pages 14 & 15.)

OBJECTIVE DEFINITION.

Objective definition is determined by the breadth of the boundary between two neighbouring image fields of different but uniform densities. The smaller the breadth of this boundary the better the definition. This can be measured by means of a recording densitometer. (See Fig. 2 - opposite page.)

SUBJECTIVE OR INDIVIDUAL DEFINITION.

Subjective definition depends on the suddenness of change over from one light stimulus to another, and the greater the difference between two light stimuli, the better the individual definition appears. The subjective impression of definition is influenced by contrast which means that given two images of equal objective definition, the one with the greater contrast will give the human eye the impression that it has the better definition.

Similarly, when two images have equal objective contrast, the one with the better objective definition gives to the human eye the impression that it is of greater contrast. Contrast and definition therefore influence each other from the visual point of view although technically they have different definitions. Contrast and definition are the two most important characteristics of a radiograph from the visual point of view.

Although it is important at all stages to obtain optimum definition, the maximum contrast is not always desirable. It should always be kept in mind that the radiologist requires a radiograph which is of high quality from a diagnostic rather than a pictorial view, and therefore the ultimate technical judgment cannot be based solely on photographic value.

Innumerable factors influence contrast and definition and these are summarised in the form of a family tree. Those factors influencing contrast are enumerated on Table I (page 14), and those influencing definition are shown on Table II (page 15).

## TABLE I.

### FACTORS INFLUENCING CONTRAST.

- I. RADIATION
  - Quality of Primary X-rays.
  - Amount of exposure.
  - REDUCTION OF SCATTERED RADIATION
    - By reducing the formation of scattered radiation.
      - By quality of X-rays.
      - By diaphragm cone or compression.
    - By preventing scattered radiation reaching the film.
      - By Potter-Bucky grid diaphragm.
      - By Lead Support.
      - By Intensifying Screens.
- II. PROCESSING CONDITIONS
  - Film Contrast.
  - Type of Developer.
  - Developing time & temperature.
  - Reduction.
  - Intensification.
- III. VIEWING CONDITIONS.
  - Varying the intensity of illumination.
  - Uniform illumination.
  - Colour of film base.
  - Masking.

## DESCRIPTION OF TABLE I.

COLUMN I. When exposing an X-ray film the quality and quantity of radiation largely determine the contrast of the radiograph.

COLUMN II. After exposure the contrast of the film can be influenced to some extent by the processing conditions.

COLUMN III. This tabulates the modification of the subjective contrast by altering the conditions of inspection.

TABLE I copied from "Photographic Aspects of Radiography". (Kodak Ltd.)

## TABLE II.

### FACTORS INFLUENCING DEFINITION.

| I. GEOMETRIC FACTORS | II. PHOTOGRAPHIC FACTORS | III. MOTION FACTORS. |
|---|---|---|
| Focal spot (size, form and homogeneity.) | Type of intensifying screen and film without screen. | Movement of the object and exposure time. |
| Focus-object-film distances. | Parallax of two film emulsions and divergence of screen light. | |

TABLE II copied from "Photographic Aspects of Radiography".

(Kodak Ltd.)

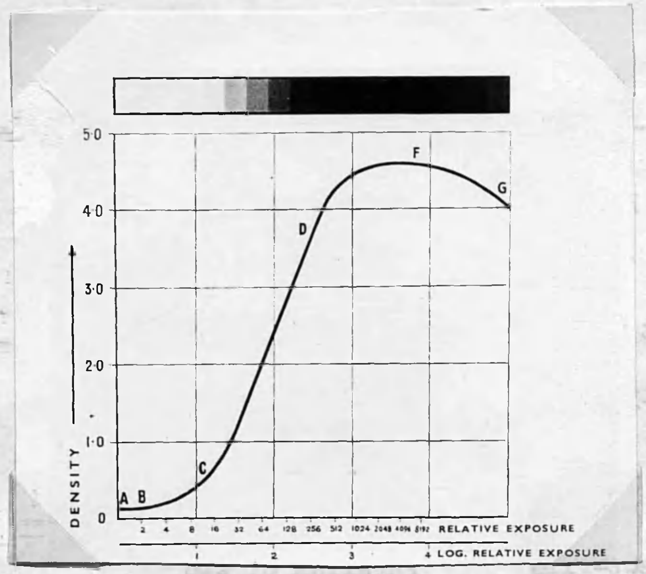



FIG. 3. CHARACTERISTIC DENSITY CURVE.

| | |
|---|---|
| A - B | Fog Density. |
| Point B | Threshold Value. |
| B - C | Foot or toe of curve. |
| C - D | Straight line portion gives a direct measure of the contrast of the particular film emulsion or period of correct exposure. |
| D-F-G | Over exposure region. |

Copied from "Photographic Aspects of Radiography".

(Kodak Ltd.)

"Sensitometry is the quantitative study of the characteristic of photographic materials under controlled exposing and processing conditions." Longmore (1).

In the case of X-ray films this sensitometer test is made by exposing an X-ray film placed between intensifying screens so that different areas of the film receive different known exposures. The exposures (E) are measured by the product of the X-ray intensity (I) and the exposure time (t), i.e. $E = I \times t$. The exposure for each step is so arranged that each subsequent step receives twice the exposure given to the previous one. A typical processed strip is shown in the top half of Fig. 3 (opposite page.)

The various densities of each step are measured and the value D plotted on the ordinate of the diagram and the corresponding X-ray exposures plotted on the abscissa on a logarithmic scale. The curve obtained in this way is called the characteristic curve and the general shape is similar for all types of photographic materials. Vide Fig. 3 (opposite page.)

## COMPARISON BETWEEN TWO DIFFERENT X-RAY EMULSIONS.

In order to compare the properties of two X-ray emulsions they may be exposed side by side between intensifying screens and exposed "in steps" to X-rays by doubling the exposure with each step. By so called "sensitometric" comparison and plotting of a characteristic curve, the manufacturers are able to control the properties of X-ray emulsions. As a result a uniformly high standard can be obtained.

## INTENSIFYING SCREENS.

Intensifying screens are employed as a means of utilising wasted radiation, thus reducing the time of exposure. The fluorescence of the screens are in proportion to the intensity of the X-radiation. Only about 3% of the total X-ray energy absorbed is emitted from the intensifying screen surface as fluorescent light, but this is sufficient to effect a considerable reduction in exposure.

Radiographs taken in conjunction with intensifying screens usually have higher contrast than those taken without screens. This is partly due to the fact that the scattered rays are absorbed to some extent by the screens before reaching the film, and partly due to the fact that the exposure is made by reflected fluorescent light rather than by direct X-rays.

The types of intensifying screens are as follows:-

1. ULTRA SPEED TUNGSTATE SCREENS.

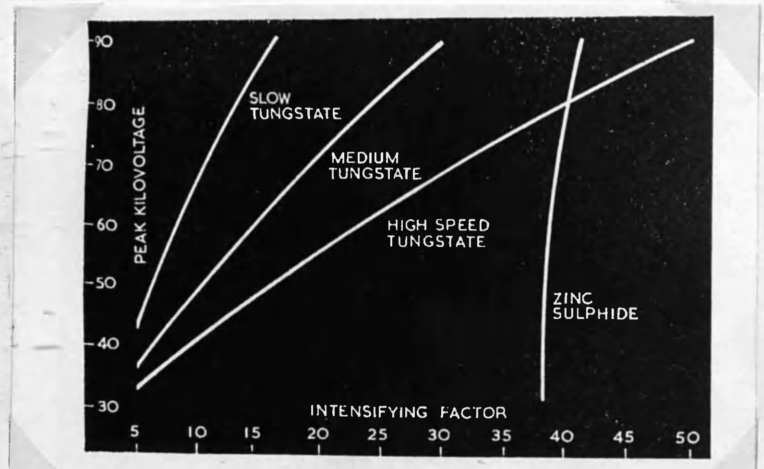
   In this type of screen the Calcium Tungstate grains are large and coarse. The coarseness gives high speed but at the same time produces some loss of definition of the image detail. The speed is the important asset but the screen possesses all the qualities of a general purpose screen.

2. HIGH DEFINITION TUNGSTATE SCREENS.

   As their name implies, these screens are designed specifically to give the sharpest definition and this is obtained by having the tungstate grains finely divided and uniformly dispersed throughout its layers. They are little more than half as fast as Ultra Speed Tungstate Screens but are unsurpassed in resolution of detail and freedom from "graininess."

3. FLUORAZURE OR ZINC SULPHIDE SCREENS.

These screens are made from Zinc Sulphide specially treated to reduce after-glow. They have one outstanding feature; they are faster than Calcium Tungstate screens, especially in lower kilovoltage (K.V.), but the Zinc Sulphide crystals are comparatively large and tend to produce loss of definition. The main feature of this type of screen is the fact that irrespective of what kilovoltage (K.V.) is used, the intensifying factor is stable. (See Fig. 4, opposite page 19.)




*Curves for the four types of screens named.*

FIG. 4. RELATIVE PRACTICAL SPEED OF SCREENS.

Copied from Longmore's "Medical Photography", 4th Edition, Fig. 58, Page 14

(Ref: 1 - page 21.)

INTENSIFYING FACTOR.

The most important radiographic property of X-ray intensifying screens is their "intensifying factor" which is the numerical expression which denotes the exposure required with screens as compared with an exposure without screens for the same type of film. The "intensifying factor" is usually expressed as a whole number; if the number is given as 20, the exposure is only 1/20th of that, without screens.

INTENSIFYING FACTOR AND KILOVOLTAGE (K.V.)

The "intensifying factor" of Calcium Tungstate Screens varies with the quality of the radiation reaching the screens, but with Fluorazure Screens this factor does not apply. Tasker (4) has shown that the "intensifying factor" of Tungstate Screens varies from 15 to 30 over a range of 40 to 90 kilovoltage (K.V.) and exposure times of 0.1 to 5.0 seconds, whilst, with the same conditions, the Zinc Sulphide Screens maintain the same factor of 40. (See Fig. 4, opposite page.) This significant feature of fluorazure screens was found to be of great importance in later experiments.

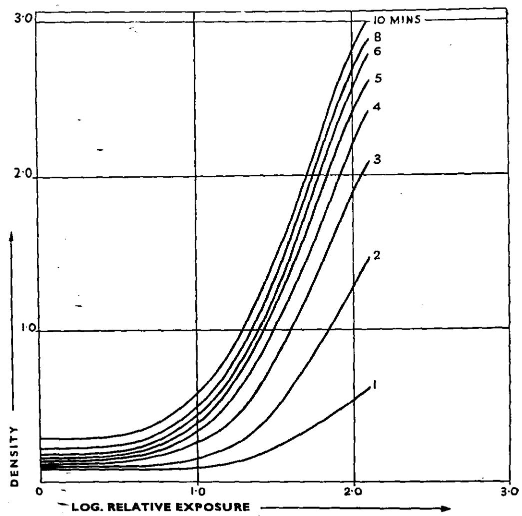



Fig. [redacted] Characteristic curves of X-ray films exposed in conjunction with intensifying screens at various developing times. (Developed in D.19b at 65° F.)

FIG. 5.

Copied from "Photographic Aspects of Radiography".

(Kodak.)

INTENSIFYING FACTORS AND DEVELOPMENT.

An increase in the development time produces a lower intensifying factor; longer development time alters more of the image which is to be developed. This accounts for the practice in some instances of developing the non-screen image for a longer time than one produced with screens.
(See Fig. 5 - opposite page.)

Exposure time is influenced by the following factors:-

1. The Object Factor.

   The thickness, atomic weight and density of the object to be radiographed.

2. Photographic Factor.

   Type of film, screen and development.

3. Grid Factor.

   Bucky Grid diaphragm on stationary grid.

4. Filter Factors.

   The inherent filtration of the tube.

5. Apparatus Factor.

   The circuit of set, potential and current curve.

Since so many factors influence exposure it is of the greatest importance to standardise the developing conditions. Apart from its convenience, standardised development is a valuable guide in assessing the correct exposure.

## REFERENCES.


1. LONGMORE, T.A. (1949) "Medical Photography"
   4th Edition, London. The Focal Press.

2. KODAK, Ltd., (1948) "Photographic Aspects of Radiography"
   2nd Edition, London.
   Medical Department of Kodak Ltd.,

3. KODAK, Ltd., "Medical Radiography"
   London.
   Medical Department of Kodak Ltd.,

4. MEES, C.E.K., (1921) "The Fundamentals of Photography"
   2nd Edition, Rochester, N.Y.
   Eastman.

5. SCHALL, W.E., (1943) "X-Rays"
   5th Edition, Bristol.
   John Wright & Sons, Ltd.,

6. ILFORD, Ltd. "Intensifying Screens"
   London.
   Ilford Ltd.

# CHAPTER 3.

## Preliminary Tests.

## CHAPTER 3.

## PRELIMINARY TESTS.

This chapter must deal with detailed technicalities, without which the report would be valueless to a skilled radiologist. It is suggested that less specialised readers may omit all but the various conclusions and the Physicist's report or densitometer test. The X-ray negatives used were of no special pathological interest nor diagnostic value; they were utilised purely as a means of duplicating X-ray films to improve the technique. The results are not contained within the thesis but can be studied in the separate accessory file. This chapter describes only the initial experiment and shows steady progress towards the ultimate method adopted for copying radiographs which, in brief, amounts to radiographing radiographs on fine grain single-coated photographic film.

EXPERIMENT No: 1. Film Nos: 1 & 2.

An X-ray negative (film No:1) of average contrast and definition was placed in a cassette in contact with a Red Seal X-ray film and interposed between double ultra speed intensifying screens.

Exposure. 45 K.V. 75 M.A. .5 Second. 40" distance.

Developer. PQX2, $3\frac{1}{2}$ minutes. 65° F.

Report. As anticipated, the positive copy (film No:2) showed no evidence of bone structure.

Conclusions. Valueless. The screens and film were too rapid so it was decided to try a much slower X-ray film and the choice was Ilford Standard X-ray film.

Physicist's Report or Densitometer Test. It was not considered necessary to undertake a densitometer test on the results of this experiment.

EXPERIMENT No: 2. Film Nos: 3,4 & 5.

The Red Seal X-ray film used in the previous experiment was replaced by a standard X-ray film and interposed between double ultra speed intensifying screens.

Exposure. As in Experiment No: 1.

Developer. As in No: 1 Experiment.

Film No: 3 X-ray negative on Ilford Standard X-ray films.

Film No: 4 Positive film from No: 3 on Standard X-ray film.

Film No: 5 The negative copy from positive No: 4 shows no image.

Report. The positive film showed a faint image with heavy background fogging. There was lack of contrast and definition, and it was impossible to reproduce a satisfactory duplicate.

Conclusions. This showed an improvement from Experiment No: 1, but was still unsuccessful. The fluorescence from the double intensifying screen was too great. It was therefore decided to use only one screen.

Densitometer Test Report. No test was required on the result of this experiment.

EXPERIMENT No: 3. Film Nos: 6 to 10.

This phase involved blacking out the back intensifying screen by the insertion of a double black paper wrapper to reduce the fluorescence, and Ilford Standard X-ray films were again employed.

| | | |
|---|---|---|
| Film No: 6 | A lateral head X-ray negative. | |
| Film No: 7 | Positive film from No:6 | @ 100 M.A.,50 K.V. 2 Secs.,40" D. |
| Film No: 8 | Duplicate from Positive No:7 | @ 100 M.A.,50 K.V. 1 Sec. 40" D. |
| Film No: 9 | Positive film from No: 6 | @ 100 M.A.,50 K.V. 1 Sec. 40" D. |
| Film No:10 | Duplicate from Positive No:9 | @ 100 M.A.,50 K.V. 1 Sec. 40" D. |

<u>Developer</u>. PQX2 for $3\frac{1}{2}$ mins., @ 65° F.

<u>Report</u>. The positive film showed appreciable improvement from previous experiments but considerable background fogging was still present, with definition and contrast moderate.

The duplicate showed too great contrast; there was a lack of definition with accentuated background fogging.

<u>Conclusions</u>. It was then possible to make a recognisable copy from an original, and, as the films on loan for copying could not be kept indefinitely, it was decided to proceed to experiment with these films. Every degree of contrast and definition was present, so a good cross section of film varieties was available.

# CHAPTER 4.

## Experiments in the duplication of radiographs of specific Bone Conditions.

# CHAPTER 4.

## FURTHER EXPERIMENTS EMPLOYING THE DUPLICATING TECHNIQUE DEMONSTRATING CERTAIN BONE CONDITIONS.

EXPERIMENT No: 4. Film Nos: 14 to 76.

This experiment was really a continuation of Experiment No: 3. The method of copying, although unsatisfactory, was the best so far achieved. The films available for duplication showed a variety of pathological conditions, so it was of interest to observe the results from a diagnostic viewpoint. When necessary the kilovoltage (K.V.), milliamperage (M.A.), time and development were altered to suit the qualities of the various films, but the technique was the same as in Experiment No: 3, where the back intensifying screen was blacked-out and the copies were made on Standard X-ray film. The film target distance was kept at 40" throughout the whole experiment.

Once again it must be stated that the ensuing experiments still deal with variations in technique and no comment is made about the cross-section of X-ray negatives used in the experiments. As these early experiments did not produce satisfactory positive copies in all cases, it was not considered necessary always to make a negative duplicate, and the reader can confine his attention to the conclusions.

The first part of the experiment consisted of an endeavour to obtain an average exposure from an average occipito-frontal negative by various alterations of kilovoltage (K.V.), milliamperage (M.A.) and time. The variety of subjects have numerical notations, and the films are filed separately. The only good example of the technique is shown in Envelope A, (page 32.)

I. Average occipito-frontal X-ray negative.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 14 | Positive taken at | 100 M.A. | 55 K.V. | 2 | Seconds. |
| Film No. 15 | " " " | 75 M.A. | 55 K.V. | 2 | Seconds. |
| Film No. 16 | " " " | 75 M.A. | 45 K.V. | 2 | Seconds. |
| Film No. 17 | " " " | 75 M.A. | 50 K.V. | 2 | Seconds. |
| Film No. 18 | " " " | 100 M.A. | 45 K.V. | 2 | Seconds. |
| Film No. 19 | " " " | 100 M.A. | 45 K.V. | 0.5 | Second. |
| Film No. 20 | " " " | 100 M.A. | 50 K.V. | 1 | Second. |
| Film No. 21 | " " " | 100 M.A. | 50 K.V. | 0.5 | Second. |

Conclusions. There was no dubiety that the best result was that obtained with 100 M.A., 50 K.V., 0.5 Second.

| | | | | |
|---|---|---|---|---|
| Film No. 22 | Copy taken from positive at | 100 M.A. | 50 K.V. | 2 Seconds. |
| Film No. 23 | " " " " " | 155 M.A. | 50 K.V. | 1 Second. |
| Film No. 24 | " " " " " | 75 M.A. | 55 K.V. | 2 Seconds. |

Conclusions. The best result was obtained with 100 M.A., 50 K.V., 2 Seconds, but the copy, poor. Contrast was too great, definition was poor and there was heavy background fogging.

II. Average occipito-mental X-ray negative.

| | | | | |
|---|---|---|---|---|
| Film No. 25 | Positive taken at | 100 M.A. | 50 K.V. | 0.6 Second. |
| Film No. 26 | " " " | 100 M.A. | 50 K.V. | 0.3 Second. |

Conclusions. The better positive was No. 26, which was still too dark.

Film No. 27 Copy taken from positive No. 26 at 100 M.A. 45 K.V. 1 Second.

Conclusions. The copy was too dark. Failure.

III. Primary Epithelioma. (X-ray G.R. Infirmary) Anderson.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 28. | Lateral oblique jaw positive at | 100 M.A. | 50 K.V. | 1 | Second. |
| Film No. 29 | " " " " " | 100 M.A. | 50 K.V. | 0.5 | Second. |
| Film No. 30 | Copy of positive at | 100 M.A. | 50 K.V. | 0.5 | Second. |

Conclusions. No. 29 was the best positive copy. The copy of No. 30 was only moderate in quality.

IV. Osteomyelitis. (X-ray G.R. Infirmary) McArthur.

Film No. 31 Positive at 100 M.A. 50 K.V. 0.5 Second.
Film No. 32 Copy from positive at 100 M.A. 50 K.V. 0.5 Second.

Conclusions. The result was poor.

V. Fibrous Dysplasia of Bone. (X-ray G.R. Infirmary) McShane.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 33 | Positive at | 75 M.A. | 45 K.V. | 0.5 | Second. |
| Film No. 34 | " " | 100 M.A. | 50 K.V. | 1 | Second. |
| Film No. 35 | " " | 75 M.A. | 45 K.V. | 0.5 | Second. |
| Film No. 36 | " " | 100 M.A. | 45 K.V. | 1 | Second. |

Conclusions. No. 33 was an excellent positive, showing delicacy of bone structure. No negative copy was taken at this phase in the experiment.

VI. Secondary Sarcoma from Mandible. (X-ray G.R. Infirmary) Paterson.

Film No. 37 Positive at 100 M.A. 50 K.V. 1 Second.

Conclusions. The results were moderate.

