PROCESSING KODAK 'INDUSTREX' FILMS

An X-ray film consists of a transparent flexible support coated on both sides with an emulsion of silver halide (e.g. bromide or iodide) suspended in gelatin, the silver halide being distributed throughout the emulsion as minute crystals. After exposure, the film is processed to produce an image. It is treated first with a *developing solution* which renders the latent image visible, and next with a *fixing solution* which dissolves away the unexposed silver halide. It is then *washed in water* to remove the fixing solution and by-products, and finally dried. Although, in radiography, much depends upon the correct selection of film and the exposure technique applied, high quality radiographs can only be obtained if processing is correctly carried out.

Automatic processing

Exposed X-ray films can be processed automatically in a machine such as the KODAK RP 'X-Omat' Processor, Model M6AW (modified). These machines are of the roller-transport type. Once the film has been placed on to the film feed tray, it is automatically carried through developer, fixer, wash and drying stages, then deposited into a receiving tray, ready for viewing. The main advantages of automatic processing are:

- Large processing capacity with minimum labour
- Rapid access to finished radiographs
- Consistent processing quality

The KODAK RP 'X-Omat' Processor, Model M6AW (modified) has a processing track which accepts films up to a maximum width of 43 cm. The standard dry-to-dry processing time is 8½ minutes and the processing capacity is as shown in Table 1.

Table 1

Size	Films per hour
35 × 43 cm	34
24 × 30 cm	45
18 × 24 cm	90
10 × 40 cm	125

As outlined above, the automatic processor transports films through all stages of processing to the dry stage at a constant speed by a system of rollers. The developer and fixer solutions are automatically replenished and continuously recirculated to promote thorough agitation. Solution and dryer temperatures are controlled within close limits. This combination of correct replenishment, controlled temperature and agitation produces uniform processing quality.

Kodak

Chemicals for automatic processing
Before mixing or using chemicals, read the precautionary advice provided by the supplier.

KODAK RP 'X-Omat' processing chemicals are specially formulated for machine processing. They contain additives to control film hardness — which is essential for satisfactory film transport.

The bulk storage of developer and fixer solutions is achieved by the provision of large volume (114 litre) replenisher tanks which are installed close to the machine or a KODAK Automixer IPD which holds 38 litres each of these processing solutions. Packs of chemical concentrate are diluted with water and mixed directly into the replenisher tanks as required or automatically if an Automixer is used. The solution tanks within the machine are initially filled from the replenisher supply tanks. When the Processor developer tank is filled with replenisher a small quantity of developer *starter* solution is added. This adjusts the activity of the fresh developer replenisher to produce optimum film speed and contrast.

Once film processing commences, automatic developer and fixer replenishment keeps the solution activity constant. Under normal operating conditions, the developer and fixer solutions in the machine need only be changed approximately once every three months.

Fresh batches of replenisher are mixed directly into the supply tanks as and when required — without interrupting the processing operation.

Replenishment
Machine processing requires both developer and fixer solutions to be automatically replenished while films are being processed. The quantity of developer and fixer replenisher required depends upon the average film density and the type and area of film processed.

The replenisher pumps only operate while each film passes between the entry rollers, therefore, *replenishment rates* are quoted in millilitres per minute. Full details of replenishment rates are given in the operating instructions for X-OMAT Processors.

Washing
The water supply to an automatic processor is required in sufficient quantity and at a temperature which will provide efficient film washing. The KODAK RP 'X-Omat' Processor, Model M6AW (modified) requires a water flow of 5 litres per minute at a temperature of 20°C. This is usually provided by means of a thermostatic mixing valve which blends hot and cold water to the required temperature. Correct water temperature and flow will ensure that films are properly washed so that the radiographic image will not deteriorate during its useful life.

Providing the recommended developing, fixing and washing conditions are met, radiographs should achieve a permanence of over 10 years, although much will also depend upon their correct storage (see page 5, "Permanence of the radiographic image").

In certain circumstances, when a lower standard of permanence is acceptable, wash water at a lower temperature than that recommended may be used.

Drying
Films are transported from the wash stage through the dryer section. The wet films are carried past streams of warm air which impinge on each side, thus providing an efficient drying action. The temperature of the drying air depends upon the relative humidity of the surrounding air, but the most even drying is achieved by using the lowest temperature consistent with complete drying.

Manual processing
If the volume of work is very small or if time is of relatively little importance, radiographs may be processed by hand. The most common method of manual processing of industrial radiographs is known as the tank method. In this system, the developer, fixer and wash water are contained in tanks deep enough for the film to be hung vertically. Thus, the processing solutions have free access to both sides of the film and both emulsion surfaces are uniformly processed to the same degree. Usually, a water rinse or acid stop bath tank is placed between developer and fixer stages. The all important factor of temperature can be controlled by regulating the temperature of the water jacket in which the processing tanks are immersed.

After the wash stage, a tank is provided which contains a final rinse solution. This is a wetting agent which conditions the films to promote even drying. Drying is achieved by hanging the films in a dust-free atmosphere or in a special drying cabinet.

Films to be processed are attached to stainless steel hangers then immersed in developer, stop bath, fixer, wash and final rinse solutions for pre-determined intervals.

When tension-type hangers are used, films can be left in them right through the drying stage, but if channel-type hangers are used, films should be transferred to hanger bars and clips to prevent drying marks at the edges of the film.

Even and efficient processing is achieved by agitating the films at intervals while they are in the various solutions. To ensure maximum evenness, films should be agitated both vertically and horizontally.

KODAK Chemicals for manual processing
KODAK Developer and Fixer Chemicals for manual processing are available in both liquid concentrate and powder form. They are added to water and are ready for use after mixing directly in the processing tanks.

The liquid chemicals are convenient to use, being quickly diluted with water. The powder chemicals require dissolving in water, but they are easily stored and transported. Powder chemicals are, therefore, particularly suitable for use in site situations, where the transport of liquid chemicals could be difficult and costly.

KODAK Liquid Processing Chemicals
LX-24 X-ray Developer
FX-40 X-ray Liquid Fixer

KODAK Powder Processing Chemicals
D-19 Developer Powder
UNIFIX Powder (includes a hardener)

KODAK Sundry Chemicals
Indicator Stop Bath
HX-40 X-ray Liquid Hardener (for addition to FX-40 X-ray Liquid Fixer)
'Photo—Flo' 600 Solution

Processing procedure
After attaching the exposed films to the hangers, processing can commence. Films are immersed in the developer and kept there for the correct developing time with intermittent agitation.

Next they are placed in the stop bath, agitated and transferred to the fixer. The films are then fixed, washed and dried. (A summary of the complete manual processing operation is shown in Appendix "A").

It is important that, as far as possible, the temperature of all processing solutions is kept the same. This is normally achieved, in manual processing equipment, by the use of a temperature-controlled water jacket. The developer temperature is most important because, together with the time of development, it affects the film speed and contrast.

Developing time and temperature
The image recorded in the emulsion of KODAK 'Industrex' Films by correct exposure will have received optimum development after the following times: *4 minutes* in KODAK LX-24 X-ray Developer (diluted 1 + 5), *5 minutes* in KODAK D-19 Developer (working strength) at 20°C with intermittent agitation. A small increase in effective film speed can be obtained by extending development to the maximum times shown in Table 2. However, this additional development will also produce a slight increase in granularity.

A temperature below 15°C retards the action of the chemicals and is likely to result in under-development, whereas an excessively high temperature may not only affect the photographic quality by producing fog, but may also cause frilling or soften the emulsion.

If it is not feasible to maintain the solutions at 20°C, change the developing time as indicated in Table 2.

Table 2

Time/Temperature Development of KODAK 'Industrex' Films MX, AX and CX

Temperature of developer °C	KODAK LX-24 X-ray Developer		KODAK D-19 Developer Powder	
	Minutes NORMAL develop-ment	Minutes MAXIMUM develop-ment	Minutes NORMAL develop-ment	Minutes MAXIMUM develop-ment
18	5	10	6	12
19	4½	9	5½	11
20	**4**	**8**	**5**	**10**
21	3½	7	4½	9
22	3¼	6½	4	8
24	2½	5	3½	7

Note that developing times of less than 4 minutes may produce poor uniformity and should be avoided wherever possible. Further, if processing must be done at temperatures around 24°C, the fixer solution should be renewed frequently, the films should be fully fixed to provide maximum hardening and the washing time should be limited to 15 minutes. (See Processing in Tropical Climates.)

Manual developers and replenishment
As a developer is used, its developing power decreases, partly because of the consumption of the developing agent in changing the exposed silver bromide to metallic silver, and also because of the restraining effect of the accumulated reaction products of the development. The extent of this decrease in activity will depend on the number of films processed and their average density. Even when the developer is not used, the activity may decrease slowly because of aerial oxidation of the developing agent.

Some compensation must be made for the decrease in developing power if uniform radiographic results are to be obtained over a period of time. The best way to do this is to use the replenisher system, in which the activity of the solution is not allowed to diminish but is maintained by suitable chemical replenishment.

In this context, replenishment means the addition of a stronger-than-original solution to revive or restore the developer to its approximate original strength. Therefore the replenisher performs the double function of maintaining both the liquid level in the developing tank and the activity of the solution. Merely adding original-strength developer would not produce the desired regenerating effect.

The practical aspects of replenishment
The surface of the developer in the tank should always be kept at the correct height so that the films are fully immersed. However, developer is carried out of the tank on films when transferring them to the stop bath. The quantity carried out will vary according to the size of the films and length of time the hangers are drained back. We can, therefore, use the addition of replenisher to maintain the solution height and, at the same time, restore developer activity. If a standardized draining back time is established e.g., 5 seconds, then adjustments to the degree of replenishment and, therefore, the *stablized* level of developer activity, can be made by varying the dilution of the replenisher concentrate.

Initial adjustments are made to maintain optimum developer activity for the work undertaken. This is determined by visual appraisal or a suitable monitoring procedure. (See Process Control page 6).

It is not practicable to continue replenishment indefinitely. At a certain point the performance of the developer deteriorates due to the effects of aerial oxidation and the build-up of gelatin, sludge and solid impurities. This stage is reached earlier if the process is used infrequently with relatively low film throughput. However, as a guide, the developer should be discarded when a quantity of replenisher, equal to that of the original developer, has been added or after one month, which ever occurs first.

A typical replenished manual process would operate as follows:-

Processing KODAK 'Industrex' Films having an average density of 2.0.

Developer	LX-24 diluted 1 + 5
Replenisher	LX-24 diluted 1 + 3*
Draining back time	5 seconds

*Dilution can be adjusted between 1 + 2 and 1 + 4 to obtain a stable degree of developer activity. The higher the resulting average densities — the stronger dilution of replenisher required. The lower the resulting average densities the weaker dilution of replenisher required.

Stop baths

It is desirable to arrest the action of the developer remaining in a film emulsion, and to neutralize its alkalinity before the film is put into the fixer. This is best done by the use of an acid stop bath between developer and fixer.

KODAK Indicator Stop Bath is recommended with KODAK X-ray Films. 35 ml of the concentrate per litre of bath makes a solution of the proper strength for X-ray films. The stop bath, before use, is yellow in colour and appears practically clear under safelight illumination. When the yellow changes to a purplish blue, which appears dark under the safelight, the bath is exhausted and should be discarded.

Alternatively, a suitable stop bath can be made up to the Kodak Stop Bath SB-1a formula. This will provide a 3.5% (approx.) solution of acetic acid and is made as follows:-

To make 1 litre of working solution:
Take 750 ml of water
Add 44 ml of acetic acid (80%)*
Then add water to make up to 1 litre

*ACETIC ACID (25-80%): CORROSIVE — Causes burns. Do not breathe vapour.
Avoid contact with skin and eyes. In case of contact with skin or eyes, rinse immediately with plenty of water.

When development is complete, the films should be removed from the developer, allowed to drain for 5 seconds, then immersed in the stop bath. Films should be immersed in the stop bath for 30 to 60 seconds (ideally at 18 to 21°C) with moderate agitation, then transferred to the fixing bath.