VII. Leontiasis Ossea. (X-ray G.R. Infirmary) O'Donnell.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 38 | Positive at | 75 M.A. | 45 K.V. | 1 | Second. |
| Film No. 39 | Copy at | 75 M.A. | 45 K.V. | 0.5 | Second. |
| Film No. 40 | Positive at | 75 M.A. | 45 K.V. | 1 | Second. |
| Film No. 41 | Copy at | 75 M.A. | 45 K.V. | 0.5 | Second. |

Conclusions. The result of this experiment was unsatisfactory. There was too much contrast and definition was lacking.

VIII. Adamantinoma. (X-ray G.R. Infirmary) Carson.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 42 | Positive at | 100 M.A. | 50 K.V. | 1 | Second. |
| Film No. 43 | Positive at | 100 M.A. | 50 K.V. | 1 | Second. |
| Film No. 44 | Copy at | 100 M.A. | 50 K.V. | 0.5 | Second. |
| Film No. 45 | Positive at | 100 M.A. | 50 K.V. | 1 | Second. |
| Film No. 46 | Positive at | 100 M.A. | 50 K.V. | 1 | Second. |
| Film No. 47 | Copy at | 100 M.A. | 50 K.V. | 0.5 | Second. |

Conclusions. The result was unsatisfactory. There was still too much contrast and a lack of definition.

IX. Osteoma of Frontal Sinus. (X-ray G.R. Infirmary) James.

Film No. 48 A positive copy at 100 M.A. 45 K.V. 1 Second.

Conclusions. The results were similar to previous efforts so no negative copy was taken.

X. Fibrous Osteoma. (X-ray G.R. Infirmary) Murphy.

Film No. 49 Positive at 75 M.A. 45 K.V. 0.3 Second.
Film No. 50 Positive at 75 M.A. 45 K.V. 0.3 Second.

Conclusions. There was no appreciable improvement in result so no negative copy was taken.

XI. Osteoclastoma. (X-rays G.R.Infirmary) McMahon.

| | | | | |
|---|---|---|---|---|
| Film No. 51 | Positive at | 75 M.A. | 45 K.V. | 1 Second. |
| Film No. 52 | " " | 75 M.A. | 45 K.V. | 0.5 Second. |
| Film No. 53 | " " | 75 M.A. | 45 K.V. | 0.5 Second. |
| Film No. 54 | " " | 75 M.A. | 45 K.V. | 1 Second. |
| Film No. 55 | " " | 75 M.A. | 45 K.V. | 0.5 Second. |
| Film No. 56 | " " | 75 M.A. | 45 K.V. | 1 Second. |
| Film No. 57 | " " | 75 M.A. | 45 K.V. | 0.5 Second. |
| Film No. 58 | " " | 75 M.A. | 45 K.V. | 1 Second. |

Conclusions. The positive results were satisfactory and it was obvious that the change of exposure time influenced the qualities of the positive film. It was not considered necessary to take negative copies.

XII. Familial Multilocular Cyst. (X-rays G.R.Infirmary) Goughan.

Film No. 59 Positive copy at 75 M.A. 45 K.V. 0.5 Second.
Film No. 60 Negative copy at 75 M.A. 45 K.V. 0.5 Second.

Conclusions. This was the best positive copy produced by this method. The original X-ray was of suitable contrast and definition, and the exposure was just sufficient to bring out the details. The copy was moderately good but still inferior to the original.

XIII. Dentigerous Cyst. (X-rays G.R. Infirmary) Cathie.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 61 | Positive | at 100 M.A. | 50 K.V. | 2 | Seconds. |
| Film No. 62 | Copy | at 75 M.A. | 45 K.V. | 1 | Second. |
| Film No. 63 | Positive | at 100 M.A. | 50 K.V. | 2 | Seconds. |
| Film No. 64 | Copy | at 75 M.A. | 45 K.V. | 1 | Second. |

Conclusions. Both positive and negative copies were moderately good and showed a consistency in results, but they were definitely inferior to the originals.

XIV. Dental Cyst. (X-rays G.R. Infirmary) McNab.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 65 | Positive | at 100 M.A. | 45 K.V. | 1 | Second. |
| Film No. 66 | Positive | at 100 M.A. | 50 K.V. | 1 | Second. |

Conclusions. The results were still unsatisfactory and similar to previous tests.

XV. Ossifying Fibroma. (X-rays G.R. Infirmary) Harrington.

This was a case of a large ossifying fibroma of the right mandible, and a smaller one of the left side of the mandible. Various X-rays of the stages of treatment were available.

| | | | | | |
|---|---|---|---|---|---|
| Film No. 67 | Positive | at 100 M.A. | 50 K.V. | 0.5 | Second. |
| Film No. 68 | Positive | at 100 M.A. | 50 K.V. | 2 | Seconds. |
| | | No copies taken. | | | |
| Film No. 69 | Positive | at 100 M.A. | 50 K.V. | 0.2 | Second. |
| Film No. 70 | Copy of 69 | @ 75 M.A. | 45 K.V. | 1 | Second. |
| Film No. 71 | Positive | at 100 M.A. | 50 K.V. | 0.4 | Second. |
| Film No. 72 | Copy of 71 | @ 75 M.A. | 45 K.V. | 1 | Second. |
| Film No. 73 | Positive | at 100 M.A. | 50 K.V. | 0.5 | Second. |
| Film No. 74 | Copy of 73 | @ 75 M.A. | 45 K.V. | 1 | Second. |
| Film No. 75 | Positive | at 100 M.A. | 50 K.V. | 0.4 | Second. |
| Film No. 76 | Copy of 75 | @ 75 M.A. | 45 K.V. | 1 | Second. |

Conclusions. The experiments were still unsatisfactory and no improvement in quality was obvious.

A.


X-Ray
A.1.

X-Ray
A.2.


X-Ray
A.3.

## ENVELOPE A.

This envelope contains an average example of the quality of duplicates obtained by using the technique of Experiment No: 4 which is explained in the narrative below.

### NARRATIVE OF RADIOGRAPHS.

X-RAY A.1. This shows a lateral head X-ray negative on Red Seal X-ray film taken on a Sterling Dental X-ray machine, at 100 M.A., 60 K.V., 5 seconds, 5' distance and developed in PQX2 developer for 3½ minutes at 65° F.

X-RAY A.2. This is the positive film of A.1 taken on standard X-ray film with the back ultra speed intensifying screen blacked-out, at 100 M.A., 50 K.V., 0.3 second, 40" distance, developer PQX2 at 65° F., for 3½ minutes.

X-RAY A.3. This is the copy taken through the positive A.2, of the original A.1, on standard X-ray film, at 100 M.A., 50 K.V., 0.5 second, 40" distance, developer PQX2 at 65° F., for 3½ minutes.

GENERAL CONCLUSIONS OF EXPERIMENT No: 4.

Three X-rays in Envelope A, (page 32) were the best results obtained by Experiment No: 4, on a cross-section of specified bone conditions. They were obtained by what was considered the ideal exposure at that stage of the investigation.

The initial objective was accomplished of making a duplicate within the confines of the X-ray department, and without utilising photographic equipment, but the quality of the duplicates left much to be desired. The intermediate or positive copy was in most cases of a high standard, showing great delicacy of bone structure with good subjective definition and contrast.

A personal observation, made with considerable emphasis, is that a positive copy shows the bone structure in a more natural relationship. This confirms an opinion that a positive copy should always be studied in conjunction with the more commonly viewed negative copy, particularly in cases of doubtful pathological significance.

It was noted in student classes that students were, without exception, able to diagnose much better from positive copies than from the original X-ray negative or from negative duplicates.

The main fault in the positives was a varying degree of fogging, depending on the original negative. The final processing, to obtain the duplicate, accentuated this fogging, increased the contrast and showed considerable loss in the definition. From previous experiments on the subject, this fault was always a problem.

Finally, it was obvious that it was impossible to prepare a good duplicate from a poor or indifferent film, and this would apply to any method of reproduction.

Before assessing the probable contributory factors of deterioration in the quality of the duplicates, it was considered advisable to make a densitometer test of this particular method. Such a test would supply comparable objective readings of the original and the copy as a guide to future experiments.

DENSITOMETER TEST ON METHOD OF EXPERIMENT No: 4.

A densitometer is an instrument specially designed for measuring the densities in a photographic silver image. For the purpose of the investigations the instrument used was an "Eel Universal Densitometer." This is a photo-electric instrument which is extremely easy to manipulate. As the same instrument was used throughout the experiments, accuracy of comparison was assured. When a densitometer test for a particular experiment was required, an X-ray negative was taken of an optical density stepwedge alongside a metal mesh. (Vide X-ray B.1, Envelope B - page 37.) The purpose of the mesh was to give a subjective indication of the resultant contrast; to observe that proper contact had been made, and also as a means of recognising the positive easily. The stepwedge was a piece of metal with a graduated series of six steps ranging from 1 mm thick for the first step to 6 mm for the sixth. This appliance gives a graduated series of steps ranging from first perceptible density, and each succeeding step gives a reading of greater opacity.

From the original X-ray film a negative duplicate was made through a positive copy, employing the various adaptations of technique, and it was from a comparison of the densities of each step of the original negative and of the duplicate film that an assessment of improvement or deterioration was accurately shown in graph form.

The method employed to reach the final reading was to take the average of three readings of each step and to subtract the fog density of each film. This gave a more accurate calibration, as the fog density of each film varied considerably.

Envelope B (page 37) contains an original X-ray negative (B.1) of a mesh and stepwedge, and also the positive film (B.2) and the duplicate film (B.3.)

The method of assessing the densitometer readings is shown on page 39; page 40 shows the readings in table form, and on page 41 in graph form. The assessment of the readings is summarised under 'Conclusions' on page 42.

B.

## ENVELOPE B.

This envelope contains a Mesh and Stepwedge X-ray negative, a positive copy and a duplicate negative, following the same technique as Experiment No: 4. Examples of X-ray duplication of these are shown in Envelope A. This Stepwedge will be used throughout the research as a means of making densitometer tests for the various experiments to give scientific calibration of density tests. The densitometer readings will illustrate the objective intensification of the different techniques and, by a series of graphs, the progress or deterioration will be shown.

## NARRATIVE OF RADIOGRAPHS.

**X-RAY** B.1. X-ray negative of Mesh and Stepwedge.

**X-RAY** B.2. Positive copy on Standard X-ray film with only an ultra speed front screen and exposure at 100 M.A., 50 K.V., 0.3 sec., 40" distance.

**X-RAY** B.3. Negative duplicate on Standard X-ray film with ultra speed front screen only, at 100 M.A., 50 K.V., 0.3 sec., 40" distance. Developer - PQX2 for 3½ minutes at 65° F.

## DETAILS OF DENSITOMETER TEST READINGS FOR EXPERIMENT No:4.

X-RAY B.1. (Envelope B.) X-ray negative of mesh and stepwedge taken on Red Seal film at 100 M.A., 50 K.V., 0.04 second, 40" distance.

Fog Density = 0.29.

| | | | | Average. | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.65 | 0.65 | 0.66 | 0.65 | 0.36 |
| 2 | 0.83 | 0.82 | 0.80 | 0.82 | 0.53 |
| 3 | 1.01 | 1.01 | 1.01 | 1.01 | 0.72 |
| 4 | 1.34 | 1.30 | 1.32 | 1.32 | 1.03 |
| 5 | 1.66 | 1.68 | 1.68 | 1.67 | 1.38 |
| 6 | 2.12 | 2.11 | 2.14 | 2.12 | 1.83 |

The graph line is shown in blue (page 41.)

X-RAY B.3. This film is the negative duplicate of B.1., following the technique of Experiment No: 4, and showing details of exposure on page 38.

Fog Density = 0.56

| | | | | Average. | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.59 | 0.59 | 0.57 | 0.58 | 0.02 |
| 2 | 0.65 | 0.65 | 0.63 | 0.64 | 0.08 |
| 3 | 0.95 | 0.95 | 0.95 | 0.95 | 0.39 |
| 4 | 1.61 | 1.59 | 1.60 | 1.60 | 1.04 |
| 5 | 2.07 | 2.01 | 2.02 | 2.03 | 1.47 |
| 6 | 2.11 | 2.11 | 2.13 | 2.12 | 1.56 |

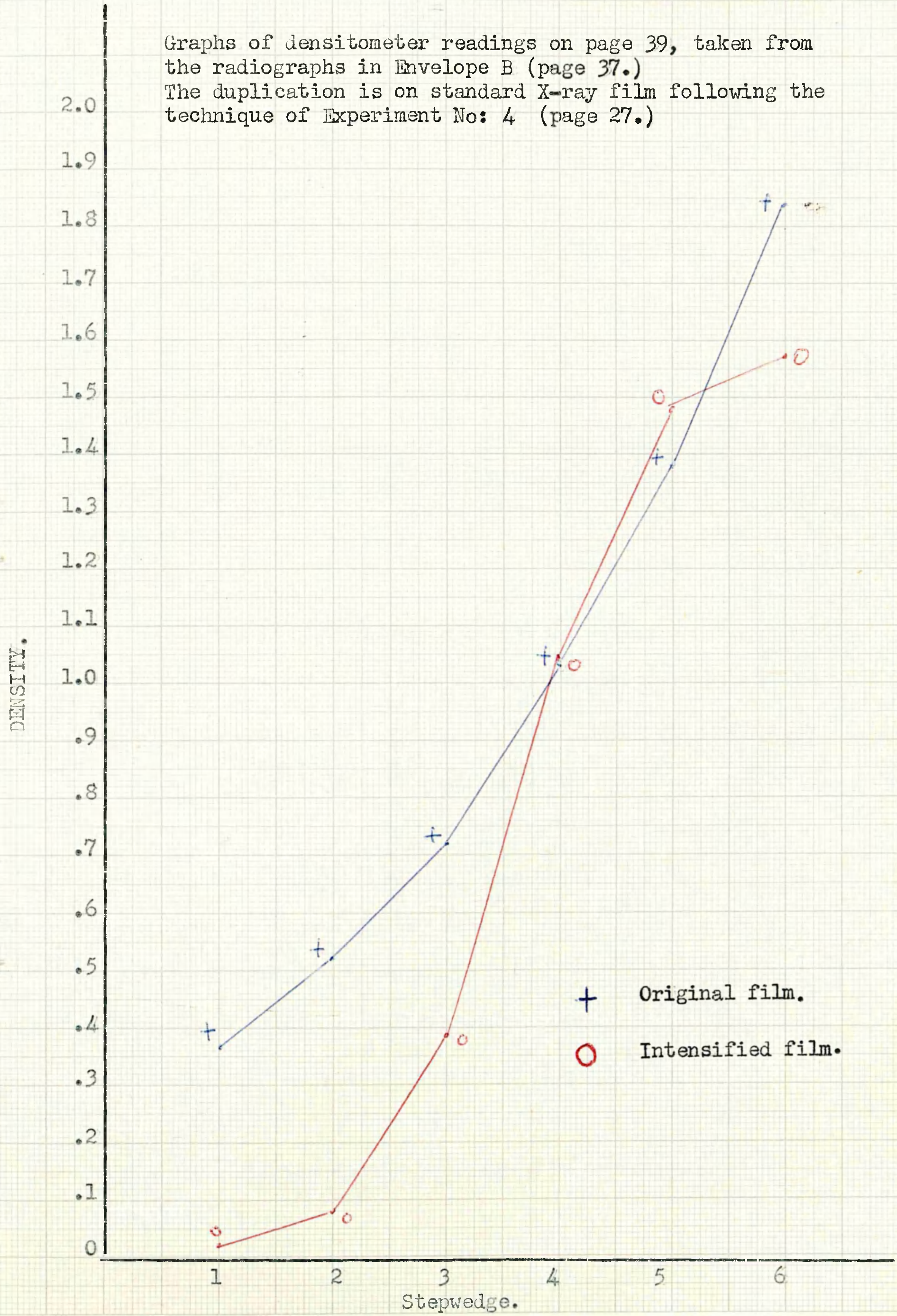
The graph line is shown in red (page 41.)

## ENVELOPE B.

## STEPWEDGE CALIBRATIONS.

| Number of Steps. | Density above background. Original Film Less Fog Density | Intensified Film. Less Fog Density. |
|---|---|---|
| 1 | .36 | .02 |
| 2 | .53 | .08 |
| 3 | .72 | .39 |
| 4 | 1.03 | 1.04 |
| 5 | 1.38 | 1.47 |
| 6 | 1.83 | 1.56. |

Fog Density of 0.29 for original film and 0.56 for the intensified film are subtracted from the densitometer readings.


Graphs of densitometer readings on page 39, taken from the radiographs in Envelope B (page 37.)
The duplication is on standard X-ray film following the technique of Experiment No: 4 (page 27.)
DENSITY.
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
Stepwedge.
+ Original film.
O Intensified film.

## CONCLUSIONS OF STEPWEDGE TEST.

The graphical illustration of the densitometer readings (page 41) confirms that the duplicate film was subjectively and objectively inferior to the original. The result was as expected and the possible causes of the deterioration were then considered.

1. DOUBLE COATED X-RAY FILM.

The sensitised emulsion of both sides of the thick base caused loss of definition, therefore it was desirable to use a single-coated and much slower film which would also show less contrast.

2. INTENSIFYING SCREENS.

The excessive fluorescence of the ultra speed intensifying screen was responsible for the background fogging. This fluorescence acted as the printing light and it was difficult to control with calcium tungstate screens, where the intensifying factor varies with the kilovoltage (K.V.) The insertion of a double black wrapper between the back screen and the film was only partially successful in keeping radiation to a minimum to avoid veiling of the image. A controlled light with the minimum of X-ray effect was therefore essential. A fluorazure screen was then considered because of the lighting quality (vide page 18 (3)). This screen is coated with zinc sulphide and the intensifying factor is stable, irrespective of the kilovoltage (K.V.)

# CHAPTER 5.

## Experiments with the Fluorazure Screen.

# CHAPTER 5.

## EXPERIMENTS WITH FLUORAZURE SCREEN AND STANDARD X-RAY FILM.

EXPERIMENT No: 5. Film Nos: 77 to 82.

This experiment consisted of a series of tests with the same occipito-mental X-ray negative from which different positives were made for comparison on standard X-ray film, the first on an ultra speed intensifying screen, and the remainder on fluorazure intensifying screens. The exposure and developing times were altered as shown below.

| | | | | | |
|---|---|---|---|---|---|
| Film No.77 Ultra speed intensifying screen at - 100 M.A. | 50 K.V. | 1 | Second | 3 | mins. developing |
| Film No. 78 Fluorazure screen at 100 M.A. | 50 K.V. | 1 | Second | 3 | mins. " |
| Film No. 79 Fluorazure screen at 100 M.A. | 50 K.V. | 0.5 | Second | 2 | mins. " |
| Film No. 80 Fluorazure screen at 100 M.A. | 50 K.V. | 0.5 | Second | 3 | mins. " |
| Film No. 81 Fluorazure screen at 100 M.A. | 50 K.V. | 1 | Second | 3½ | mins. " |
| Film No. 82 Copy from film 79 at 100 M.A. | 50 K.V. | 0.5 | Second. | | |

**Conclusions.** It was very obvious that comparison of the ultra speed and fluorazure screen positives showed no appreciable difference in quality, and the different times of development reacted as expected.

It was therefore decided to try a different type of film, essentially a single-coated film.

An Ilford fine grain photographic film was selected and the following experiment took place.

EXPERIMENT No: 6. Film Nos. 83 to 85.

A single front Ilford fluorazure screen was used in the appropriate cassette. The original X-ray was placed on the screen and an Ilford fine grain single-sided photographic film was placed in contact. The X-ray exposure was made at 40" distance, 100 milliamperage (M.A.), 45 kilovoltage (K.V.) and one second exposure. The photographic film was developed in Ilford PQX2 X-ray developer for 3½ minutes at 65° F., washed and fixed in the usual way. This supplied the positive film. The same procedure was repeated, using the positive as the contact. With fine grain photographic film in the cassette, another exposure was made with the milliamperage (M.A.) and kilovoltage (K.V.), distance and time as before. Again standardised developing and fixing methods were used and the duplicate was completed. (See envelope C, page 46, X-rays C.1, C.2 and C.3.)

## ENVELOPE C.

This envelope contains an example of duplication following the technique as described in Experiment No. 6 (page 45), where a single fluorazure screen and fine grain photographic film were used for the first time.

### NARRATIVE OF RADIOGRAPHS.

X-RAY C.1. A duplitized X-ray negative of a lateral head, with bone anomaly consistent with Paget's Disease confined to the lower jaw.

X-RAY C.2. The positive film taken from C.1, by using fine grain photographic film with a single front fluorazure screen and following the technique of Experiment No. 6 (page 45.)

X-RAY C.3. This is the duplicate film of C.1, made through the positive C.2, and following exactly the same technique.

Conclusions. The results were surprisingly good. The duplicate, or copy, by this simple method appeared to the naked eye better than the original. Confirmation of this apparent improvement was desired, so Dr. Lenihan, the Consultant Physicist to the Western Regional Hospital Board, was consulted.