Fixing

The purpose of fixing is to remove all the undeveloped silver salts of the emulsion, leaving the developed silver as a permanent image.

KODAK Fixers suitable for this purpose are:
FX-40 — a rapid liquid fixer, and
'Unifix' Powder

A *hardener* is normally used in fixers to harden the gelatin of the emulsion to prevent softening in the wash water or when drying with heat. It also speeds up drying and renders the final radiograph more resistant to damage.

KODAK 'Unifix' Powder includes a hardener but KODAK FX-40 X-ray Liquid Fixer requires the addition of HX-40 X-ray Liquid Hardener, which is available separately.

Correct fixing

Films should be allowed to remain in the fixer for twice the time that it takes to clear the film of all milkiness. The time is also affected by the temperature of the fixer. The efficiency of fixing falls off rapidly at temperatures below 15°C, and fixers should be used within the range 18 to 24°C.

Replenishment of fixers

In manual processing, fixers can be replenished to a limited extent by the addition of small quantities of fresh fixer, but fixers are normally used by extending the time that films are immersed, to the point when the clearing time is twice that when the fixer was fresh.

It is then replaced with a fresh bath. The total fixing time for KODAK 'Industrex' Films in *fresh* fixers at 20°C is as follows:

In KODAK FX-40 X-ray Liquid Fixer — 3 minutes
In KODAK 'Unifix' Powder — 5 minutes

For the best results and the most efficient fixing, use two successive fixing baths. Clear the film of all milkiness in the first bath, noting the time taken, then drain back for 10 seconds. Fix in the second bath for the same time that was needed in the first and, again, drain back for 10 seconds before transferring to the wash. When the first bath becomes so exhausted that the clearing time has doubled, discard it, move the second fixer into first place and make up a fresh second fixer. After this procedure has been repeated four times, i.e., when five sets of first and second baths have been used to their capacity, discard both baths and re-start with a fresh pair.

Washing

After fixing, films must be washed in water to remove fixer chemicals and solubilized silver salts. If this is not done, the image will become discoloured and fade.

Correct washing will ensure that radiographs can be satisfactorily stored as a lasting record for most commercial purposes. However, prolonged washing, particularly in water which is too warm, can cause the gelatin in the film emulsion to soften. This can be avoided by keeping within the times and temperatures recommended below and by ensuring that the fixer solution contains hardener.

Efficient washing depends upon the following conditions:

1) Sufficient *water flow* to carry the fixer away rapidly.
2) *Time* to allow the fixer to diffuse from the film.
3) Correct *water temperature.*

When processing manually, *films should be washed for 10 to 30 minutes* at a flow rate sufficient to renew the wash tank *four times every hour.* The water temperature should be within the range 15° to 24°C. At temperatures over 24°C the wash times should be shortened to 10 to 15 minutes and the fixing time increased up to 10 minutes, to ensure adequate hardening. **Give this treatment if roller-type dryers are being used.**

Drying

After washing, films must be dried before they can be viewed and stored for future reference. It is essential that films are dried correctly so that radiographs will be free from any visible marks which may interfere with interpretation.

Some factors which affect drying efficiency are:

1) Even wetness at the start of drying.
2) Ambient humidity in the work room.
3) The moisture content (humidity) of the air used for drying.
4) The rate of change of air at the film surface.
5) Cleanliness of the air used for drying.

Films in tension-type hangers, where the film is held at the corners only, can remain in these hangers for drying.

Films in channel-type hangers should be removed and attached to bars and clips to prevent sticking in the channels and uneven wetness around the edges of the film.

To ensure even wetness before drying, the films should be immersed for 30 to 60 seconds in a wetting agent such as KODAK 'Photo-Flo' 600 Solution, then allowed to drain for 1 or 2 minutes before placing them in a drying cabinet.

Drying cabinets are commercially available in which a fan draws air from the surrounding area through a filter. The air is then dried with a heater element and circulated over the films. The air carrying the moisture from the films is then passed out into the surrounding area. In average conditions, these cabinets will dry films in 20 to 30 minutes. Most cabinets have thermostatic air temperature control but where an adjustable temperature control is fitted, to obtain optimum evenness, use the lowest temperature which will dry films in the available time.

N.B. A too rapid drying rate, caused by excessively high temperatures, may result in drying marks. When combined with vibration of the drying cabinet under these conditions, density variations can occur along the boundaries between wet and dry areas of the film surface.

Processing in tropical climates

X-ray processing techniques used for normal temperatures may, with KODAK Materials and formulae, be used with safety at temperatures up to 24°C. The recommendations outlined below, however, are intended as a guide to the techniques found, by practical tests in the laboratory and in the tropics, to be most suitable for the temperature range 24°-32°C.

Under such conditions, it is still possible to obtain results of the highest quality, provided the developing time is adjusted to give the correct degree of development and methods are adopted for minimizing the degree of swelling and softening of the emulsion on the film. This can best be achieved by the addition of a fairly high concentration of a neutral chemical (such as sodium sulphate) to the developer. At the same time, a reduction in the time for which the film is subjected to washing is advantageous for preventing undue swelling.

The various solutions and the times for which they should be used are given below.

These recommendations should only be used when it is impracticable to cool the solutions and to maintain them at a more normal level of temperature.

Processing in the temperature range 24° to 32°C

For these higher temperatures, sodium sulphate should be added to KODAK D-19 Developer, in the proportions shown in Table 3. The developer solution should be stirred continuously while the sodium sulphate is being added and until it is completely dissolved.

Table 3

Range of temperatures	Quantity of sodium sulphate (anhydrous)* per litre
24° to 27°C	50 grams
27° to 29°C	75 grams
29° to 32°C	100 grams

* If crystalline sodium sulphate (decahydrate) is used in place of anhydrous, multiply the weights given by 2¼.

The required developing time in the unsulphated developer being known for a temperature of 20°C, the times required for sulphated D-19 Developer at temperatures of 24°-32°C may be found in the body of Table 4 below.