# CHAPTER 6.

## Physicist's Tests.

## CHAPTER 6.

## PHYSICIST'S TEST.

On Dr. Lenihan's advice, an X-ray film was taken of a metal mesh and optical stepwedge.

Following the technique described in Experiment No. 6 (page 45), a duplicate of this film was made through an intermediate positive. These films are shown in Envelope D, page 50 - X-rays D.1, D.2 and D.3.

Page 52 shows the detailed method of obtaining the densitometer readings, and presented in table form on page 53, and page 54 shows the comparison in graphic form.
The conclusions are presented on page 55.

D.

ENVELOPE D.

This envelope contains an X-ray negative of a metal stepwedge duplicated on fine grain photographic film and made for the purpose of a densitometer test, to compare with the previous graph on page 41. The details are shown on pages 52 and 53, and the graph on page 54.

NARRATIVE OF RADIOGRAPHS.

X-RAY D.1. A duplitized X-ray negative of a mesh and stepwedge on Red Seal film, with exposure 100 M.A., 50 K.V., 0.04 second, 40" distance.

X-RAY D.2. The positive or intermediate copy on fine grain photographic film, following the technique of Experiment No. 6, (page 45.)

X-RAY D.3. The duplicate film of D.1 taken through the positive and following exactly the same technique.

**Conclusions.** See page 55.

# DENSITOMETER READING DETAILS.

X-RAY D.1. X-ray negative of mesh and stepwedge.

Fog Density 0.26

| | | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|---|
| Step No. | 1 | .82 | .81 | .82 | .82 | .56 |
| | 2 | .98 | .96 | .96 | .97 | .71 |
| | 3 | 1.19 | 1.18 | 1.18 | 1.18 | .92 |
| | 4 | 1.41 | 1.41 | 1.43 | 1.42 | 1.16 |
| | 5 | 1.68 | 1.68 | 1.68 | 1.68 | 1.42 |
| | 6 | 1.99 | 1.96 | 1.95 | 1.97 | 1.71 |

The graph line is shown in blue, page 54.

X-RAY D.3. This is the radiographic copy of D.1.

Fog Density 0.35

| | | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|---|
| Step No. | 1 | .62 | .62 | .59 | .61 | .26 |
| | 2 | .90 | .90 | .91 | .90 | .55 |
| | 3 | 1.29 | 1.27 | 1.30 | 1.29 | .94 |
| | 4 | 1.64 | 1.64 | 1.66 | 1.65 | 1.30 |
| | 5 | 2.03 | 2.00 | 2.00 | 2.01 | 1.66 |
| | 6 | 2.35 | 2.35 | 2.34 | 2.35 | 2.00 |

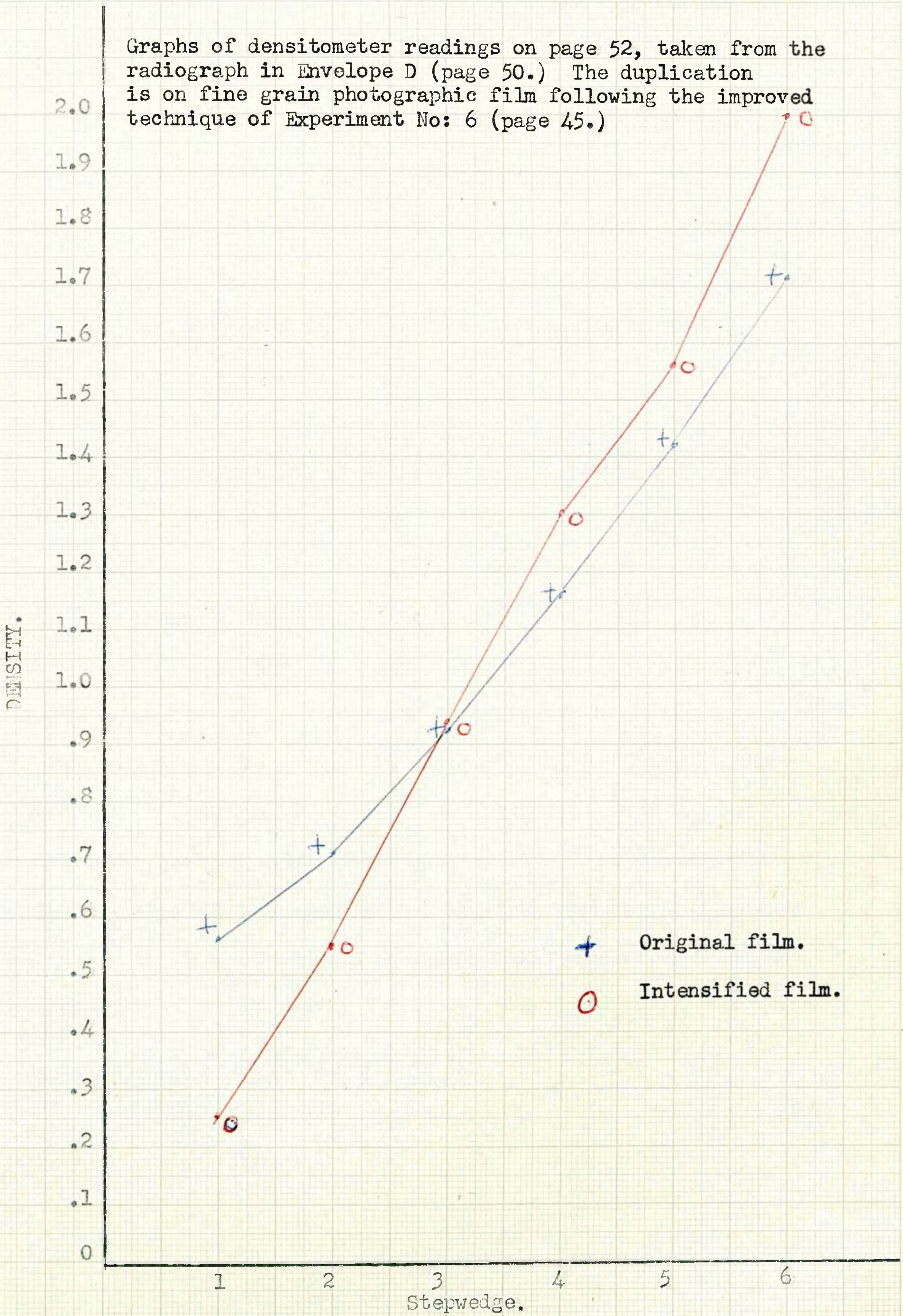
The graph line is shown in red, page 54.

## ENVELOPE D.

## DENSITOMETER READINGS FOR RADIOGRAPHIC INTENSIFICATION.

Measurements on film prepared at Glasgow Dental Hospital on 26.10.55, using stepwedge of six calibrations, the thickest 6 mm. and the thinnest 1 mm.

| Number of Steps. | Density above background. Original Film Less Fog Density | Intensified Film. Less Fog Density |
|---|---|---|
| 1 | .56 | .26 |
| 2 | .71 | .55 |
| 3 | .92 | .94 |
| 4 | 1.16 | 1.30 |
| 5 | 1.42 | 1.66 |
| 6 | 1.71 | 2.00 |


Graphs of densitometer readings on page 52, taken from the radiograph in Envelope D (page 50.) The duplication is on fine grain photographic film following the improved technique of Experiment No: 6 (page 45.)
DENSITY.
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
Stepwedge.
Original film.
Intensified film.

## CONCLUSIONS FOLLOWING THE PHYSICIST'S DENSITOMETER TEST.

The densitometer readings confirmed both the subjective and objective improvement in the reproductions. The graph shows an intensification but not throughout the whole negative. The lower readings show a loss in density, but the upper readings show a density gain. This was due to the contrast being greater in the copy, the black portions being blacker and the white portions whiter.

Comparison should be made with the first set of densitometer readings and graph shown on page 41. The improvement in intensification was marked.

This opened a field of great possibilities. Would it be possible by manipulation of the milliamperage (M.A.) kilovoltage (K.V.) exposure and development, to alter the graph so that even more improvement would be apparent in the duplicates, or even to show something in a copy not obvious in an original?

It was considered at this stage that the duplication of an X-ray negative, by a simple method, had been established and that the potentialities of the application of that method were greatly increased.

# CHAPTER 7.

**Improved technique in the duplication of radiographs demonstrating bone conditions.**

# CHAPTER 7.

EXPERIMENT No: 7. Film Nos. 83 to 127.

The initial objective of duplicating radiographs for teaching purposes was accomplished. X-ray negatives had been duplicated by a simple technique which did not require any photographic appliance and did not interfere with the normal routine of the X-ray department. The results visually were so satisfactory that interest was engendered in the diagnostic value of the duplicate. As a result of this possibility, it was considered advisable to duplicate a cross section series of X-ray negatives showing pathological conditions, employing the following standard technique throughout the chapter.

| | | |
|---|---|---|
| Milliamperage | 100 | |
| Kilovoltage | 45 | |
| Exposure | 1 | second |
| Distance | 40 | inches |
| Development | | Ilford PQX2 for $3\frac{1}{2}$ mins. at 65° F. |
| Screen | | Front Fluorazure. |
| Film | | Ilford fine grain single-coated photographic. |

IA. PAGET'S DISEASE. Patient - Stevens.

For the first example of this disease, an unusual case was selected in which the disease was confined to the lower jaw. The radiographic appearance showed the typical fluffy or mottled effect, resembling cotton wool, and in addition a stage of the disease demonstrating loss of bone trabeculation but still containing strut or stress trabeculae. The result of duplicating radiograph No. 86 is contained in Envelope E, page 58, E.1, E.2 & E.3.

| | | |
|---|---|---|
| Film No. 83 | X-ray negative (lateral head.) | Illustrated in Envelope E, page 58, 2nd Copy. |
| Film No. 84 | Positive. | |
| Film No. 85 | Copy of Film No. 83. | |
| Film No. 86 | X-ray negative (lateral oblique jaw) | Illustrated in Envelope E, page 58 - 1st Copy. E.1, E.2 & E.3. |
| Film No. 87 | Positive | |
| Film No. 88 | Copy of film No. 86. | |

E.

## ENVELOPE E.

Envelope E contains an example of the bone dysplasia called Paget's Disease, and illustrates the apparent improvement in the quality of the duplicate when compared with the original.

### NARRATIVE OF RADIOGRAPHS.

X-RAY E.1. X-ray negatives of a case of Paget's Disease confined to the lower jaw.

X-RAY E.2. Positive film on fine grain photographic film.

X-RAY E.3. Duplicate negative on fine grain photographic film.

Conclusions. The original X-ray negative was excellent in both subjective contrast and definition with the resulting positive and duplicate showing an apparent visual improvement.

The bone texture shows more contrast and the cotton wool effect intensified.

From a publication aspect this copy should photograph better than the original.

Radiographical comparison shows the typical appearance intensified, which diagnostically is of value for teaching purposes.

IB. PAGET'S DISEASE. Patient - Whitefield. Skull affected.

The second series of films dealing with Paget's Disease are not illustrated with the thesis. Films 89 to 91 illustrate a case of a skull showing the characteristic bone changes. Films 92 to 94 are a composite group of intra-oral radiographs and these also show satisfactorily the cotton wool appearance in the alveolus, characteristic of Paget's Disease.

Film No. 89 X-ray negative - lateral head.
Film No. 90 Positive.
Film No. 91 Copy of film No. 89.
Film No. 92 Composite intra-oral X-ray negative.
Film No. 93 Positive of film No. 92.
Film No. 94 Copy of film No. 92.

Conclusions. The copy of the skull radiograph shows surprisingly good duplication considering the poor quality of the original negative. The copies of the composite group, with average X-ray negative tonal values, appear as good as the original.

II. OSTEOMYELITIS. Patient - Stewart. Mandible.

The example selected of osteomyelitis showed a typical adult case affecting the mandible. Such cases are now relatively uncommon in this country since the advent of antibiotics. This case showed an advanced condition of the disease with sequestration of the bone. The films are not included within the thesis but the bone condition makes an interesting study in the series of films which accompanies the thesis.

Film No. 95 Composite X-ray negative.
Film No. 96 Positive of film No. 95.
Film No. 97 Copy of film No. 95.

Conclusions. The results were excellent and visually the copy was obviously better than the original.

## III. LAMINAGRAMS OF THE TEMPORO-MANDIBULAR JOINT.

Patient - Sarah Armstrong.

In Glasgow Dental Hospital and School, laminagraphy is an important study. Duplication of the laminagrams is made so that teaching and hospital material can be separated. The results of duplication are illustrated in the thesis in Envelope F, page 62, F.1, F.2 and F.3.

| | |
|---|---|
| Film No. 98 | X-ray negative of right and left temporo mandibular joints in closed and open position. |
| Film No. 99 | Positive of film No. 98. |
| Film No. 100 | Copy of film No. 98. |

F.

## ENVELOPE F.

This envelope contains an example of excellent duplication of a laminagram of the temporo-mandibular joint.

### NARRATIVE OF RADIOGRAPHS.

X-RAY F.1. Right and left laminagrams of the temporo-mandibular joint in closed and open positions.

X-RAY F.2. Positive film on fine grain photographic film.

X-RAY F.3. Duplicate film on fine grain photographic film.

Conclusions. The condyle and associated anatomical areas showed up clearly and the results were considered extremely satisfactory. The positive copy was particularly good and thought to be more suitable for publication than a negative duplicate. Students were able to identify much more in the positive copy than in either the original or the duplicate negative.

IV. MAXILLARY SINUSES (OCCIPITO-MENTAL PROJECTION.) Film Nos: 101 to 106.

This X-ray was of no pathological interest but was used merely to show good anatomical structure for the experiment. The test was made to observe the effect of varying the exposure time without altering the other factors.

| | | |
|---|---|---|
| Film No. 101 | P.A. X-ray negative of sinuses. | |
| Film No. 102 | Positive at 100 M.A. 45 K.V. 1 | second. |
| Film No. 103 | Positive at 100 M.A. 45 K.V. 1.5 | second. |
| Film No. 104 | Positive at 100 M.A. 45 K.V. 3 | seconds. |
| Film No. 105 | Positive at 100 M.A. 45 K.V. 5 | seconds. |
| Film No. 106 | Copy from positive at 100 M.A. 45 K.V. 1 second. | |

Conclusions. The duplicate showed greater contrast than the original and the longer the exposure the greater the increase in density. As the result of this experiment in alteration of exposure time, there appeared no warrant for further departure from the suggested standardised technique meantime. Consequently the standard technique of 100 M.A., 45 K.V., 1 second exposure and 40" distance will continue as the standard unless otherwise stated.

V. OSSIFYING FIBROMA OF THE MANDIBLE. Patient - Herrington.
Film Nos: 107 to 121.

Ossifying Fibroma is a benign tumour of slow growth characterised by a definite outline of demarcation from the unaffected bone tissues and the tumour structures show a fibrular ossification. The X-rays of this particular case had already been copied in an early experiment in the series (vide Item XV, Experiment No. 4, page 31.) The films No. 67 to 76 are contained in the separate file.

The pathological interest in this case was due to the size of the tumour in the right mandible and to the presence of another smaller tumour of the same kind in the left mandible. The series of radiographs Nos: 107 to 121 shows the pathological condition before operation and various stages in post-operative healing. The larger tumour No: 107 to 109 is illustrated in Envelope G, page 66, G.1, G.2 and G.3.

| | | |
|---|---|---|
| Film No. 107 | This is the original X-ray negative showing a large ossifying fibroma. | Envelope G, |
| Film No. 108 | A positive of No. 107. | G.1,G.2 & G.3. |
| Film No. 109 | A negative copy of No. 108, i.e., a copy of the original X-ray negative. | 1st Copy. |
| Film No. 110 | Left lateral oblique jaw X-ray negative showing smaller tumour. | |
| Film No. 111 | A positive of film No. 110. | |
| Film No. 112 | The copy of film No. 110. | |
| Film No. 113 | Occipito-frontal X-ray negative showing large ossifying fibroma. | Envelope G, G.1,G.2 & G.3. |
| Film No. 114 | Positive. | 2nd Copy. |
| Film No. 115 | Copy. | |
| Film No. 116 | Left lateral oblique jaw X-ray negative after removal of smaller tumour. | |
| Film No. 117 | Positive. | |
| Film No. 118 | Copy. | |
| Film No. 119 | Occipito-frontal X-ray negative after removal of large ossifying fibroma. | |
| Film No. 120 | Positive. | |
| Film No. 121 | Copy. | |

G.

## ENVELOPE G.

This envelope contains a good example of a pathological bone condition confirmed as an ossifying fibroma of the mandible.

### NARRATIVE OF RADIOGRAPHS.

X-RAY G.1. X-ray negative of the pathological bone condition.

X-RAY G.2. Positive film on fine grain photographic film.

X-RAY G.3. Duplicate of the bone condition on fine grain photographic film.

Conclusions. This method was a considerable improvement on the previous duplication method (vide Item XV of Experiment No. 4, page 31, series Nos. 67 to 76.) It however confirms the fact that the contrast in the copy was accentuated. There was a further loss of definition in the duplicate if an original X-ray negative lacked tonal values, i.e. contrast and definition.

VI. OCULAR HYPERTELORISM. Patient - Miss Wright.
Film Nos: 122 - 127.

Ocular Hypertelorism is an osteodystrophy, or bone dysplasia, showing abnormal anatomical structure, characterised radiographically by lateral displacement of the orbits and due to an aberration of the normal growth function of the sphenoid bone; the cause is unknown. This X-ray was included as one of the duplication series as it was a type of film which, for its teaching value, was necessary in a dental school. Consequently the ability to make copies was of extreme importance.

Film No. 122 Occipito-frontal X-ray negative showing the anomaly.
Film No. 123 Positive.
Film No. 124 Copy.
Film No. 125 Occipito-mental X-ray negative.
Film No. 126 Positive.
Film No. 127 Copy.

Conclusions. Satisfactory.

GENERAL CONCLUSIONS OF EXPERIMENT NO: 7.

The X-ray negatives in this experiment were a good cross section of the varying types encountered in hospital or in private practice. Each film has its own degree of contrast and definition, and for different purposes, one or the other or both are required; but it should be remembered that, in a generalised X-ray of a skull, all the anatomical structures cannot be brought out to the same degree of definition and contrast. Therefore exposure is determined on the particular structure which requires to be shown clearly.

The general conclusion to be drawn from the experiment is that a copy was visually as good as its original when the original shows good contrast and definition.

The experiment confirmed the belief that it was possible to make satisfactory duplicates with a standardised technique. It also envisaged the possibility that by various manipulations of exposure, film and development, it might be possible to improve the technique in such a way as to show greater intensification in an X-ray duplicate. If further intensification were possible, it might be also within the bounds of possibility that an anatomical structure or a pathological condition, not obvious in an original X-ray negative, might be made visible in a copy.

It was decided to carry out, at a later date, experiments on fractures of the scaphoid bone where a fracture not demonstrable in an X-ray negative was known clinically to exist.

# CHAPTER 8.

## Applications of the duplicating technique.

# CHAPTER 8.

## APPLICATIONS OF DUPLICATING TECHNIQUE.

### 1. DUPLICATION WITHIN THE X-RAY DEPARTMENT.

Occasions arise in every X-ray department when a copy of a radiograph is desirable. A patient may not be available for further X-rays although the condition may be of great clinical interest, and further radiographs would be of great teaching value. Occasions may also arise when an X-ray should be sent with a clinical report in order to simplify the latter; it is inadvisable to send away the only available radiographs.

Again, the medico-legal position is eased for hospitals when it is difficult and often unwise to send out originals which might not be returned.

### 2. CLINICAL TEACHING.

A composite radiograph can be formed by fixing a series of radiographs upon a clear cellophane background. The series may consist of several phases of similar pathological conditions such as a variety of impacted teeth, as shown in Envelope H, (page 74), or a progressive series of the same case from early onset to completion of treatment. In Envelope I (page 76), the progress of root treatment and bone regeneration is presented through the various periods of treatment. This method has greater value than the projection individually of its component radiographs. Comparisons and contrasts can be detected more easily by the student observer.

In practice it has been seen in Glasgow Dental Hospital that students learn more quickly from positive copies than from negative copies which previously constituted the entire field of X-ray teaching films.

EXPERIMENT No: 8. Film Nos: 128 to 144.

Film No. 128 This first test was a series of dental X-rays of varying contrast and definition mounted on a clear base.
Film No. 129 Positive film.
Film No. 130 Copy of composite X-ray negative.

Conclusions. The results were excellent and up to expectations.

Film No. 131 This is a composite series of 16 intra-oral negatives of dental impactions.
Film No. 132 Positive film.
Film No. 133 Copy of dental impactions.

The results are illustrated in Envelope H, page 74.
(X-rays H.1, H.2 & H.3.)

Film No. 134 Five X-ray negatives of eruption and dentigerous cysts.
Film No. 135 Positive.
Film No. 136 Copy.

Conclusions. The results were again excellent.

Film No. 137 A series of X-ray negatives of pulpotomy, root treatment and bone regeneration.
Film No. 138 Positive.
Film No. 139 Copy.

This series is shown in Envelope I, page 76.
(X-rays I.1, I.2 & I.3.)