Table 4

Developing time (minutes) in non-sulphated D-19	Calculated developing time (minutes) in sulphated D-19			
at 20°C	24°C	27°C	29°C	32°C
5	6	4½	3	2¼
7	8½	6½	4¼	3¼
8	9½	7	4¾	3½
10	12	9	6	4½

Hardening stop bath

The use of a hardening stop bath, made up according to KODAK formula SB-4 below, is recommended between developing and fixing, particularly in the range 24°-32°C. The films should be immersed for 3 minutes; for the first 30 to 45 seconds, they should be agitated vigorously, otherwise streakiness may result. After the equivalent of fifty 35 x 43 cm films per 25 litres have been treated, the bath should be replaced, otherwise scum markings will result.

If excess swelling is noticed, the stop bath may be prepared in more concentrated form by using only 75 per cent of the quantity of water stated in the formula.

Kodak formula SB-4. Tropical hardening stop bath

500 ml	Water
30 grams	Potassium chrome alum*
60 grams	Sodium Sulphate (anhydrous)
Water, to make 1 litre	

*POTASSIUM CHROME ALUM: HARMFUL.
Harmful if swallowed. Avoid contact with eyes and skin.

Fixing and washing

The following KODAK Fixers are recommended — FX-40 X-ray Liquid Fixer with HX-40 X-ray Liquid Hardener and 'Unifix' Powder. At temperatures in the range 24° to 32°C, all types of film should be fixed for not less than 10 minutes, and washed for 10 to 15 minutes at a flow rate sufficient to renew the wash tank four times every hour.

Permanence of the radiographic image

Fixing chemicals not adequately removed from films by washing will, over a period of time, cause discoloration of the film and fading of the developed image. When it is known that films must be preserved indefinitely or when there is doubt as to the adequacy of the washing procedures, the amount of fixing chemicals remaining in the film after washing should be determined. This can be done in one of two ways depending on the object in view.

Washing for long-term storage

Films of archival interest should remain unchanged for long periods of time under good storage conditions.* Washing for this indefinite preservation of films is defined by British and International Standards in terms of the concentration of residual thiosulphate in the film. Acceptable methods for measurement are described in ISO 417-1977 and BS 5706: 1979 "Methods for the determination of thiosulphate and other residual chemicals in processed photographic films, plates and papers: methylene blue photometric method and silver sulphide densitometric method". The methylene blue method described in these documents measures directly the concentration of thiosulphate ion. The silver sulphide densitometric method measures thiosulphate (as well as other residual chemicals) and requires that a calibration curve be used relating the silver density produced to the thiosulphate content as measured by the methylene blue method.

For test films or any other films intended for archival keeping, the method for determining residual thiosulphate should be chosen from those covered in the standards mentioned above.

Note that while KODAK Hypo Estimator and KODAK formula HT-2 hypo test solution (the HT-2 test) provide a quick, convenient means for estimating the amount of hypo (thiosulphate ion) retained in the emulsion, they cannot be used to determine the concentration of residual thiosulphate in terms of the archival washing standards referred to in the International Standards.

The methylene blue method measures *only* thiosulphate. The technique is complex, and the sample must be tested within two weeks of processing. The silver densitometric method measures thiosulphate and other residual chemicals. The technique is simpler and the results are not affected as much by the length of time between processing and testing. Like the HT-2 test, the silver densitometric method lacks sensitivity at low levels of thiosulphate. It is not sensitive enough to measure thiosulphate reliably below about 0.7 $\mu g/cm^2$. The two procedures for methylene blue method described in the standards cover the range of 0.1 to 45 $\mu g/cm^2$ of the test sample. This is the only method considered sufficiently reliable for determining such a low concentration as 0.7 $\mu g/cm^2$ of thiosulphate ion. If the film is double coated, the residual thiosulphate ion is assumed to be divided equally between the two sides. Therefore, the concentration per square centimetre of emulsion is one half of the total determined by either variant of the methylene blue method. The maximum permissible concentration of residual thiosulphate ion for coarse-grain films, such as industrial X-ray films, is 4 $\mu g/cm^2$ of thiosulphate ion for a double-coated film.

* ISO 5466 "Practice for the storage of processed safety photographic film".

Both British Standards (BSI) and International Standards (ISO) are obtainable from: British Standards Institute, Linford Wood, Milton Keynes, Bucks. MK14 6LE.

Commercial washing

Films intended for ordinary commercial use should show no image change for several years under normal storage conditions. Adequate washing reduces the residual fixer content of a processed film to an acceptable level.

The KODAK Hypo Estimator used with Kodak hypo test solution HT-2 provides a simple, convenient method for measuring washing efficiency and can be used for cursory estimates of the keeping quality of films. It is especially useful for comparing variations within a test or for comparing several films in the same process. It has the additional advantages of being fast and easy to do.

Kodak formula HT-2 hypo test solution

Water	750 ml
* Acetic Acid (80% solution)	44 ml
Silver Nitrate	7.5 grams
Water to make	1.0 litre

* ACETIC ACID (25-80%): CORROSIVE — Causes burns.
Do not breathe vapour.
Avoid contact with skin and eyes. In case of contact with skin or eyes, rinse immediately with plenty of water.

Store the solution in a screw-cap or glass-stoppered brown bottle away from strong light. Avoid contact of test solution with the hands, clothing, negatives, prints or undeveloped photographic materials; otherwise, black stains will ultimately result.

The KODAK Hypo Estimator J-11 consists of four colour patches reproduced on a strip of transparent plastic. It is used in conjunction with Kodak formula HT-2. For use in the test, an unexposed piece of film of the same type is processed with the radiographs whose fixer content is to be determined. After the test film is dried, one drop of the Kodak formula HT-2 solution is placed on it and allowed to stand for two minutes. The excess test solution is then blotted off, and the stain on the film compared with the colour patches of the KODAK Hypo Estimator. The comparison should be made on a conventional X-ray illuminator. Direct sunlight should be avoided since it will cause the spot to darken rapidly.

For commercial use, the test spot should be no darker than two thicknesses of Patch 4 of the Hypo Estimator. Two thicknesses can be obtained by folding the estimator along the centre of the patch.

Storage conditions

Radiographs are best stored in conditions where relative humidity is between 30 and 50% and the temperature does not exceed 20°C. However, processing for long-term storage should always be the rule whenever it is known that relative humidity and temperatures are likely to be constantly excessive, as is the case in tropical, and subtropical areas.

Process control

Variations in the complete radiographic process can be due to many factors including X-ray generating equipment and film processing. In this section, a method of controlling film processing will be described. However, the wider subject of controlling the complete process of both exposure and film processing is covered in "Radiography in Modern Industry".

For most radiographic applications, adherence to the procedures outlined in this information sheet — regarding both manual and automatic processing — will produce adequate radiographic uniformity.

However, it may be desirable to record and measure the performance of a process so that it can be controlled within known limits. This can be done by:

(a) measuring the effect that the processing solutions have on the film in terms of speed, contrast and fog.
(b) recording the results.
(c) setting limits.
(d) interpreting the results and taking corrective action.

The procedure

Before starting process control, it must be confirmed that the process is already normal and producing satisfactory film quality. Process control can then start.

First a sheet of film is exposed then cut into a number of strips. These control strips are processed at pre-determined intervals. As each strip is processed, it is assessed, either visually or with a densitometer.

Visual assessment is achieved by comparing the densities of successive strips with that of the first strip. It relies upon the ability of the eye to detect density differences and can provide a reasonable degree of control. However, the use of a densitometer will provide more accurate and positive process control. When a densitometer is used, the densities are recorded and plotted on a chart. This shows whether the degree of development is constant or changing. Upper and lower limits are marked on the chart to provide controls against which the plot can be monitored. The results are interpreted and corrective action taken if necessary.

Variables in the process control procedure

There are a number of variables which should be considered if accurate results are to be obtained:

a) *Uneven exposure*

The control strips are made by exposing a sheet of film with X-rays then cutting the film into strips. When the film is positioned centrally beneath the X-ray tube, the outer extremities of the film will be further away from the source of X-rays than the centre, thus causing a variation of exposure at the edges compared with the centre. It follows that this exposure variation can be minimized by keeping the f.f.d. as long as possible.

b) *Latent image fading*

There will be a difference between the density of the first control strip processed and strips exposed at the same time but processed at later intervals. The density achieved will gradually become less as the interval between exposure and processing increases. This effect is known as latent image fading and is most severe if either high energy radiation or blue light is used for the exposure. It is minimized by using a direct exposure to X-rays generated at approximately 80 kV.

Latent image fading can also be reduced by keeping the exposed film at a low temperature — i.e. lower than 5°C. The effects of fading are further minimized by keeping the exposed set of strips for a pre-determined time, before starting to use them.

c) *Repeatability of exposure*

There will be a variation in the film density achieved between one set of strips and another, owing to minor fluctuations in the output of the X-ray equipment. By processing one strip from each set together, this variation can be taken into account when the strips are plotted on the chart.

d) *Developer temperature*

Any change in developer temperature will affect the degree of development and thus the film density (i.e. film speed). Therefore, the temperature should be checked and adjusted if necessary before processing a control strip.

Technique

In process control we wish to monitor the degree of development applied to films during processing. Changes in the degree of development can affect the speed, contrast and fog density of films and we wish to keep these development changes within known limits so that optimum radiographic quality can be maintained.

Within the recommended development range of a film, a change of speed does not substantially alter the average gradient (film contrast) or fog. It therefore follows that, provided fluctuations in the degree of development are within the recommended development range, then a measurement of *speed,* i.e. density, only is sufficient for control purposes.

Process control film strips are, therefore, made by exposing them to a density of 2.0, or a density which represents the optimum level required for the work being done. At the same time, it is a simple matter to shield part of the strips from exposure, so that an area of each strip can be used to measure fog and base density.

Exposing the strips

Load a sheet of X-ray film, of a grade normally in use, into a cassette and place it face up on the exposure table (See Figure 1). Use a sheet of 5 mm lead, large enough to cover the cassette completely. Place the lead across the cassette to mask a part of the film during exposure. The lead thickness should be sufficient to shield the film so that the shielded film density is not significantly greater than that obtained from a processed and totally unexposed piece of film, i.e. fog plus base density.

N.B. The f.f.d. should be as long as possible to ensure even coverage of the film so that there is no significant exposure variation over the film area.

Exposure at **80 kV.** The exposure time should be sufficient to produce the required control density. If necessary, a preliminary test, to determine the correct exposure, can be made by making a series of stepped exposures, as follows:

Mark lines across the front of the cassette to give approximately ten equal steps. Cover up the first step with the lead sheet and expose for ten seconds, then cover up the next step and expose for four seconds and so on through the sequence 10, 4, 6, 8, 12, 16, 24, 32 and 48 seconds. Accumulatively, this will produce a series of exposures as follows: NIL, 10, 14, 20, 28, 40, 56, 80, 112 and 160 seconds. Then, after processing, use a densitometer to select the exposure giving the required density. Note the exposure conditions for future reference.

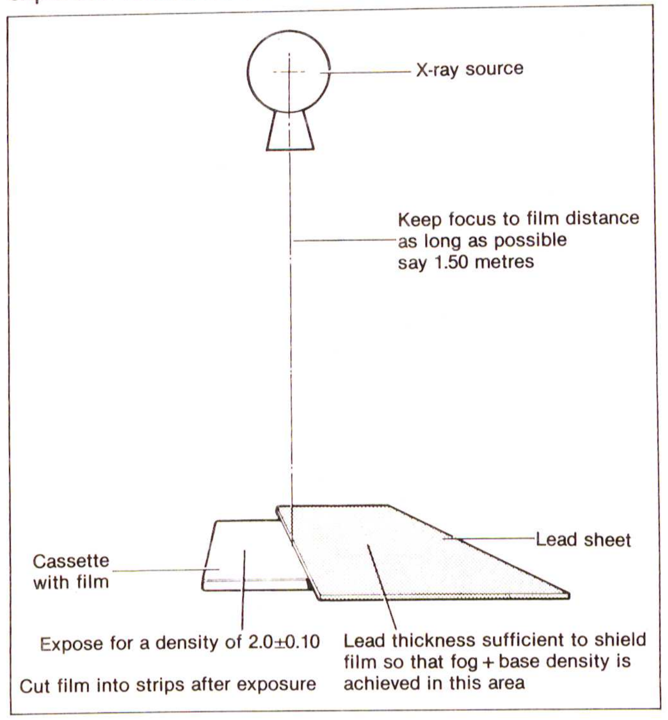

Figure 1

Preparing the strips for use

After exposing the sheet of film, remove it from the cassette in the darkroom, cut it into a convenient number of strips across the film so that each strip has an exposed area and an unexposed area. Place the set of strips in a light-proof envelope ready for use.