Film No. 140 X-ray negative of osteomyelitis.
Film No. 141 Positive.
Film No. 142 Copy.

Conclusions. The results were extremely satisfactory.

Film No. 143 This was a positive photographic print from the copy made by contact printing.
Film No. 144 This was a negative photographic print made in the same way.

Conclusions. Satisfactory.

H. . . . .

## ENVELOPE H.

These pictures show an example of a series of tooth impactions mounted in the form of a composite radiograph.

### NARRATIVE OF RADIOGRAPHS.

X-RAY H.1. Sixteen intra-oral X-ray films mounted on a clear cellophane base.

X-RAY H.2. The positive film on fine grain photographic film.

X-RAY H.3. The copy on fine grain photographic film.

Conclusions. The positive copies were brilliant in their detail and when photographed on to a 2" slide, projected well.
Sixteen films on one slide may be more than can be comfortably accepted visually, and it may be wise to reduce the numbers.

I.

## ENVELOPE I.

This envelope contains an X-ray series taken at different intervals, to demonstrate the progress of treatment in a case undergoing pulpotomy and root treatment.

### NARRATIVE OF RADIOGRAPHS.

X-RAY I.1. This shows a series of twelve intra-oral X-ray films mounted on a base of clear cellophane.

X-RAY I.2. Positive film of X-ray I.1 on fine grain photographic film.

X-RAY I.3. Duplicate negative or copy of X-ray I.1.

Conclusions. The noteworthy point in the grouping was that the whole series of a case could be mounted as one X-ray negative, which is most valuable as a teaching aid. The duplicate was still satisfactory and fulfilled its purpose but, once again, the outstanding feature was the positive film showing great detail and in proper perspective. This film proved of inestimable value to students.

## 3. DENTAL PROSTHETICS.



In dental prosthetics, before replacing natural teeth with dentures, it is important that the teeth to be extracted should be shown in relationship to the soft tissue profile and, at the same time, the vertical height of the face should be recorded. Over a period of time this record can be studied for correction during the subsequent changes that take place in the alveolus due to the natural resorption following tooth extraction. A positive lateral skull radiograph is superimposed over a soft tissue profile radiograph to give the relationship between the teeth and soft tissue profile, thus recording the vertical facial height. When the teeth are extracted and the dentures inserted, another lateral head radiograph is taken together with a soft tissue X-ray. Most dentures are now made of radiolucent acrylic resin so it is necessary that the outline of the teeth and dentures should be made radiopaque. A positive radiograph is then made and superimposed over the soft tissue X-ray and this shows the relationship of hard and soft tissues before and after extraction. The same patient can now be re-examined during suitable intervals and alterations noted in the vertical height and hard and soft tissue relationship. Recording of vertical height, prior to tooth extraction, is of great importance as so much of the facial pain of edentulous patients is entirely due to imbalance of the temporo-mandibular joint, due to loss of vertical height.

This technique can also be adopted in orthodontics where a change in relationship of the skeletal and soft tissues can be noted, particularly in cases of Class II and Class III malocclusion (i.e. mandibular retrusion and protrusion) following treatment.

Film No. 145 Positive film of a lateral head X-ray negative superimposed over soft tissue profile.
Film No. 146 A negative film taken from the superimposed X-rays.
Film No. 147 A copy of the original superimposed film.

<u>Conclusions</u>. This experiment was not satisfactory owing to the double X-ray films.

The following series showed a case before and after teeth extraction, and after experiments to procure the proper outline of the teeth and dentures.

Film No. 148 A lateral head cephalostat with teeth in position superimposed over soft tissue outline as shown in X-ray J.1 of Envelope J, page 81.
Film No. 149 This is an X-ray negative following extractions and with the denture inserted in the mouth. The incisors were coated with Barium paste but this was not successful. The outline of the dentures cannot be seen.
Film No. 150 This film shows a faint outline of the occluding surface of the dentures.
Film No. 151 This film shows the outline of the dentures and position of the artificial teeth. Tinfoil was placed over the incisor teeth and on the base of the dentures.
This method gave satisfactory results as shown in X-ray J.2 of Envelope J, page 81.

## 4. <u>PROJECTION SLIDES</u>.

It was discovered that in a composite periapical X-ray film, 2" slides could be made either from the positive or from the copy by the simple method of cutting out the required portion of the film and inserting it in a mount. These were found to compare favourably with the originals.

5. PUBLICATION.

In most cases the duplicate X-ray film appeared better visually or subjectively than the original. This was due to the greater contrast which sometimes suggested better definition. The improved contrast and definition in the copy made it more suitable to photograph for publication. In the process of copying there was always available an excellent positive film from which a photographic copy could easily be made by the simple process of contact printing.

(See Nos. 143 & 144 of series.)

J.

These X-rays show an example of the superimposition of hard and soft tissues of the skull before and after extractions, and demonstrate a method of controlling the proper vertical height dimension which is an essential in the retention of the original profile of the face, and in maintaining the natural equilibrium between the jaws.

## NARRATIVE OF RADIOGRAPHS.

X-RAY J.1. This film was a lateral head X-ray negative with the teeth in position superimposed over a supplementary soft tissue outline.

X-RAY J.2. This was the same case at a later date with the teeth extracted and the dentures in position. The tinfoil outline shows the tooth position.

Conclusions. As resorption of the alveolus takes place there is a resultant loss of vertical height and distortion of the profile outline. Periodically this must be corrected by alterations in the denture, and reference can be made to the original alignment and relationship of the hard and soft tissues.

# CHAPTER 9.

## CHEST RADIOGRAPHY.

Duplication of chest radiographs.
General Conclusions.
Report from Mass Radiography Centre.

# CHAPTER 9.



## DUPLICATION OF CHEST RADIOGRAPHS.

EXPERIMENT No: 9. Film Nos. 152 - 163.

As it was now possible to obtain satisfactory X-ray copies of bone conditions, it was decided at this juncture to duplicate large and miniature chest radiographs by radiographical methods.

Soft tissues were now involved, and it was anticipated that difficulties would be encountered in reproducing structures showing comparatively little contrast and definition. The primary object was to copy chest radiographs without losing detail, and not necessarily to improve the diagnostic value of the original. Unless specified, no alteration has been made in the technique already described for duplicating, as standardisation was considered important. The Consultants and Staff of the Mass Radiography Centre in Elmbank Street, Glasgow, gave their utmost co-operation and I wish to express my indebtedness to them.

The investigation was divided into two phases:-

1. Duplication of large X-ray negatives of chests.
2. Duplication of miniature films of chests.

The large films of the series (Nos: 152, 155, 158 and 161) were all of the same patient. They were taken at various intervals and are included in the accompanying X-ray file. Nos: 161 to 163 are included in Envelope K, (page 86) as examples of the standard obtained in copying. Conclusions are appended following each experiment. Finally, general conclusions of the entire investigation are given; these include a report by Mr. McCurdie, Superintendent of the Mass Radiography Centre, Glasgow.

DUPLICATION OF LARGE X-RAY NEGATIVES OF CHESTS.

Film No. 152 A chest X-ray negativw GLA 5182475 Date: 12.3.53.
Film No. 153 Positive of film No. 152.
Film No. 154 Copy of film No. 152.

**Conclusions.** The original negative showed good subjective contrast and definition. The positive film showed subjectively an improvement in contrast and definition but the copy showed evidence of too much contrast with consequent loss of definition.

Film No. 155 A chest X-ray negative 5182475 Date: 21.4.53.
Film No. 156 Positive of film No. 155.
Film No. 157 Copy of film No. 155.

**Conclusions.** The original negative was thin, lacking in contrast and definition. The positive film showed considerable improvement subjectively, but the copy had lost this improvement and showed too much contrast.

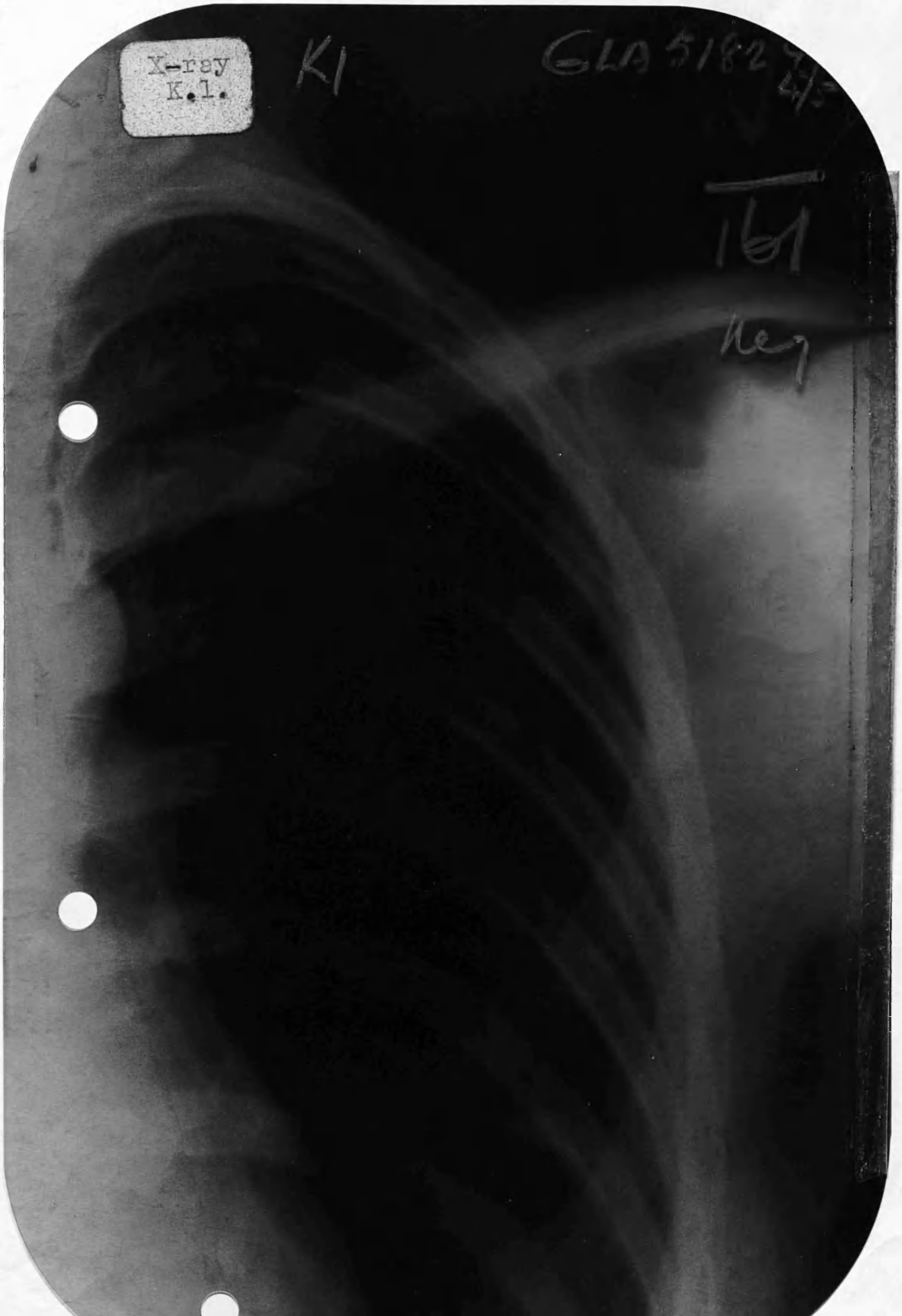
Film No. 158 A chest radiograph GLA 5182475 Date: 2.3.54.
Film No. 159 Positive of film No. 158
Film No. 160 Copy of film No. 158.

**Conclusions.** The original negative of this series had better contrast and definition in comparison with the original in series 155-157. The positive film maintained the same improvement and the copy showed a corresponding loss.

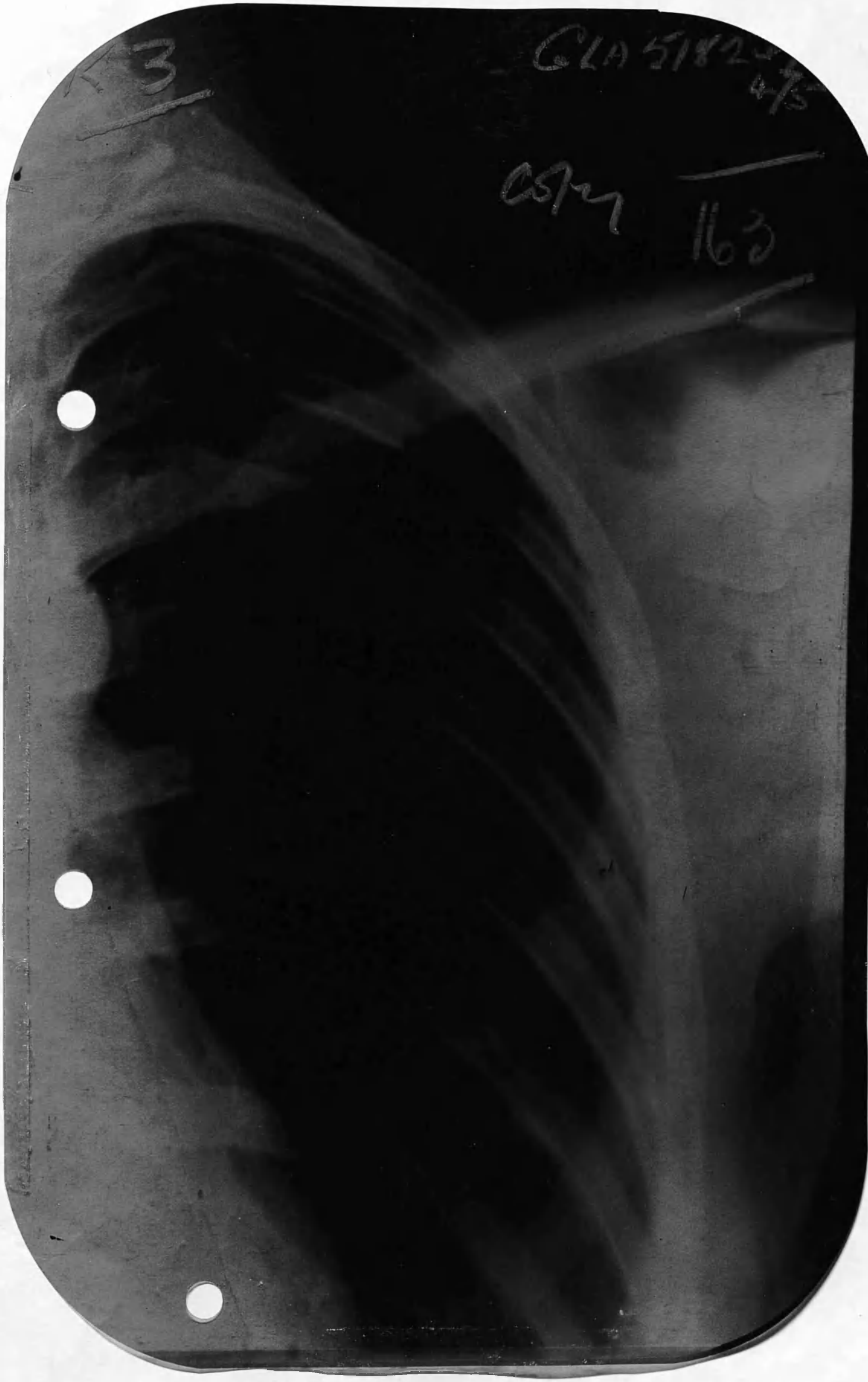
Film No. 161 A chest radiograph 5182475 Date: 7.9.54.
Film No. 162 Positive of film No. 161
Film No. 163 Copy of film No. 161.

In this case, developing time was altered to 2½ minutes, and a clear blue base sheet was placed behind the copy. These films (No: 161 - 163) are shown in Envelope K, page 86.

K.


X-ray
K.1.
K1
GLA 5182


X-ray
E.2.


163

X-ray
K.4.

## ENVELOPE K.

This envelope contains an example of the quality of duplication of chest radiographs obtained by the radiographical technique.

### NARRATIVE OF RADIOGRAPHS.

X-RAY K.1. An X-ray negative of one side of the chest.

X-RAY K.2. Positive or intermediate film.

X-RAY K.3. Copy of the original negative (K.1.)

P.S. The standard technique was followed except that in this case the development of the copy was done at 2½ minutes instead of the usual 3½ minutes.

FILM K.4. This is a piece of blue base X-ray negative. If this coloured base is superimposed over the copy it gives improved viewing.

Conclusions. The original negative was an excellent example of good contrast and definition which subjectively was improved in the positive film and, by shortening the developing time in making the copy, a very favourable duplicate was made. Subjective improvement can be further enhanced by superimposing a clear sheet of blue base film which gives the impression of further gain in contrast and definition.

GENERAL CONCLUSIONS IN THE DUPLICATION OF LARGE X-RAY NEGATIVES OF CHESTS.

It was quite obvious that duplication of large X-ray negatives of the chest was satisfactory and, subjectively, the copy K.3 (shown in Envelope K) appears as good as, if not better, than the original K.1. A further improvement was shown when viewed over the clear blue base.

At the moment the copy shows no apparent improvement in the diagnostic value. The intermediate or positive films all showed a very definite consistency in reproduction, with no obvious loss in contrast or definition.

It should be emphasised that throughout the whole research, the intermediate films retained a definite consistency and subjectively enhanced the details of original X-rays.

Consideration should be given to more frequent examination of positive radiographs, particularly in doubtful or illusive pathological conditions. The diagnostic value of positive copies was sometimes greater than that of the original negative.

EXPERIMENT No: 10. Film Nos. 164 to 170.

Comparative success having been accomplished in the duplication of large X-ray films of chests, a series of 35 and 45 mm miniature films were copied. As miniature films were the type taken as general routine in mass chest radiography, the possibility of copying them successfully would be important, not exclusively from a diagnostic angle, but also in order to retain originals within a department. This would permit copies to be sent to interested parties if a patient were transferred from one location to another, or under any circumstances in which copies might be helpful or desirable.

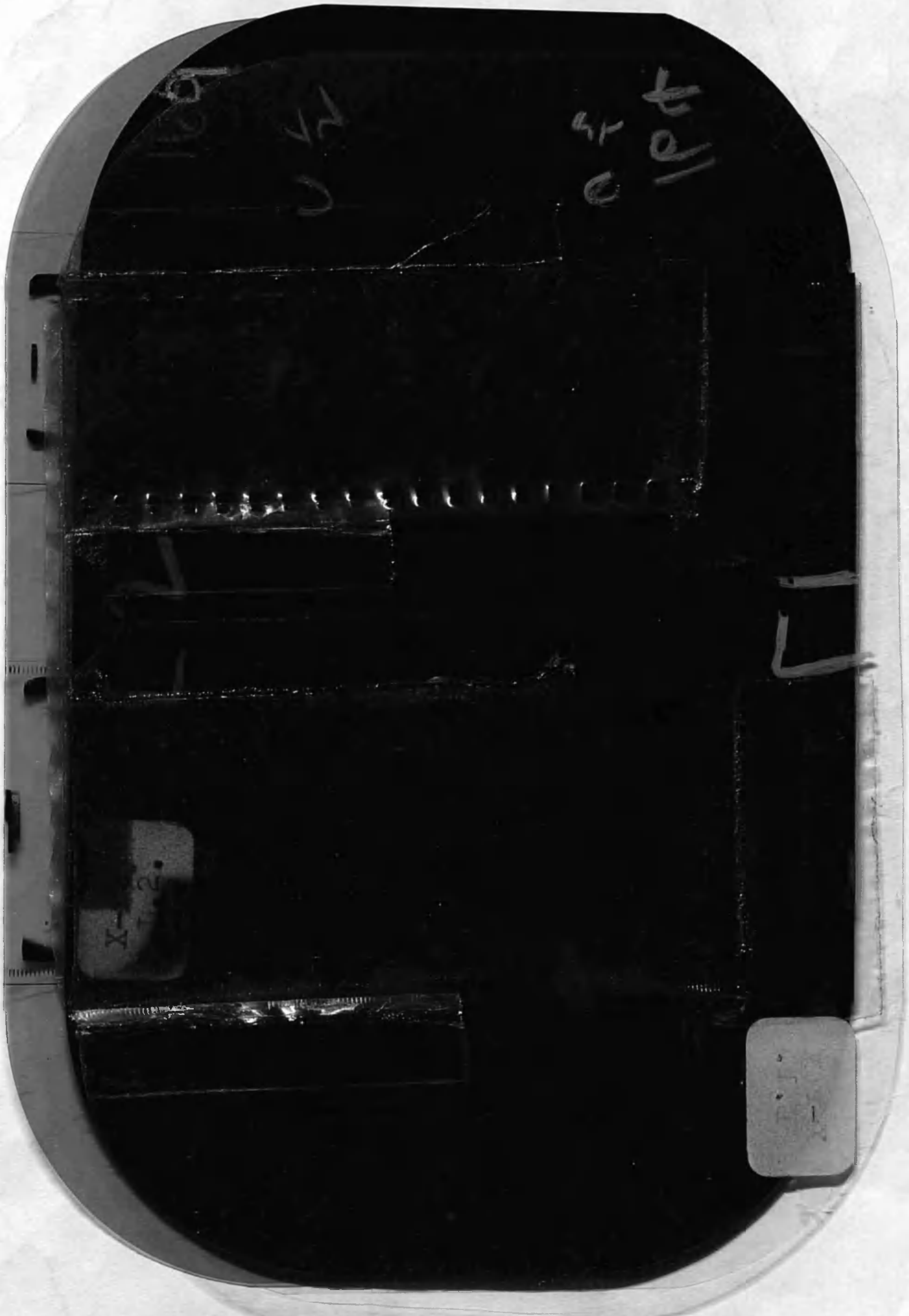
| | | |
|---|---|---|
| Film No. 164 | A series of 35 & 45 mm chest films mounted on a clear base. | |
| Film No. 165 | Positive. | Developed at 3½ minutes. |
| Film No. 166 | Copy. | |
| Film No. 167 | Positive. | Developed at 2½ minutes. |
| Film No. 168 | Copy. | |

Conclusions. The results obtained were extremely disappointing. Both positive and negative copies were blurred and appeared out of focus. The cause appeared to be due to printing from the non-emulsion side of the original film and using insufficient padding within the cassette to make good contact. The original miniature films were remounted on a clear base with the emulsion side uppermost, to make contact with the emulsion surface of the copying film. This alteration in technique solved the problem of obtaining a satisfactory copy of a miniature film.

| | |
|---|---|
| Film No. 164 | The original X-ray negative in altered position with emulsion side uppermost. |
| Film No. 169 | Positive film of No. 164. |
| Film No. 170 | Duplicate film of No. 164. |

**Conclusions.** The alteration in the method of inserting the film in the cassette solved the problem, and the results of duplication were satisfactory. The films are shown in Envelope L, page 91, and numbered L.1, L.2 & L.3.

L.



## ENVELOPE L.

This envelope contains an example of the quality obtained in the duplication of miniature chest X-rays by the radiographic technique.

### NARRATIVE OF X-RAY FILMS.

X-RAY L.1. The originals consisting of 35 & 45 mm chest X-rays which were loaned from the Mass Radiography Centre, Glasgow, and attached to a clear base for insertion into the cassette.

X-RAY L.2. Positive or intermediate film.

X-RAY L.3. The duplicate of the original X-ray film.

P.S. The developer and fixer were different from the previous experiments, but this made no difference to the results. The developer now in use in the department is Pentelex M & B., and the fixer is 1 minute Amfix. Unless otherwise stated, this is the developer and fixer which will be used in all further experiments.

Conclusions. Subjectively the results were excellent. The positive appeared to have lost nothing in contrast or definition. The copy however showed greater contrast and appeared to have lost some of the finer structure shown in the original. Considering the size of the originals, the results were surprisingly good. The superimposition of the clear blue base material improved the visual effect, but from a diagnostic value, there was no obvious improvement. I am indebted to the Mass Radiography Centre, Glasgow, for their report which is shown on page 93.

# Report on X-ray Photographic Tests carried out on Miniature and Large Films of Chests by Mr. H. Armour Clark, Dental Hospital, Glasgow.

The original miniature chest films (35 mm. Gevaert) were fairly contrastive, and the further contrast effect obtained by reproducing, did not improve the diagnostic value. Where contrast was low, original miniature chest films would benefit from reproduction, so far as improved contrast is concerned, but it is doubtful if the resultant loss of definition would be acceptable.

## Large Film Technique.

Several large films of chests of average subjects were reproduced and, in every case, there was a marked increase in contrast with corresponding loss of definition. As with the miniature tests, the loss of definition outweighed any advantage of increased contrast. It is felt that with a variation in reproduction technique, the contrast/definition balance may be improved.

As a means of reproducing films for record purposes, this method shows as good, or better, results than with any other method. The "intermediate" films are particularly striking, and it would seem that further experiment with these would produce profitable results.

Mr. McCurdie,
Superintendent Radiographer,
Mass Radiography Service,
Glasgow.

9th October, 1956.

# CHAPTER 10.

## Further experiments to improve the existing technique of duplication.

# CHAPTER 10.

## FURTHER EXPERIMENTS TO IMPROVE TECHNIQUE.

Satisfactory subjective and objective duplication of X-ray negatives having been accomplished, it was desired to improve the technique so that it might be possible to show not only a better copy but one with an increased diagnostic value.

Since the duplicating method was established, a comprehensive cross-section of X-ray negatives had been copied following the standardised technique of 100 M.A., 45 K.V., 1 second and 40" distance, and developed at 68° F. for 3½ minutes. To obtain the optimum standard of duplication with a possibility of enhanced diagnostic value, a series of experiments was considered in which the milliamperage (M.A.) and kilovoltage (K.V.) factors were altered and the developing time varied. A stepwedge X-ray negative was used as the basis of comparison, and from each copy, employing the varying alterations of technique, densitometer readings were taken, and the findings displayed in graph form.

Conclusions are made from the evidence of each phase, and final conclusions are made when all alterations in technique have been completed. It was hoped that a better method of duplication might be discovered.

The details of this investigation are described in Experiment No: 11, and each series of alterations in technique designated by a capital alphabetical letter with an explanatory heading before each experiment.

# EXPERIMENT No: 11.

**11A.** Film Nos. 169 to 177.

This experiment consisted of a series of exposures with changing milliamperage (M.A.) values, ranging from 200 M.A. to 75 M.A., but keeping the milliampere-second (M.A.S.) exposure value constant. The standardised technique was followed using fine grain photographic film, a front fluorazure screen, and throughout this experiment, the development was 3½ minutes at 68° F, in standard X-ray developer (Pentelex M & B.)

Film No. 169 This film is a good X-ray negative of a mesh and stepwedge on Red Seal film between High Definition (H.D.) Intensifying Screens, taken at 100 M.A., 50 K.V., 0.04 second & 40" distance.

This film was used in the ensuing tests as the standard of comparison.

| | | | | | | |
|---|---|---|---|---|---|---|
| Film No. 170 | Positive film from No. 169, | 200 M.A. | 45 K.V. | ½ | Sec. | 40" D. |
| Film No. 171 | Duplicate film through 170, | 200 M.A. | 45 K.V. | ½ | Sec. | 40" D. |
| Film No. 172 | Positive film from No. 169, | 155 M.A. | 45 K.V. | .7 | Sec. | 40" D. |
| Film No. 173 | Duplicate film through 172, | 155 M.A. | 45 K.V. | .7 | Sec. | 40" D. |
| Film No. 174 | Positive film of No. 169, | 100 M.A. | 45 K.V. | 1 | Sec. | 40" D. |
| Film No. 175 | Duplicate film through 174, | 100 M.A. | 45 K.V. | 1 | Sec. | 40" D. |
| Film No. 176 | Positive film through 169, | 75 M.A. | 45 K.V. | 1.3 | Sec. | 40" D. |
| Film No. 177 | Duplicate film through 176, | 75 M.A. | 45 K.V. | 1.3 | Sec. | 40" D. |

## DENSITOMETER READINGS.

The graph line of the standard X-ray negative of No. 169 is shown in blue throughout this experiment. The duplicate X-rays are shown in different colours and demonstrate clearly an increase or decrease in intensification.

The readings of these X-rays are included in the thesis but the films are not included. They are filed and available, if desired, under specific numbers.

To give a more accurate recording, the final figure is obtained by subtracting the Fog Density of each film from the average of three densitometer readings of each stepwedge. The readings for each experiment are shown graphically and the results recorded in the conclusions. Consequently, the remainder of this chapter, apart from the conclusions, is essentially technical in nature.

EXPERIMENT 11A.

Constant Milliampere-Second Exposure Readings.

Film No. 169 X-ray film of mesh and stepwedge.

Fog Density = 0.23.

| | | | | Average. | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | .84 | .85 | .88 | 0.86 | 0.63 |
| 2 | 1.02 | 1.06 | 1.05 | 1.04 | 0.81 |
| 3 | 1.22 | 1.23 | 1.22 | 1.22 | 0.99 |
| 4 | 1.37 | 1.39 | 1.38 | 1.38 | 1.15 |
| 5 | 1.55 | 1.55 | 1.56 | 1.55 | 1.32 |
| 6 | 1.70 | 1.70 | 1.70 | 1.70 | 1.47 |

The graph line is shown in blue, page 99.

Film No. 171 This is the duplicate taken at 200 M.A. 45 K.V. ½ Sec. 40" D.

Fog Density = 0.31

| | | | | Average. | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.91 | 0.87 | 0.90 | 0.89 | 0.58 |
| 2 | 1.24 | 1.24 | 1.22 | 1.23 | 0.92 |
| 3 | 1.43 | 1.44 | 1.42 | 1.43 | 1.12 |
| 4 | 1.66 | 1.66 | 1.64 | 1.65 | 1.34 |
| 5 | 1.90 | 1.91 | 1.90 | 1.90 | 1.59 |
| 6 | 2.15 | 2.18 | 2.19 | 2.17 | 1.86 |

The graph line is shown in red, page 99.

Film No. 173 This is the duplicate taken at 155 M.A., 45 K.V., 0.7 Second, 40" D.

Fog Density = 0.29

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1. | 0.85 | 0.84 | 0.87 | 0.85 | 0.56 |
| 2 | 1.11 | 1.08 | 1.12 | 1.10 | 0.81 |
| 3 | 1.31 | 1.35 | 1.32 | 1.33 | 1.04 |
| 4 | 1.59 | 1.64 | 1.59 | 1.61 | 1.32 |
| 5 | 1.85 | 1.90 | 1.87 | 1.87 | 1.58 |
| 6 | 2.18 | 2.22 | 2.24 | 2.21 | 1.92 |

The graph line is shown in green, page 99.

Film No. 175 This is the duplicate taken at 100 M.A., 45 K.V. 1 second, 40" D.

Fog Density = 0.23.

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.76 | 0.74 | 0.78 | 0.76 | 0.53 |
| 2 | 0.92 | 0.93 | 1.10 | 0.98 | 0.75 |
| 3 | 1.19 | 1.21 | 1.21 | 1.20 | 0.97 |
| 4 | 1.42 | 1.43 | 1.46 | 1.44 | 1.21 |
| 5 | 1.75 | 1.76 | 1.76 | 1.76 | 1.53 |
| 6 | 1.96 | 1.95 | 1.99 | 1.97 | 1.74 |

The graph line is shown in brown, page 99.

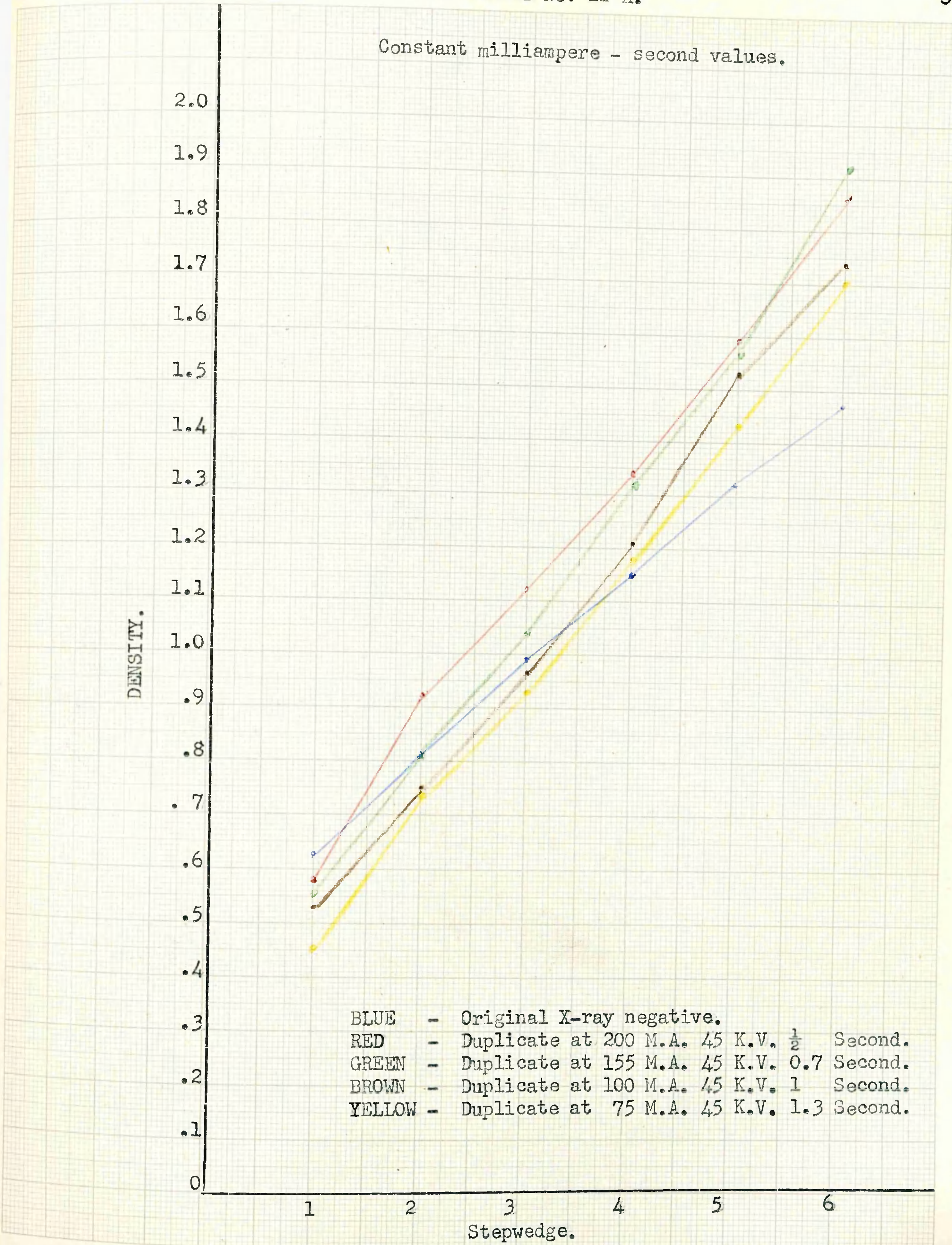
Film No. 177 This is the duplicate taken at 75 M.A., 45 K.V., 1.3 second, 40" D.

Fog Density = 0.37

| | | | | Average. | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.83 | 0.80 | 0.84 | 0.82 | 0.45 |
| 2 | 1.11 | 1.10 | 1.13 | 1.11 | 0.74 |
| 3 | 1.28 | 1.32 | 1.31 | 1.30 | 0.93 |
| 4 | 1.53 | 1.58 | 1.55 | 1.55 | 1.18 |
| 5 | 1.78 | 1.79 | 1.83 | 1.80 | 1.43 |
| 6 | 2.07 | 2.07 | 2.08 | 2.07 | 1.70 |

The graph line is shown in yellow, page 99.

EXPERIMENT No: 11 A.



## CONCLUSIONS OF EXPERIMENT No: 11A.

The result of this experiment on a constant milliampere-second (M.A.S.) value as shown graphically on page 99, demonstrated clearly that all the copies showed a greater proportional density value than the original X-ray negative.

The most successful was the 200 M.A., 45 K.V., ½ second and 40" distance, comparable to an exposure of 100 M.A.S., 45 K.V., 1 second, 40" distance, which previously had been used throughout the whole technique of duplication. The result confirmed the efficiency of the standardised technique.

EXPERIMENT No: 11B. Film Nos: 178 - 185.

(Varying Milliamperage.)

This experiment consisted of a further series of investigations varying the milliamperage (M.A.) from 75 to 200, but with the penetration, exposure and focal film-distance constant at 45 K.V., 1 second and 40" distance. The standard X-ray negative for comparison was still No: 169, and it was from this film that the positive and duplicate were reproduced and shown in the graph as Blue. Again the details must be given in a purely technical manner.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Film No. 178 | Positive film from 169 | @ 75 M.A. | 45 K.V. | 1 Sec. | 40"D. | |
| Film No. 179 | Duplicate of 169 through 178 | @ 75 M.A. | 45 K.V. | 1 Sec. | 40"D. | |
| Film No. 180 | Positive film from 169 | @ 100 M.A. | 45 K.V. | 1 Sec. | 40"D. | |
| Film No. 181 | Duplicate of 169 through 180 | @ 100 M.A. | 45 K.V. | 1 Sec. | 40"D. | |
| Film No. 182 | Positive of film 169 | @ 150 M.A. | 45 K.V. | 1 Sec. | 40"D. | |
| Film No. 183 | Duplicate of 169 through 182 | @ 150 M.A. | 45 K.V. | 1 Sec. | 40"D. | |
| Film No. 184 | Positive of film 169 | @ 200 M.A. | 45 K.V. | 1 Sec. | 40"D. | )Broad |
| Film No. 185 | Duplicate of 169 through 184 | @ 200 M.A. | 45 K.V. | 1 Sec. | 40"D. | )Focus. |

## DENSITOMETER READINGS.

### EXPERIMENT 11B.

(Varying Milliamperage (M.A.) - other factors remaining constant.)

The readings of X-ray Negative No: 169, page 97, are again taken as the standard for comparison and are shown as previously in the graph as blue.

Film No: 179 This is the duplicate of No: 169 taken at 75 M.A., 45 K.V., 1 second, 40" D.

Fog Density = 0.28.

| | | | | Average. | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.87 | 0.85 | 0.90 | 0.87 | 0.59 |
| 2 | 1.06 | 1.10 | 1.12 | 1.09 | 0.81 |
| 3 | 1.33 | 1.34 | 1.35 | 1.34 | 1.06 |
| 4 | 1.58 | 1.58 | 1.58 | 1.58 | 1.30 |
| 5 | 1.86 | 1.90 | 1.87 | 1.88 | 1.60 |
| 6 | 2.13 | 2.15 | 2.14 | 2.14 | 1.86 |

The graph line is shown in red, page 104.

Film No: 181 This is the duplicate of No: 169 taken at 100 M.A., 45 K.V., 1 second, 40" D.

Fog Density = 0.27

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.77 | 0.78 | 0.76 | 0.77 | 0.50 |
| 2 | 0.95 | 0.94 | 1.00 | 0.96 | 0.69 |
| 3 | 1.16 | 1.19 | 1.15 | 1.17 | 0.90 |
| 4 | 1.38 | 1.36 | 1.36 | 1.37 | 1.10 |
| 5 | 1.64 | 1.64 | 1.65 | 1.64 | 1.37 |
| 6 | 1.85 | 1.86 | 1.88 | 1.86 | 1.59 |

The graph line is shown in green, page 104.

Film No. 183 This is a duplicate of No. 169 taken at 155 M.A., 45 K.V., 1 second, 40" distance.

Fog Density = 0.40.

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.75 | 0.71 | 0.69 | 0.72 | 0.32 |
| 2 | 0.95 | 0.96 | 1.01 | 0.97 | 0.57 |
| 3 | 1.19 | 1.22 | 1.20 | 1.20 | 0.80 |
| 4 | 1.44 | 1.41 | 1.43 | 1.42 | 1.02 |
| 5 | 1.68 | 1.69 | 1.68 | 1.68 | 1.28 |
| 6 | 1.95 | 1.96 | 1.95 | 1.95 | 1.55 |

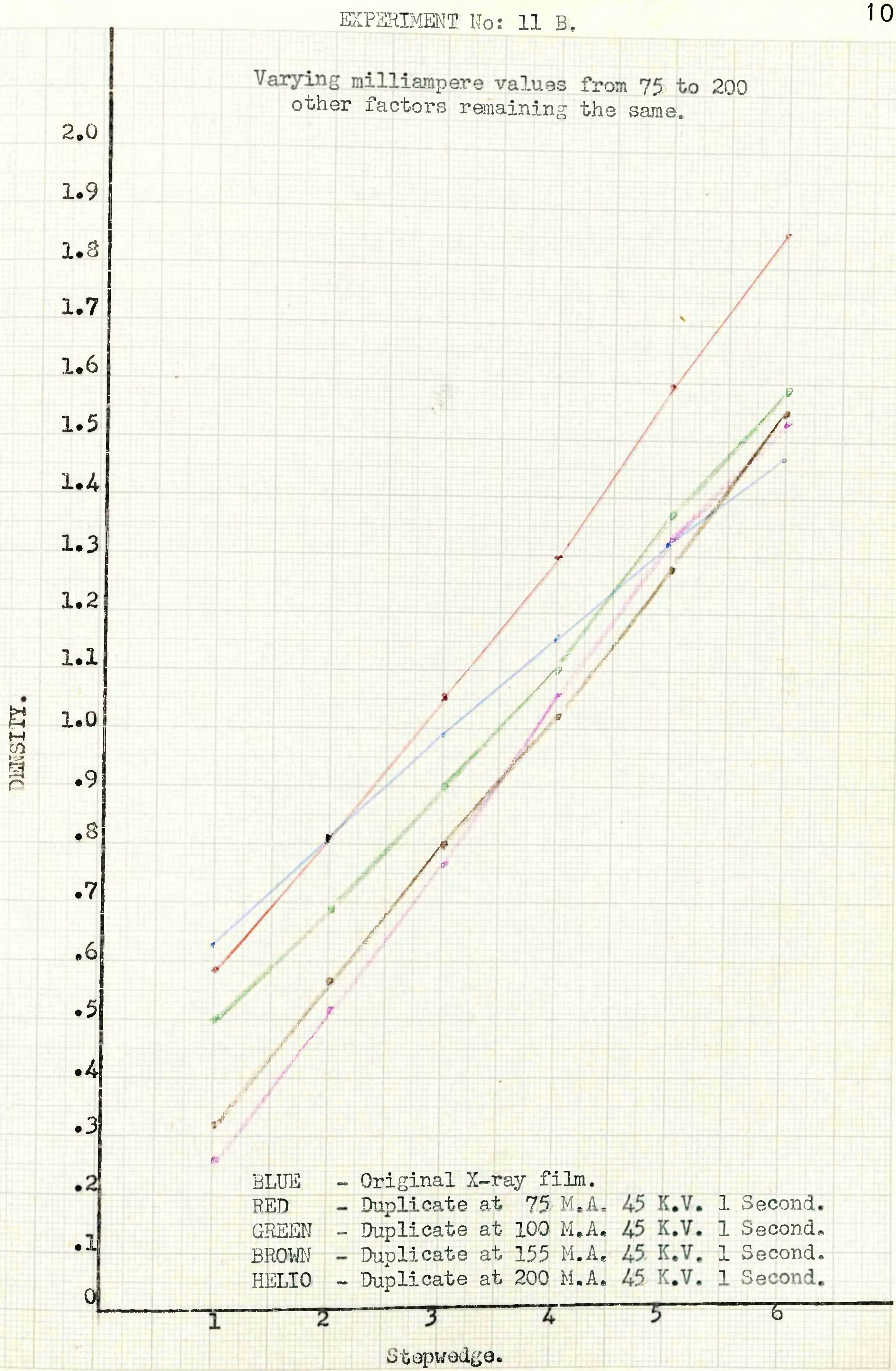
The graph line is shown in brown, page 104.