The way the strips are kept and subsequent sets exposed will depend upon the frequency and time scale over which the strips are used. For most purposes, it is sufficient to process one strip every day, in which case one set can be exposed once a week.

To reduce the effects of latent image fading, in this case, the set of strips can be kept for a week before use. It may be necessary to process a complete set of strips during the course of every day, in which case each set can be exposed at the beginning of the day on which they will be used. Alternatively, five sets can be exposed once a week.

As mentioned earlier, the effects of latent image fading can be minimized by keeping the exposed strips in a refrigerator at a temperature less than 5°C. To prevent condensation, place the exposed control strips in an air-tight container before storage in a refrigerator. After removing the container, always allow time for the films to reach room temperature before opening to avoid condensation on the film.

Processing the control strips

Before starting process control, make sure that the process is in good condition.

If automatic processing is being used, check that replenishment rates and temperatures are adjusted as recommended in the instruction manual.

With manual processing, use a suitable film hanger and process the film with the exposed area at the lower end. Check the developer temperature and record it immediately before processing the strip.

Automatic processors, such as the KODAK RP 'X-Omat' Processor, Model M6AW (modified) have the developer automatically maintained at a pre-set temperature within very close limits and it is only necessary to check the temperature gauge and that the solution temperature pilot lights are functioning normally, before processing a control strip. Developer temperature should be checked with a thermometer once a week as part of the weekly maintenance routine. Always precede the control strip with a cleaning film. Control strips less than 70 mm wide and less than 120 mm long should be taped to a leader.

Recording the results

We have seen, from the section "Technique" on page 7 that we can detect changes in the degree of development by measuring variations in density. Therefore, to record the results, use a densitometer to read the control density and fog density areas of the strips and plot them on a chart (See Figure 2).

Process density aim

From the control density readings, establish a process density aim by taking an average of the first five strips of the first set and record this on the chart.

Control limits

Having established a process density aim which represents a steady degree of development for the process, it is now necessary to fix higher and lower limits. The positions of the limits will depend upon the amount of variation in developer activity that can be allowed, from the radiographic point of view, but they should not be placed to allow variations in developer activity which would be outside the recommended development range of the films in use. For most applications a satisfactory degree of control can be achieved by positioning the limits plus and minus 0.15 of a control density aim between 1.50 and 2.50.

The fog plus base density of most films should not be above 0.30. A significant increase in fog density would usually be accompanied by a large increase in the high density reading and indicate gross over-development, unsafe safelamps or some other irregularity. A limit of 0.30 on the chart will provide an adequate reference point.

Changing to a new set of strips

When the last strip of the set is processed, process with it the first strip of the new set of strips. Plot the two readings on the chart and join them with a line. This will indicate any range of density due to a variation of exposure between the first and second set. Re-establish the control density aim parallel to this line and fix new control points. This will provide the aim and control limits for the second set of strips. Repeat this procedure for each new set of strips.

This method of recording the results can be adapted to suit any individual requirement, providing the following points are considered.

1) A period of process control should run throughout the working life of each "mix" of developer.
2) The Control Density Aim should be based on average densities achieved over a number of strips processed from the first set.

Interpreting the results

Providing the plotted control strip densities keep within the upper and lower control limits illustrated, the process will have sufficient stability for most industrial radiographic applications. Changes in the degree of development within these process control limits will not adversely affect radiographic quality in terms of contrast or fog density. If the process moves outside the limits, start by checking the most likely factors such as developer temperature and replenishment rates. Should these be normal, and the trend continues, check for contamination of the developer. Very small amounts of fixer can seriously affect developer activity. If contamination is suspected, change the chemistry.