Film No. 185 This is the duplicate of No. 169 taken at 200 M.A., 45 K.V., 1 second, 40" distance, but with a broad focus.

Fog Density = 0.45

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.74 | 0.68 | 0.70 | 0.71 | 0.26 |
| 2 | 0.95 | 0.96 | 0.99 | 0.97 | 0.52 |
| 3 | 1.21 | 1.24 | 1.21 | 1.22 | 0.77 |
| 4 | 1.52 | 1.49 | 1.51 | 1.51 | 1.06 |
| 5 | 1.80 | 1.78 | 1.76 | 1.78 | 1.33 |
| 6 | 1.99 | 1.99 | 2.00 | 1.99 | 1.54 |

The graph line is shown in helio, page 104.


EXPERIMENT No: 11 B.
Varying milliampere values from 75 to 200 other factors remaining the same.
DENSITY.
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1
2
3
4
5
6
Stepwedge.
BLUE - Original X-ray film.
RED - Duplicate at 75 M.A. 45 K.V. 1 Second.
GREEN - Duplicate at 100 M.A. 45 K.V. 1 Second.
BROWN - Duplicate at 155 M.A. 45 K.V. 1 Second.
HELIO - Duplicate at 200 M.A. 45 K.V. 1 Second.

## CONCLUSIONS OF EXPERIMENT No: 11B.

The results of varying the milliampere (M.A.) values from 75 to 200 (other factors remaining constant) are shown graphically on page 104. The lowest value of 75 milliamperes shows the greatest intensification and a gradual decrease in density value in the higher milliamperage range. The improvement by reducing the milliamperage to 75 was most marked and further investigation was necessary to confirm this finding, with the possibility of an improved technique. This investigation will be described later in this chapter.

## EXPERIMENT No: 11C.

Film Nos: 186 - 191.

This investigation was carried out to determine the effect of kilovoltage (K.V.) variations. A series of exposures was made with penetration values ranging from 45 kilovolts (K.V.) to 75 kilovolts (K.V.) with time and milliamperage (M.A.) constant at 1 second and 100 milliamperes (M.A.) The standard X-ray negative for comparison remained No. 169 and it was from this film that the duplicates were made. It is shown in the graph as a blue line.

| | |
|---|---|
| Film No. 175 | This exposure of 100 M.A., 45 K.V., 1 second, 40" distance, has already been made in Experiment No. 11A, therefore, instead of repeating them, the densitometer readings of the duplicate film No. 175, detailed on page 99, were used for the purpose of the graph line. |
| Film No. 186 | Positive film from 169 at 100 M.A. 55 K.V. 1 Sec. 40" D. |
| Film No. 187 | Duplicate of 169 through 186 at 100 M.A. 55 K.V. 1 Sec. 40" D. |
| Film No. 188 | Positive film from 169 at 100 M.A. 65 K.V. 1 Sec. 40" D. |
| Film No. 189 | Duplicate of 169 through 188 at 100 M.A. 65 K.V. 1 Sec. 40" D. |
| Film No. 190 | Positive film from 169 at 100 M.A. 75 K.V. 1 Sec. 40" D. |
| Film No. 191 | Duplicate of 169 through 190 at 100 M.A. 75 K.V. 1 Sec. 40" D. |

## DENSITOMETER READINGS.

## EXPERIMENT No: 11C.

Film No. 169 This is the X-ray negative used as a standard for comparison with the duplicate film, and the graph line shown in blue, page 109, was taken from the densitometer readings detailed on page 97.

Film No. 175 This exposure of 100 M.A., 45 K.V., 1 second, 40" distance, having been taken in Experiment No. 11A, the densitometer readings recorded on page 98 are used to give the red graph line shown on page 109.

Film No. 187 This film is the duplicate of No. 169 taken at 100 M.A., 55 K.V., 1 second, 40" distance.

Fog Density = 0.45.

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.83 | 0.79 | 0.80 | 0.81 | 0.36 |
| 2 | 1.09 | 1.05 | 1.10 | 1.08 | 0.63 |
| 3 | 1.35 | 1.35 | 1.33 | 1.34 | 0.89 |
| 4 | 1.62 | 1.60 | 1.61 | 1.61 | 1.16 |
| 5 | 1.82 | 1.81 | 1.85 | 1.83 | 1.38 |
| 6 | 2.06 | 2.04 | 2.07 | 2.06 | 1.61 |

The graph line is shown in green, page 109.

Film No. 189 This film is the duplicate of No. 169 at 100 M.A., 65 K.V., 1 second, 40" distance.

Fog Density = 0.62

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.84 | 0.79 | 0.80 | 0.81 | 0.19 |
| 2 | 1.00 | 0.99 | 1.01 | 1.00 | 0.38 |
| 3 | 1.24 | 1.24 | 1.23 | 1.24 | 0.62 |
| 4 | 1.52 | 1.48 | 1.51 | 1.50 | 0.88 |
| 5 | 1.76 | 1.78 | 1.78 | 1.77 | 1.15 |
| 6 | 1.95 | 1.97 | 1.95 | 1.96 | 1.34 |

The graph line is shown in brown, page 109.

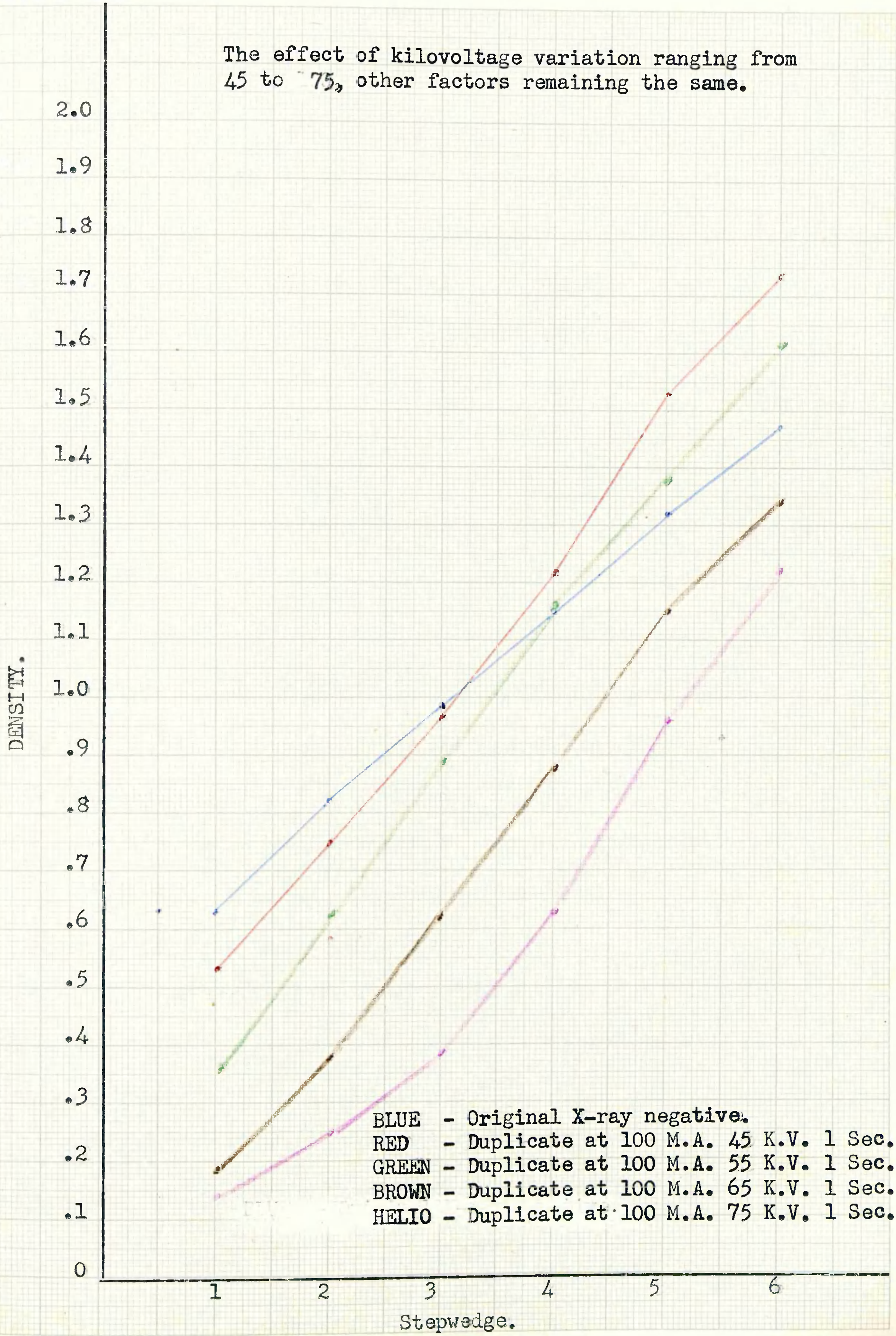
Film No. 191 This film is the duplicate of No. 169 at 100 M.A., 75 K.V., 1 second, 40" distance.

Fog Density = 0.64

| | | | | Average | Less Fog Density. |
|---|---|---|---|---|---|
| Step No. 1 | 0.78 | 0.78 | 0.78 | 0.78 | 0.14 |
| 2 | 0.88 | 0.89 | 0.90 | 0.89 | 0.25 |
| 3 | 1.02 | 1.05 | 1.03 | 1.03 | 0.39 |
| 4 | 1.27 | 1.27 | 1.28 | 1.27 | 0.63 |
| 5 | 1.63 | 1.60 | 1.58 | 1.60 | 0.96 |
| 6 | 1.87 | 1.85 | 1.85 | 1.86 | 1.22 |

The graph line is shown in helio, page 109.

EXPERIMENT No: 11 C.



## CONCLUSIONS TO EXPERIMENT No: 11C.

This experiment proved conclusively, as shown graphically on page 109, that the increase in the kilovoltage (K.V.), (other factors remaining constant), showed a corresponding decrease in density values in the higher kilovoltage range. The duplicate of 45 kilovolts (K.V.) showed the greatest intensification, confirming the necessity of a low kilovoltage.

This result suggested that improvement in duplication might be attained by a lower kilovoltage than 45 K.V., but unfortunately a lower kilovoltage was not possible in the machine available.

## THE GENERAL CONCLUSIONS OF EXPERIMENTS Nos: 11A, 11B & 11C.

The graphic evidence derived from densitometer readings of the stepwedge duplication on fine grain single-sided photographic film proved conclusively that the best copy was obtained at 75 M.A., 45 K.V., 1 second, 40" distance, and developed in standard X-ray developer for 3½ minutes at 68° F.

This suggested that the results from the previous technique using 100 milliamperes improved by reducing the milliamperage to 75 M.A., other factors remaining the same.

Confirmation of this statement required further investigation, and Experiment No: 11D followed to confirm the validity of this finding.

EXPERIMENT No: 11D.

Film Nos: 192 - 195.

As a result of investigations 11A, 11B and 11C in which there was a controlled alteration in the milliamperage (M.A.) and kilovoltage (K.V.), it was shown that the greatest intensification resulted from a decrease in the milliamperage (M.A.) value from 100 to 75. To confirm this, a duplicate was again taken from X-ray negative No. 169, and the densitometer readings were portrayed graphically for comparison. The X-rays can be viewed under their appropriate numbers in the separate file.

DENSITOMETER READINGS.

The densitometer readings in this series and in subsequent investigations were taken by setting the densitometer at zero after the fog density reading had been taken; this obviated subtraction.

The thickness of the film should also be taken into consideration when assessing the fog density, but a series of tests demonstrated that the thickness of films varied on an average less than .005 in the densitometer readings. This difference of film thickness was considered negligible and unnecessary for inclusion in the readings.

Film No. 192 A positive film taken from No. 169 at 75 M.A., 45 K.V., 1 second, 40" distance.

Film No. 193 A duplicate of No. 169 taken through No. 192 at 75 M.A., 45 K.V., 1 second, 40" distance.

DENSITOMETER READINGS OF DUPLICATE No. 193.

Fog Density = 0.27.

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.58 | 0.57 | 0.60 | 0.58 |
| 2 | 0.79 | 0.83 | 0.85 | 0.82 |
| 3 | 1.04 | 1.05 | 1.05 | 1.05 |
| 4 | 1.33 | 1.31 | 1.31 | 1.32 |
| 5 | 1.69 | 1.67 | 1.68 | 1.68 |
| 6 | 1.99 | 1.98 | 1.97 | 1.98 |

The graph line is shown in red, page 113.

For comparison, a duplicate was taken from the same X-ray negative No. 169 at 100 milliamperes (M.A.), other factors remaining the same.

Film No. 194 Positive of No. 169 at 100 M.A., 45 K.V., 1 sec. 40" D.

Film No. 195 Duplicate of No. 169 at 100 M.A., 45 K.V., 1 sec. 40" D.

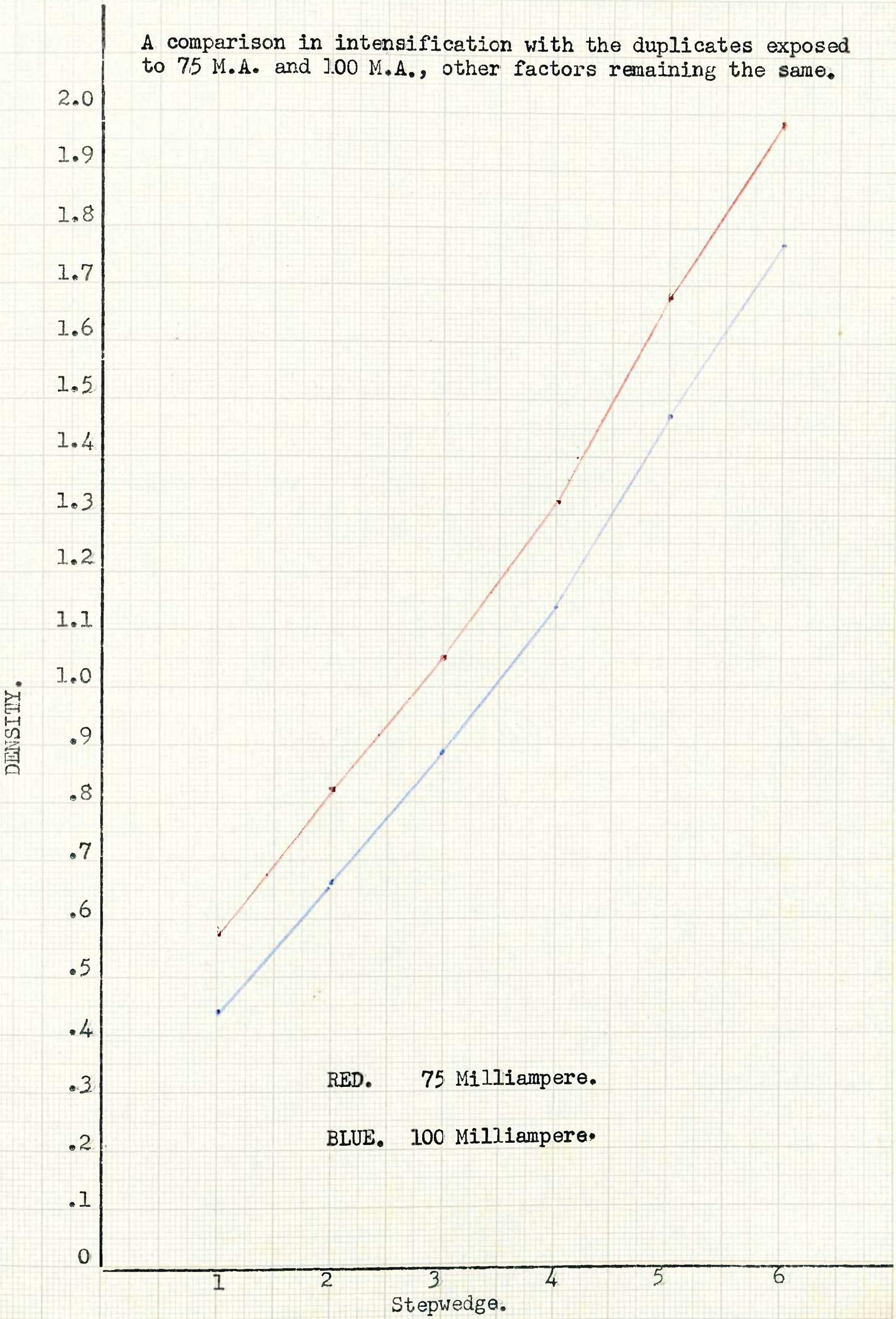
DENSITOMETER READINGS OF DUPLICATE No. 195.

Fog Density = 0.23.

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.45 | 0.43 | 0.44 | 0.44 |
| 2 | 0.62 | 0.66 | 0.71 | 0.66 |
| 3 | 0.89 | 0.90 | 0.89 | 0.89 |
| 4 | 1.15 | 1.15 | 1.13 | 1.14 |
| 5 | 1.46 | 1.48 | 1.48 | 1.47 |
| 6 | 1.78 | 1.78 | 1.76 | 1.77 |

The graph line is shown in blue, page 113.

# EXPERIMENT 11 D.



## CONCLUSIONS OF EXPERIMENT No: 11D.

The graphic evidence on page 113 showed that both lines run along a fairly parallel course but that the density was greater with 75 milliamperes (M.A.) This was an improvement on the previously standardised technique when 100 milliampere (M.A.) was used. This improvement provoked the thought that as development had also a considerable influence on contrast, a shortening of the developing time might increase the subjective and objective intensification. With that object in view, a further investigation took place to determine the effect of different developing times.

## EXPERIMENT No: 11E.

Film Nos: 196 - 204.

This investigation was conducted to study the effect of different developing times and to compare the objective results by means of densitometer readings arranged in graph form.

An X-ray negative film was taken of the mesh and stepwedge from which copies were made at different developing times, ranging from 1½ minutes to 4½ minutes. The other factors, for duplication, remained constant. The intermediate positives were developed for the same time as the copies. The numbered films are included within the separate file.

| | |
|---|---|
| Film No. 196 | X-ray negative of mesh and stepwedge taken on Red Seal film at 100 M.A., 50 K.V., 0.04 second, 40" distance, and developed for the usual 3½ minutes. |
| Film No. 197 | Positive film of No. 196 developed at 4½ minutes. |
| Film No. 198 | Duplicate film of No. 196 developed at 4½ minutes. |
| Film No. 199 | Positive film of No. 196 developed at 3½ minutes. |
| Film No. 200 | Duplicate film of No. 196 developed at 3½ minutes. |
| Film No. 201 | Positive film of No. 196 developed at 2½ minutes. |
| Film No. 202 | Duplicate film of No. 196 developed at 2½ minutes. |
| Film No. 203 | Positive film of No. 196 developed at 1½ minutes. |
| Film No. 204 | Duplicate film of No. 196 developed at 1½ minutes. |

Film No. 196 X-ray negative of mesh and stepwedge.

Fog Density = 0.26

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.61 | 0.62 | 0.62 | 0.62 |
| 2 | 0.80 | 0.80 | 0.80 | 0.80 |
| 3 | 0.87 | 0.90 | 0.91 | 0.89 |
| 4 | 1.02 | 1.04 | 1.03 | 1.03 |
| 5 | 1.15 | 1.15 | 1.16 | 1.15 |
| 6 | 1.31 | 1.32 | 1.32 | 1.32 |

The graph line is shown in blue, page 118.

Film No. 198 Duplicate film of No. 196 developed at $4\frac{1}{2}$ minutes.

Fog Density = 0.31

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.55 | 0.54 | 0.52 | 0.54 |
| 2 | 0.75 | 0.72 | 0.74 | 0.74 |
| 3 | 0.85 | 0.86 | 0.84 | 0.85 |
| 4 | 0.99 | 0.98 | 0.99 | 0.99 |
| 5 | 1.09 | 1.11 | 1.13 | 1.11 |
| 6 | 1.28 | 1.31 | 1.28 | 1.29 |

The graph line is shown in red, page 118.

Film No. 200 Duplicate of No. 196 developed at $3\frac{1}{2}$ minutes.

Fog Density = 0.31

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.50 | 0.50 | 0.47 | 0.49 |
| 2 | 0.75 | 0.79 | 0.78 | 0.77 |
| 3 | 1.01 | 1.03 | 1.02 | 1.02 |
| 4 | 1.26 | 1.30 | 1.29 | 1.28 |
| 5 | 1.45 | 1.47 | 1.47 | 1.46 |
| 6 | 1.63 | 1.64 | 1.59 | 1.62 |

The graph line is shown in green, page 118.

EXPERIMENT No: 11E (continued.)

Film No. 202 Duplicate film of No. 196 developed at 2½ minutes.

Fog Density = 0.30

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.68 | 0.68 | 0.69 | 0.68 |
| 2 | 0.99 | 1.01 | 1.00 | 1.00 |
| 3 | 1.17 | 1.24 | 1.23 | 1.21 |
| 4 | 1.44 | 1.42 | 1.44 | 1.43 |
| 5 | 1.65 | 1.62 | 1.66 | 1.64 |
| 6 | 1.84 | 1.84 | 1.83 | 1.84 |

The graph line is shown in brown, page 118.

Film No. 204 Duplicate of film No. 196 developed at 1½ minutes.

Fog Density = 0.29

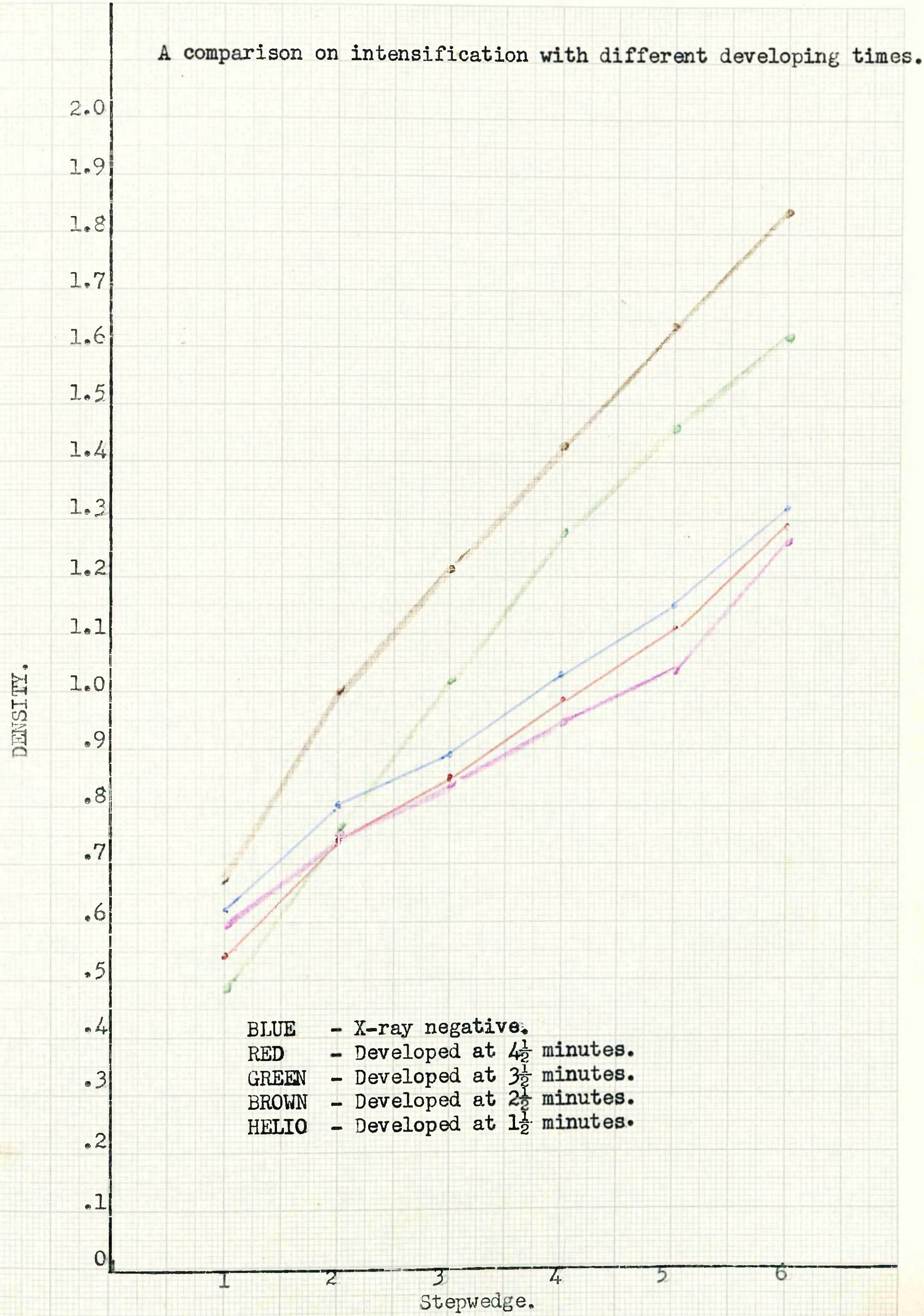
| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.60 | 0.61 | 0.59 | 0.60 |
| 2 | 0.75 | 0.75 | 0.74 | 0.75 |
| 3 | 0.84 | 0.84 | 0.83 | 0.84 |
| 4 | 0.95 | 0.96 | 0.95 | 0.95 |
| 5 | 1.03 | 1.04 | 1.05 | 1.04 |
| 6 | 1.17 | 1.16 | 1.18 | 1.17 |

The graph line is shown in helio, page 118.

The results of the various developing times are shown graphically on page 118, and the conclusions of the investigation on page 119, showing that the best results were obtained by developing the film for 2½ minutes.

EXPERIMENT 11 E.





## CONCLUSIONS TO EXPERIMENT No: 11E.

(Different developing times.)

There was overwhelming evidence that the best results were obtained by developing the film for 2½ minutes, other factors remaining the same. The results obtained from the longest developing time of 4½ minutes and the shortest of 1½ minutes were appreciably inferior in density readings to those obtained from the interim developing times of 3½ and 2½ minutes. The greatest intensification was produced by the developing time of 2½ minutes. This suggested that the previous developing technique should be altered to a developing time of 2½ minutes instead of 3½ minutes.

Further, as a result of Experiment No: 11D (page 111), in which the milliamperage (M.A.) was reduced from 100 to 75 milliamperes (M.A.) and showed an increased intensity at the lower figure, it would appear that the previous standardised technique of 100 M.A., 45 K.V., 1 second, 40" distance, developed for 3½ minutes at 68° F., should now be reduced to 75 M.A., 45 K.V., 1 second, 40" distance, and the developing time reduced to 2½ minutes at 68° F.

To confirm this conclusion, an experiment was made of duplicating an X-ray negative by the original method of 100 M.A., 45 K.V., 1 second, 40" distance, with development at 3½ minutes, and by employing the apparently improved method at 75 M.A., 45 K.V., 1 second, 40" distance, with development at 2½ minutes, in order to compare the densitometer readings in graphic form.

## EXPERIMENT No: 12.

Film Nos: 205 - 206.

This experiment was an investigation to check the evidence of the conclusions of Experiment No: 11E (page 119.)

Film No. 196 This film taken for Experiment No.11E is the X-ray negative of the mesh and stepwedge from which all duplicates are made.

Film No. 205 This film is the positive of No. 196 taken at 75 M.A., 45 K.V., 1 second, 40" distance, and developed for 2½ minutes at 68° F.

Film No. 206 This film is the duplicate of No. 196 taken at 75 M.A., 45 K.V., 1 second, 40" distance, and developed for 2½ minutes at 68° F.

The films are not included within the thesis but are available for inspection in the separate file under their appropriate numbers.

## DENSITOMETER READINGS.

Film No. 196 These readings are taken from Experiment No. 11E (page 116) and shown on the graph in blue (page 121.)

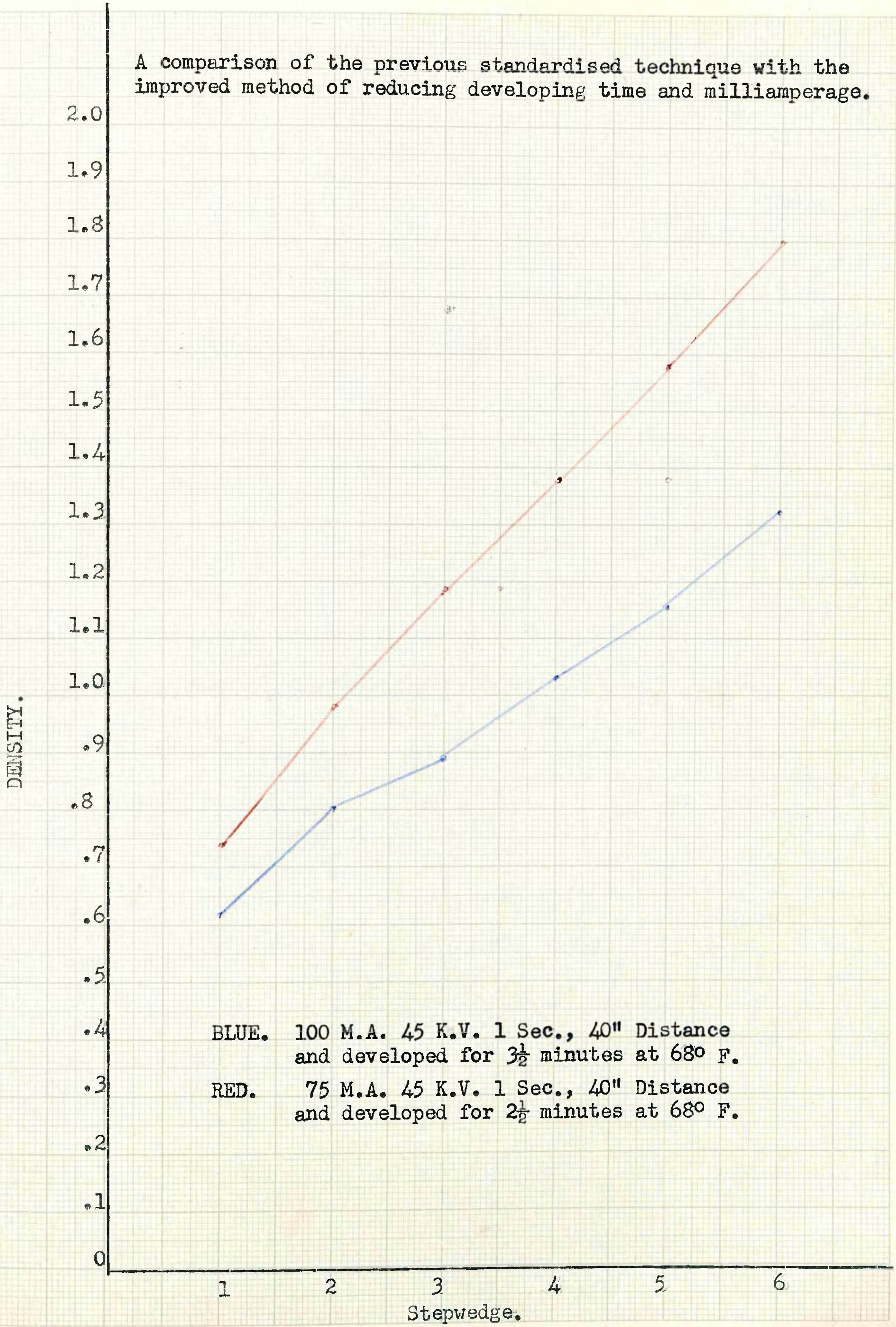
Film No. 206 This film is the duplicate of No. 196 taken at 75 M.A., 45 K.V., 1 second, 40" distance, and developed at 68° F for 2½ minutes.

Fog Density = 0.26

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | .74 | .76 | .72 | .74 |
| 2 | .96 | .98 | .99 | .98 |
| 3 | 1.17 | 1.21 | 1.20 | 1.19 |
| 4 | 1.35 | 1.39 | 1.41 | 1.38 |
| 5 | 1.57 | 1.58 | 1.59 | 1.58 |
| 6 | 1.80 | 1.80 | 1.81 | 1.80 |

The graph line is shown in red, page 121.

EXPERIMENT No: 12.



## CONCLUSIONS OF EXPERIMENT No: 12.

This investigation confirmed that by a reduction of milliamperage from 100 M.A. to 75 M.A., and a reduction in the developing time from $3\frac{1}{2}$ minutes to $2\frac{1}{2}$ minutes, an improved method of radiographic duplication was accomplished.

The objective evidence of increased intensification is shown graphically on page 121. This revised technique, by the reduction of milliamperage and of developing time, gave the best results so far available, and this method will be used in future investigations, with the exception of the following chapter, where the experiments were completed before the discovery of the improved method of duplication. The new standardised technique in radiographic duplication will be:-

| | |
|---|---|
| Milliamperage | 75 |
| Kilovoltage | 45 |
| Exposure | 1 second. |
| Distance | 40 inches. |
| Development | $2\frac{1}{2}$ minutes at 68° F. |

# CHAPTER 11.

## Duplication of X-rays by Direct Light Method and comparison with films obtained by the Radiographic Method.

# CHAPTER 11.

This chapter deals with an investigation to compare the Radiographic Method with the Direct Light Method of duplicating X-ray negatives.

Certain authorities say there is no basic difference in the photographic reaction of silver bromide emulsion when exposed to X-rays or light rays.

Experiment No. 13 was the comparison of the two methods, as the writer considers it of importance that the best method of duplication should be made available.

## EXPERIMENT No: 13.

## DUPLICATION OF X-RAYS BY DIRECT LIGHT METHOD.

During the investigations bearing on the duplication of X-ray negatives, the problem was discussed with Mr. D. Stevenson Clark of Ilford Ltd. He and his staff were most helpful in those discussions and they suggested another method of copying by using ordinary electric light and a 15 watt. bulb in place of X-rays. Although this was contrary to the original conception, it was possible to undertake it entirely in the radiographic department, but it might upset normal routine in many schools. It was decided to try out this photographic duplication and compare the results with those obtained by the radiographic technique.

The photographic technique is as follows:-

The original X-ray negative is held within an ordinary printing frame in contact with a sensitive material which is fine grain single-coated photographic film exactly the same as used in the X-ray technique. The loaded frame is exposed to a 15 watt. bulb at $4\frac{1}{2}$ feet distance; development throughout is in Ilford I.D.19, at $68^{o}$ F. This is a high contrast metol hydroquinone developer for general radiographic work.

EXPERIMENT No: 13. Film Nos: 207 - 211. Envelope M, page 126.

| | | | |
|---|---|---|---|
| Film No. 207 | Original X-ray negative. | | |
| Film No. 208 | Positive | "A" | exposure 15 seconds, development $\frac{1}{2}$ minute agitation. |
| Film No. 209 | Copy | "A" | exposure $\frac{1}{2}$ to 1 second, development 5 minutes agitation. |
| Film No. 210 | Positive | "B" | exposure 30 seconds, development $1\frac{3}{4}$ minutes continuous agitation. |
| Film No. 211 | Copy | "B" | exposure 12 seconds, development $1\frac{3}{4}$ minutes continuous agitation. |

These films are all contained in Envelope M, page 126.

M.

## ENVELOPE M.

DUPLICATION BY CONTACT PRINTING
USING 15 WATT. ELECTRIC BULB.

## NARRATIVE TO ENVELOPE M.

| | | | | |
|---|---|---|---|---|
| X-RAY No. 207 | (M.1.) | X-ray negative of a Lateral Jaw. | | |
| X-RAY No. 208 | (M.2.) | Positive film | "A" | Exposure 15 seconds. Development ½ minute continuous agitation. |
| X-RAY No. 209 | (M.3.) | Duplicate | "A" | Exposure ½-1 second. Development 5 minutes. |
| X-RAY No. 210 | (M.4.) | Positive | "B" | Exposure 30 seconds. Development 1¾ minutes continuous agitation. |
| X-RAY No. 211 | (M.5.) | Duplicate | "B" | Exposure 12 seconds. Development 1¾ minutes continuous agitation. |

## CONCLUSIONS.

The subjective results from the Direct Light method confirmed the fact that there was no basic difference in the photographic reaction of silver bromide emulsions when exposed to light or to X-rays. Such differences as existed were mainly of theoretical interest.

By a variation in exposure and developing times (or "dodging" as it is called,) the results shown in "A" (M.3.) and "B" (M.5.) gave entirely different types of copies. In comparison with the original, "A" appears thin, but although there was less contrast, no details of structure had been lost. The result was obtained by a very short exposure ($\frac{1}{2}$ second) and a long development time (5 minutes) from a positive copy obtained by a fairly long exposure (15 seconds) and a short development ($\frac{1}{2}$ minute.) The result confirmed that it was essential to aim at a well-exposed and well-developed intermediate positive from which to make the duplicate prints, and this could only be done by "dodging" exposure and development in order to reach that critical point which gave the best results from the quality or tonal values of the X-ray negative being duplicated.

Copy "B" (M.5.) appeared more like the original (M.1.) both in contrast and definition and even greater contrast could be obtained by extending the developing time.

Positive "B" (M.4.) was produced by a long exposure (30 seconds) and a short development time ($1\frac{3}{4}$ minutes) while "B" duplicate (M.5.) was obtained with a shorter exposure (12 seconds) and a short development time ($1\frac{3}{4}$ minutes.)

This "dodging" process could also be applied to the radiographic technique although standardisation of exposure and developing is advocated. It is possible that with certain X-ray negatives of low 'tonal value' the "dodging" process could result in a better duplicate. However, in criticism of this method it should be remembered that the amount of exposure has a considerable influence on contrast and again an exposure is influenced by a variety of factors (page 14.) It is of the greatest importance to keep constant as many factors as possible. One of these factors should be the standardisation of the developing conditions. Apart from its convenience standardised development is a valuable guide in assessing the correct exposure. It should also be borne in mind that an over-exposed or under-exposed radiograph cannot result in the contrast which would be obtained by the correct exposure; and incorrect exposure cannot be entirely compensated for by modifying the developing time.

To compare the subjective merits of the two methods, the original X-ray negative which was duplicated by the Direct Light method, was again used and duplicated by the radiographic technique. This investigation is shown in Experiment No: 14, page 130.

## EXPERIMENT No: 14.

Film Nos: 207,212,213, Envelope N, page 131.

The purpose of this experiment was to compare the subjective merits of radiographic duplication with the Direct Light contact printing duplication.

| | |
|---|---|
| Film No. 207 (M.1.) | This is the same X-ray negative as used in previous experiments and contained in Envelope M. |
| Film No. 212 (N.1.) | Positive film using radiographic technique. |
| Film No. 213 (N.2.) | Duplicate film by radiographic technique. |

**Technique.** As in Experiment No. 6 - 100 M.A., 45 K.V., 1 second exposure and 40" distance. Development $3\frac{1}{2}$ minutes at $68^{o}$ F. in Pentelex Developer.

The film Nos. 212 and 213 are contained in Envelope N, page 131, for subjective comparison with Film No. 207 which is contained in Envelope M, page 126.

N.

## ENVELOPE N.

## DUPLICATION BY THE RADIOGRAPHIC TECHNIQUE AS A COMPARISON WITH THE ELECTRIC LIGHT METHOD.

### NARRATIVE TO ENVELOPE N.

| | |
|---|---|
| Film No. 212 (N.1.) | This is a positive taken from film No. 169 and made by the radiographic technique. |
| Film No. 213 (N.2.) | Duplicate of film No. 169 made to compare with the Electric light Method. |

### CONCLUSIONS.

Subjectively the radiographic technique appears to give the best pictorial results showing, as expected, more contrast, but this is not necessarily always an advantage.

To decide what method gave the best results, a stepwedge X-ray negative was copied using the radiographic technique and the Electric Light Method from which densitometer readings were taken and the comparison shown in graph form. This investigation is contained in Experiment No: 15, page 133.

## EXPERIMENT No: 15.

Film Nos: 214 - 215.

This investigation was conducted to compare the results of radiographic duplication with the Direct Light Method and to show objectively in graph form from densitometer readings which method gave the better results.

Film No: 196 This X-ray negative of a mesh and stepwedge was taken as the standard and the densitometer readings from copy No. 202 (page 117) supplied the graph line shown in blue on page 136.