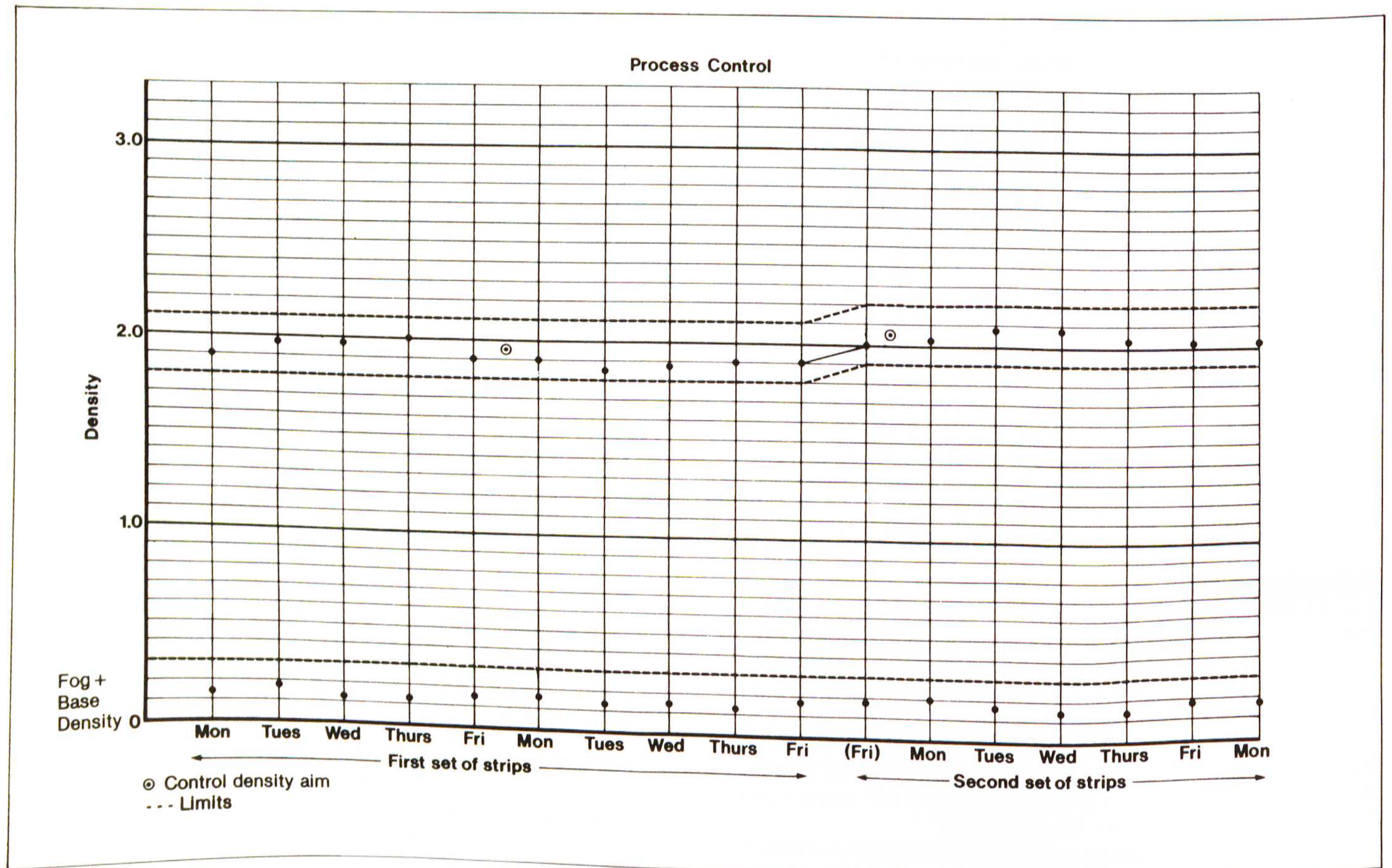

Figure 2

The radiographic workroom

Introduction

The following is intended to be a guide for those wishing to install radiographic darkroom facilities, to help them assess their needs in terms of equipment, layout and space.

Proper planning is essential. The efficient operation of the unit and the quality of work itself can be greatly affected by decisions taken during the planning stages.

When a workroom is being planned, the design will largely depend on three factors:

The volume of work anticipated

The possibility of future expansion

The amount of capital available.

There are certain basic principles which should be observed to ensure ease of working and the best radiographic quality:

☐ Darkrooms must be completely light-proof.

☐ The area must be provided with adequate ventilation and heating for healthy and comfortable working conditions.

☐ Hot and cold running water with adequate drainage must be available.

☐ There must be an adequate electricity supply.

☐ Equipment should be arranged to allow work to proceed in logical sequence. Easy access to plumbing and other services will allow maintenance to be undertaken without moving fixed equipment.

☐ It should be possible to enter and leave darkrooms without interrupting work or admitting white light.

☐ Overhead pipes, air ducting or other services across the ceiling should be avoided; they can act as dust traps and may prevent even illumination of the room. If overhead services cannot be avoided, then a false ceiling may be justified.

☐ Wherever possible, "wet" operations such as manual processing, sinks and chemical mixing should be separated from the dry operations to avoid contamination of X-ray films. The dry area includes benches where films are loaded, unloaded, and attached to hangers or fed into an automatic processor.

Administration and radiograph interpretation area

Work flow can be improved by excluding from the darkroom all operations which do not require safelight illumination, using another room or adjoining area for such operations.

Floors

Concentrated photographic chemicals can attack the fabric of the building, so it is essential that darkroom floors be covered with a material resistant to chemical action. Vinyl sheeting with welded joints can be used, but all spillage must be removed from the floor as quickly as possible to prevent discoloration or personnel slipping problems. There are also proprietary homogeneous epoxy resin floors on the market. The suitability of these floors, or any other type, in photographic workrooms should be checked with the manufacturers before deciding on their use.

Walls and ceilings

The walls or partitioning should be smooth and finished with a hard gloss or eggshell paint in any light pastel shade, or clad with pre-finished panels. Dark colours should be avoided if the full benefit of the safelight is to be gained.

All surfaces, especially ceilings, should be carefully prepared before decorating, to avoid flaking with consequent contamination of processing solutions.

Heating and ventilation

The heating system should be capable of maintaining a temperature of 18°—21°C in all workrooms. The ventilation system in the darkroom should allow for at least 12-15 air changes per hour and maintain a positive pressure. If a simple ducted system is used which introduces fresh air into the various rooms, provision should be made for regulating the supply, and it would be worthwhile incorporating a filter which could be removed for cleaning purposes.

One point to bear in mind is that no amount of ventilation, however efficient, can bring down the temperature of the room below the ambient (outside) temperature. However, small self-contained air conditioning units are commercially available which cool the incoming air and so provide a comfortable working temperature in the darkroom during hot weather. Provision may also need to be made to extract warm air from the processor dryer; advice should be obtained from the equipment manufacturer.

Water services

A good hot and cold water supply is essential. The taps should be brought out approximately 230-300 mm from the wall and 300 mm above the top of the sink. All taps should be fitted with hose unions. For efficient washing, it is advisable to have at least 8 m head of water.

Water requirements and pressure for automatic processors may exceed those for hand processing. Refer to the specification for the equipment concerned.

Unless the water supply is known to be free of suspended particles, suitable filtration should be installed to ensure clean radiographs. The filters should be capable of retaining particles measuring 10—20 microns and larger.

Sinks and benches

Sinks can be made of rigid PVC reinforced externally with fibreglass, or timber lined with sheet PVC or lead with the joints welded, or of stainless steel to ISO 683/XIII. Whichever material is used, sinks are not generally a stock item but are tailor-made for individual requirements. A 450 mm Melamine laminate or PVC splash-back should be fitted behind the sink to protect the walls. A shelf 200 mm wide fitted at the top of the splash-back is useful.

Where staff are required to work in a standing position, benches should be 0.9 m high, the tops being made of block board covered with Melamine laminate. Drawers and cupboards can be arranged beneath the bench tops, as required, for the storage of sensitized materials, cassettes, screens, etc.

Wastes

The nature of the chemicals carried into the drain requires that the waste line be constructed of corrosion-resistant material. In addition, the pipes should be able to withstand rapid changes in water temperature without cracking.

Generally, Vulcathene or PVC pipes should be used. Copper must *not* be used for waste pipes in any circumstances. The waste line must be able to accommodate the maximum flow of water from the sink and processing equipment, and should be at least 40 mm in diameter. The flow through the waste line is determined not only by its size but also by the fall of the pipe.

There is always the possibility of blockage, and enough cleaning points should be provided to enable the drainage system to be cleared of blockages wherever they might occur.

Waste disposal regulations

Although photographic processing wastes are by no means the most noxious of industrial effluents, their discharge from a commercial undertaking, as for all chemical effluents, requires the consent of the appropriate local water authority. Moreover, if it is necessary to dispose of any photographic wastes other than as trade effluent, local authority notification may be required under the Control of Pollution Act 1974.

Silver recovery
Silver recovery from used processing solutions, principally fixer, can be profitable, also important is the fact that it helps to conserve one of the world's natural resources.

Lighting and electrical
For comfortable working, the safelighting in a workroom should be as bright as is consistent with safety of the materials being handled. Always check the safelight filter recommendations given in the relevant product information sheets so that the right type is chosen, and used, correctly.

General safelighting is necessary in the workroom, the KODAK Universal Safelamp, Model 2 being ideal for this purpose. In addition, direct safelighting is normally used in areas where work is concentrated, such as the loading bench, the processing unit or the sink. This direct safelighting is best provided by the KODAK Beehive Safelamp, which can be wall-mounted or suspended from the ceiling.

In addition, a suitable white light must be provided for the room. To avoid the accidental switching-on of the white light, the switch should be positioned 2 m above floor level. Switched 13 A socket outlets should be mounted on the wall above the benches.

All electrical wiring must conform to the current edition of the I.E.E. regulations and the final approval of the local electricity board must be obtained before connection is made to the electricity supply. This applies not only to new darkrooms, but also to existing premises in which new equipment is to be installed.

Chemical mixing area
A chemical mixing area should be adjacent to the darkrooms but preferably separate from the area where sensitized materials are handled. The ventilation system should be designed to avoid transfer of air flow from the mixing room to the rest of the department, 12 to 15 air changes per hour are recommended for general room ventilation. Depending on the room layout, supplementary local exhaust ventilation may be required at the chemical mixing point.

Access to the darkroom
It should be possible to enter and leave the darkroom without admitting white light. The most convenient system, if space permits, is a labyrinth type light lock, the walls of which are painted matt black with a white line about 80 mm wide painted around the inside at eye level to assist entry and exit. The entrance should not face any source of bright light. Where space is restricted, a vestibule with double doors or curtains can be used, or alternatively, a proprietary automatic door trap.

Bulky equipment may sometimes have to be moved in and out of the darkroom, so it is an advantage to provide doors or removable panels in the walls which are wide enough for such items. An emergency exit may also be required by law.

The information given here is not exhaustive and deals only with the basic principles and requirements for efficient workrooms. The layout of every work area will be different — according to work requirements and available space. Invariably, the workrooms will be adaptations of existing buildings adjoining other areas and only very occasionally will they be tailor-made with few restraints on space.

The Design Services Department of Kodak Limited offers customers a complete laboratory planning and consultative service to meet specific needs large or small. Details of this service can be obtained by contacting the area Kodak Technical Sales Representative, the nearest Kodak Sales Centre or the appropriate Sales Division at Kodak Limited, P.O. Box 66, Hemel Hempstead, Herts. HP1 1JU.

APPENDIX A

SUMMARY OF MANUAL PROCESSING

Preparation

Develop
LX-24 *or* D-19
4 minutes | 5 minutes

Stop
½ to 1 minute

Fix
FX-40 + HX-40, 3 to 6 minutes *or* UNIFIX Powder, 5 to 10 minutes

Wash
10 to 30 minutes

Final Rinse
½ minute

Dry

1. Stir developer and fixer solutions to equalize their temperature. Use separate paddle for each tank to avoid possible contamination.
2. Check temperature of solutions with accurate thermometer and adjust to 20°C.

Steps 3-9 must be carried out under safelight conditions.

3. Load film on to processing hanger.
4. Set timer for desired period of development based on temperature of developer. (See Table 3).
5. Immerse film in Developer. Do it smoothly and without pause to avoid streaking. Start timer.
6. Agitate film — immediately. Shake vertically and horizontally several times to bathe film surfaces thoroughly. Agitate for 5 seconds, once a minute.
7. When development is complete, lift film out quickly. Then drain film back for 5 seconds into developer tank.
8. Place film in acid stop bath. Agitate hanger for 30 seconds. Lift from stop bath and drain well.
9. Immerse film in fixer. Agitate hanger vigorously for a few seconds. Film should remain in a fixer for twice the time required to "clear" (i.e. when its milky look has disappeared) never less than 2 minutes.
10. Transfer film to tank of running water. Keep ample space between hangers (water must flow over their tops). Allow adequate time for thorough washing (10 to 30 minutes).
11. Transfer film to a final rinse of KODAK 'Photo-Flo' Solution to speed drying and prevent water marks. Immerse film for about 30 seconds and drain.
12. Place in dryer or rack, in current of dust free air. Keep films well separated. When dry, remove film from hanger and insert in identified protective folders or envelopes.
(If channel-type hangers have been used, transfer the films to bars and clips before drying.)

Because of our constant endeavour to improve quality and design, modifications may be made to products from time to time. Details of stock availability and specifications given in this publication are subject to change without notice.

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