Film No: 196 was then duplicated by the Direct Light Method using the following technique. A contact printing frame held the original No. 196, and against this film was placed a single-sided fine grain photographic film at a distance of 4½ feet. This was exposed to a 15 watt. lamp for 30 seconds and developed in standard X-ray developer for 1¾ minutes with continuous agitation. This gave the positive film No. 214 (0.1.) The duplicate film No. 215 (0.2.) was now obtained through this positive film using the same technique but the exposure reduced to 12 seconds and developed at 1¾ minutes with continuous agitation. The positive and duplicate films, No. 214, 215 (0.1. & 0.2.) are contained in Envelope 0, page 134.

## DENSITOMETER READINGS OF DUPLICATE No: 215.

Fog Density = 0.10

| | | | | Average. |
|---|---|---|---|---|
| Step No. 1 | 0.25 | 0.24 | 0.29 | 0.26 |
| 2 | 0.44 | 0.47 | 0.47 | 0.46 |
| 3 | 0.66 | 0.69 | 0.68 | 0.68 |
| 4 | 0.83 | 0.86 | 0.86 | 0.85 |
| 5 | 1.03 | 1.02 | 1.05 | 1.03 |
| 6 | 1.25 | 1.24 | 1.26 | 1.25 |

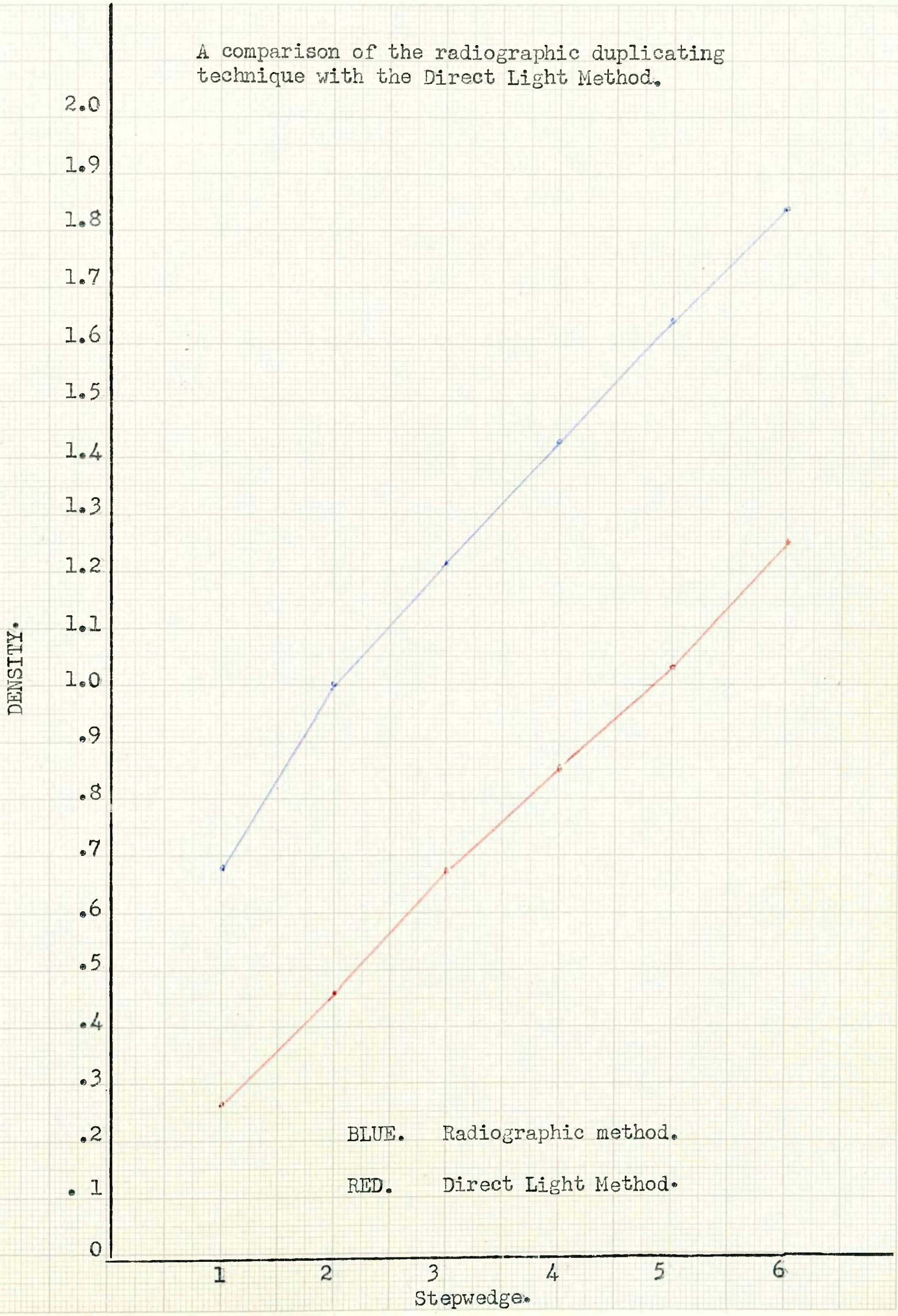
The graph line is shown in red, page 136.

0.

# NARRATIVE OF ENVELOPE O.

This contains the positive film No. 214 (O.1.) and the duplicate film No. 215 (O.2.) of the X-ray negative No. 196 obtained by the Direct Light Method as described on page 133.

The graph of film No. 196 taken from the densitometer readings on page 116 are shown in blue on page 136, and the graph line of the Direct Light Method taken from the readings on page 133 are shown in red.


A comparison of the radiographic duplicating technique with the Direct Light Method.
DENSITY.
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
. 1
0
1
2
3
4
5
6
Stepwedge.
BLUE. Radiographic method.
RED. Direct Light Method.

## CONCLUSIONS OF EXPERIMENT No: 15.

The graphs on page 136 show conclusively that the radiographic method of duplication is superior to the Direct Light Method.

The radiographic method in the investigation followed the original technique of 100 M.A. at 3½ minutes developing time. Consequently, as a result of the altered technique by reducing the milliamperage (M.A.) to 75 and the developing time to 2½ minutes, a further improvement could be shown in the radiographic method as compared with the Direct Light Method.

## CHAPTER 12.

The diagnostic value of duplication tested by copying Carpal Scaphoid fractures.

# CHAPTER 12.



The specific purpose of the original investigation was to copy X-ray negatives and collect a comprehensive series of negatives which would be of value for teaching purposes. This was successfully accomplished and many of the duplicate negatives were visually better than the original X-ray negatives. This apparent subjective improvement was confirmed objectively by the densitometer tests. The duplicate negative was further enhanced in subjective value by superimposing a clear sheet of blue base which reduced the suggestion of extreme contrast and gave a mellowing effect to the whole negative and a background comparable with the original X-ray negative.

X-ray negatives of bone conditions with soft tonal values gave the most successful results in duplication. The added advantage of a positive film, available to augment the radiographic examination, engendered a thought that duplicated X-ray negatives might have a diagnostic value. The field for this investigation would of choice be in bone fractures, because a crack fracture of bone is sometimes so fine that it cannot be distinguished radiographically for some days after the injury. In suspected fractures of the Carpal Scaphoid, the crack may be so minute that even the finest X-ray films do not demonstrate it. If a radiograph fails to show evidence of a fracture which is suspected strongly on clinical grounds, the radiograph should be repeated after two or three weeks, when the inconspicuous crack may become obvious due to traumatic hyperaemic osteoporosis.

However it should be stressed that the absence of radiographic evidence should not be allowed to outweigh a clinical diagnosis of fractured Scaphoid, and when in doubt, the suspected part should be immobilised so that there is no delay in the normal process of healing. Fortunately immobilisation does not interfere with the investigation as widening of the fracture line will appear within two or three weeks as the result of physiological osteoporosis which accompanies the resorption of the bone ends, prior to ossification of the callus at the fracture site.

It was decided to test this possible diagnostic value from duplicated X-ray negatives by a series of investigations. Mr. Barnes, the Consultant in charge of the Unit in Orthopaedics at the Glasgow Western Infirmary, and Mr. P.A. Freeman of his department agreed to assist by sending a series of suspected scaphoid fractures for duplication.

EXPERIMENT No: 16.

Film Nos: 216 - 233.

The first part of the investigation was the duplication of a series of radiographically obvious scaphoid fractures. Varying degrees of fractures were shown, with some radiographically more obvious than others. The improved technique of duplication was used in this series, namely, 75 M.A., 45 K.V., 1 second, 40" distance, and developed at 68° F. for 2½ minutes in Pentelex (M & B) Developer.

As in the previous experiments, comments of each investigation were made with general conclusions on the completion of the whole investigation.

The films were all on loan from Mr. Barnes, the Consultant Orthopaedic Surgeon of the Glasgow Western Infirmary. Therefore all the X-ray negatives may not be available for examination, but an example of the standard of duplication is shown in Envelope P, page 142.

LIST OF CASES DUPLICATED.

| | | | |
|---|---|---|---|
| Film No. 216 | X-ray negative 670/56. | Thomas McKenna. | 9/1/56. |
| Film No. 217 | Positive film. | | |
| Film No. 218 | Duplicate film. | | |
| Film No. 219 | X-ray negative 794/56. | John Davidson. | 6/3/56. |
| Film No. 220 | Positive film. | | |
| Film No. 221 | Duplicate film. (shown in Envelope P.) | | |
| Film No. 222 | X-ray negative 12498/56. | James McGhie. | 21/5/56. |
| Film No. 223 | Positive film. | | |
| Film No. 224 | Duplicate film. | | |
| Film No. 225 | X-ray negative 9604/56. | Alexander Gillan | 21/4/56 |
| Film No. 226 | Positive film. | | |
| Film No. 227 | Duplicate film. | | |
| Film No. 228 | X-ray negative 11130/56. | M. Fleming. | 16/4/56 |
| Film No. 229 | Positive film. | | |
| Film No. 230 | Duplicate film. | | |
| Film No. 231 | X-ray negative 1069/56 | L. Dyson. | 27/3/54. |
| Film No. 232 | Positive film. | | |
| Film No. 233 | Duplicate film. | | |

GENERAL CONCLUSIONS TO EXPERIMENT No: 16.

As all the scaphoid fractures were quite obvious on radiographic examination, the main purpose of this investigation was to see the results of duplication and to observe if the fractures were more obvious in either the positive or negative copies. The series of duplications were subjectively the most successful of all the duplications and it was immediately obvious that original X-ray negatives taken without Intensifying Screens were softer in tonal values and were extremely suitable for the process of duplication. An example is shown in Envelope P, (page 142) and demonstrates that the copies are definitely superior in subjective value and that the fractures are more obvious than in the original negative. The superimposition of a clear blue base background improved the subjective quality of the copy.

The positive copy, as in all previous investigations, retained and enhanced the delicacy of natural bone structure and gave the film an effect of being almost three dimensional. The width of the fracture line was more evident in the positive copy. In normal routine it is not practical to have a positive copy available but certainly in doubtful pathological conditions it may be helpful.

The results of duplication were extremely satisfactory.

## EXPERIMENT No: 17.

Film Nos: 234 - 242.

This part of the investigation dealt with a carpal scaphoid fracture strongly suspected on clinical grounds but with no definite radiographic evidence.

A radiograph of a suspected scaphoid fracture was duplicated in order to compare its diagnostic value with that of the original X-ray negative. The opinion of the Orthopaedic Surgeon was sought on the comparative values of the original film, the positive copy and the negative copy.

Q.

CASE REPORT.

PATIENT - Female. Age 13.

Glasgow Western Infirmary.

X-ray No. 5344/55.

Region Examined - Right Wrist.

Film No. 234 (Q.1.) X-ray negative of right wrist taken on 25.5.54 soon after the accident.

Copy of X-ray Report. Doubtful fracture of the waist of the Scaphoid. The patient should be re-examined in two weeks.

Film No. 235 (Q.2.) Positive film of No. 234.

Film No. 236 (Q.3.) Duplicate negative of No. 234.

The three films are contained in Envelope Q, page 145.

COMMENTS ON POSITIVE FILM AND DUPLICATE NEGATIVE.

The positive and negative copies confirmed the subjective value expressed in the General Conclusions of Experiment No. 16, (page 143.) In the Positive film (Q.2) and in the duplicate negative (Q.3) there were greater definition and contrast of bone structure, and demonstrating more clearly the suspicions of a fracture of the waist of the Scaphoid.

Specialist advice is advisable for this diagnosis.

CASE REPORT (continued.)

Film No. 237 (R.1) As requested in the first X-ray Report, an X-ray negative of the right wrist was taken on 8.6.54, fifteen days after the accident.

Copy of X-ray Report. "Negative."

Film No. 238 (R.2.) Positive film of No. 237.

Film No. 239 (R.3.) Duplicate negative of No. 237.

The three films are contained in Envelope R, page 147.

COMMENTS ON THE POSITIVE FILM AND DUPLICATE NEGATIVE.

As in the first duplicated film of this case the details of bone structure were enhanced. Without expert knowledge of diagnosing Scaphoids, the suspicion of a fracture on the waist of the Scaphoid appeared obvious, and this diagnosis of a fracture was later confirmed.

CASE REPORT (continued.)

Film No. 240 (S.1.) This is an X-ray negative taken on 21.2.55, eight months after the original suspected fracture.

Copy of X-ray Report. There is a doubtful translucent line in the waist of the Scaphoid. It is not certain whether this is due to old or recent fracture.

Film No. 241 (S.2.) Positive copy of No. 240.

Film No. 242 (S.3.) Duplicate negative of No. 240.

The three films are contained in Envelope S, page 149.

COMMENTS ON POSITIVE FILM AND DUPLICATE NEGATIVE.

The healed fracture line is more obvious in the duplicate film due to greater contrast and definition. This is demonstrated by a defect in the normal bone trabeculation.

Western Infirmary,
GLASGOW.
22.2.55.

ORTHOPAEDIC SURGEON'S REPORT ON CASE.

"She attended on 25th May 1954 with a definite fractured waist of scaphoid. She attended until 29th June when the plaster was removed and the patient failed to return.

X-ray now shows that this has healed completely and I am, like yourself, unimpressed by the objective signs. There is no other sign of injury on the X-ray and I think no treatment is desirable."

## GENERAL CONCLUSIONS TO EXPERIMENT No: 17.

The positive film and duplicate negatives of the three radiographs in the series have a subjective clarity in comparison with the original X-ray negative which should aid diagnosis. Although the diagnostic value may not be wholly conclusive, the radiographic evidence of the duplicates was confirmed by the ultimate report on this case as expressed in a copy of the letter of 22.2.55, shown on the opposite page.

# CHAPTER 13.

## Electronic Duplication.

## CHAPTER 13.

This final chapter deals with a revolutionary method of duplicating radiographs by electronic exposure control. Although outwith the original conception of the thesis, it was considered of sufficient importance to warrant inclusion as an entirely new and modern method of duplication.

However, it must be stressed, that the electronic technique does not detract or replace in any way the radiographic method of duplication.

The electronic method is particularly useful as a diagnostic aid owing to the greater detail which is able to be reproduced in the duplicate film. The radiographic technique gives an enhanced "facsimile" of the original; is particularly suitable for teaching purposes, and can be duplicated without the necessity of expensive equipment.

The limitation in diagnostic value of the radiographic duplication had always been realised, and the problem of how to get optimum diagnostic value in duplication had been given much consideration. The requirement to overcome the difficulty was a reproduction in the copy of all the details in every part of the picture regardless of the contrast of the original negative. This need could only be achieved by a process of manual "dodging" which, even if possible, would only be partially effective and, in any case, would be slow in operation, calling for individual attention by skilled operators.

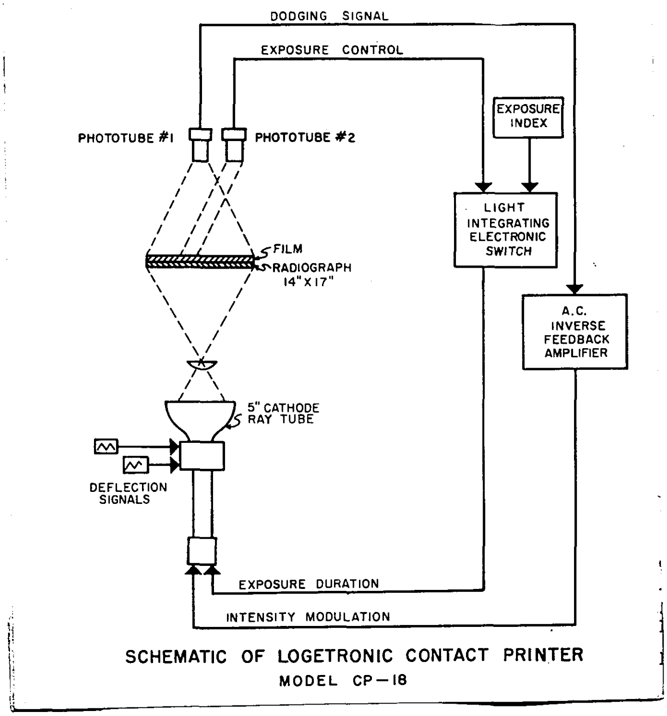



FIG. 6.

Diagram of E.M.I. Log-Etronic Contact Printer.

Diagram taken from "Logetronography", The American Journal of Roentgenology, Radium, Therapy & Nuclear Medicine. Vol. LXXVIII No. 1, July 1957.

The problem was solved by a new method of electronic exposure control; a device which gives automatic control during the printing of the radiographic duplicate.

## DESCRIPTION OF APPARATUS.*

See Diagram 6 - opposite page.

"Automatic 'dodging' and automatic exposure control are accomplished in the E.M.I.-LogEtronic printers by using a scanning light beam from a cathode ray tube as a light printing source. Whenever the exposing spot of light from the cathode ray tube encounters a dense region on the negative it instantaneously becomes brighter. Conversely brightness of the spot is instantaneously reduced for thin regions of the negative, thus producing maximum print detail in both highlights and shadows.

A Light Integrating System terminates all exposures automatically to produce a uniform pre-set print density without adjustment for widely varying negative densities."

* Copied from brochure of E.M.I. Electronics Ltd., November 1957.

## EXPERIMENT No: 18.

Film Nos: 252 - 257.

This investigation consisted of a series of duplications of X-ray negatives by the electronic photographic printer, also known as the E.M.I. Log-Etronic printer. The electronic duplication was done by E.M.I. Electronics Ltd., to whom I am most indebted for their interest and co-operation.

The first three films sent for duplication were skull radiographs of no pathological interest.

Film No. 252 X-ray negative of a lateral skull.

Film No. 253 Electronic duplication.

These films (T.1 & T.2) are contained in Envelope T, page 156 of the 1st copy of the thesis.

Film No. 254 Occipito-frontal X-ray negative.

Film No. 255 Electronic duplication.

These films (T.1. & T.2) are contained in Envelope T, page 156 of the 2nd copy of the thesis.

Film No. 256 Occipito-mental X-ray negative.

Film No. 257 Electronic duplication.

These films are contained in Envelope 47 of the Appendix.

## COMMENTS ON FILM Nos: 252 - 257.

Duplication by the electronic technique gave a relief effect with greater detail standing out from the background. There was no dubiety that details were more clearly shown, and there was evidence of a clarity of bone structure not shown in the original. The greater detail shown should provide the radiologist with diagnostic information not available in a routine radiograph.

T.

## EXPERIMENT No: 19.

Film Nos: 258 - 260.

The final investigation was made to compare the radiographic duplication with the electronic duplication. An X-ray negative of a carpal scaphoid fracture (No. 216) had already been duplicated by the radiographic technique and the three films Nos: 216 (U.1), 217 (U.2) and 218 (U.3) were sent to E.M.I. Electronics Ltd., for electronic duplication. This gave an electronic duplication of an X-ray negative, a positive radiographic film and a radiographic negative duplicate. The electronic duplications are numbered 258 (U.4), 259 (U.5) and 260 (U.6.)

The six films are contained in Envelope U, page 158 of the 1st copy of the thesis only, and were interesting as a comparison between radiographic and electronic duplication.

The relative values were obvious - radiographic duplication was an enhanced "facsimile" copy of the original, and the electronic duplication a relief duplicate with obvious diagnostic value.

As only one set of electronic copies was available, the comparative value of radiographic and electronic duplication cannot be shown in No. 2 copy of the thesis.

## REFERENCES.

W.G.C. (1957) Radiography Vol. XXIII, No. 274, page 288.

Elmer G. St.John, M.D., ) "Logetronography"
) The American Journal of Roentgenology,
Dwin R. Craig, B.S. ) Radium, Therapy & Nuclear Medicine.
Vol. LXXVIII No. 1, July 1957.

E.M.I. Electronics Ltd., "Brochure" - 1957.

Activated by the desire to obtain copies, primarily for teaching purposes, by a simple regulated technique, the experiments outlined in the preceding pages led ultimately to a standardised method for the successful duplication of radiographs.

It has been gratifying that this system of duplication has already added to the teaching potential of Radiology in the Glasgow Dental Hospital.

It is a sincere hope that other schools and other teachers, medical and dental, will derive practical benefit from the results achieved by Radiographical Duplication.