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College on Medical Physics:
Radiation Protection and Imaging Techniques

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Quality Control of Image Processing and Darkroom

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The photographic process

Emulsion making

reactants combination

$$AgNO_3 + KBr \rightarrow AgBr + KNO_3$$

physical ripening

changes in crystal size and size distribution

sensitization (digestion)

formation of silver sulfide sensitivity specks
the emulsion may be spectrally sensitized

addition of stabilizers and hardeners

stabilizers prevent deterioration of the photographic proprieties
hardeners improve the toughness of the emulsion

Latent image formation

Gurney-Mott theory

Electronic excitation (Br^- + photon $\rightarrow$ Br + electron)
Ionic migration (formation of an atom of silver at the sensitivity speck)

When the process repeats about five to ten times, the concentration of silver atoms at a unique site in completed

Processing

Developing

A reducing agent converts the five to ten atoms of silver produced on a grain to about 10^9 atoms

The reducing agent must select only the grains with the latent image

Fixing

The fixing solution dissolves the unexposed silver halide

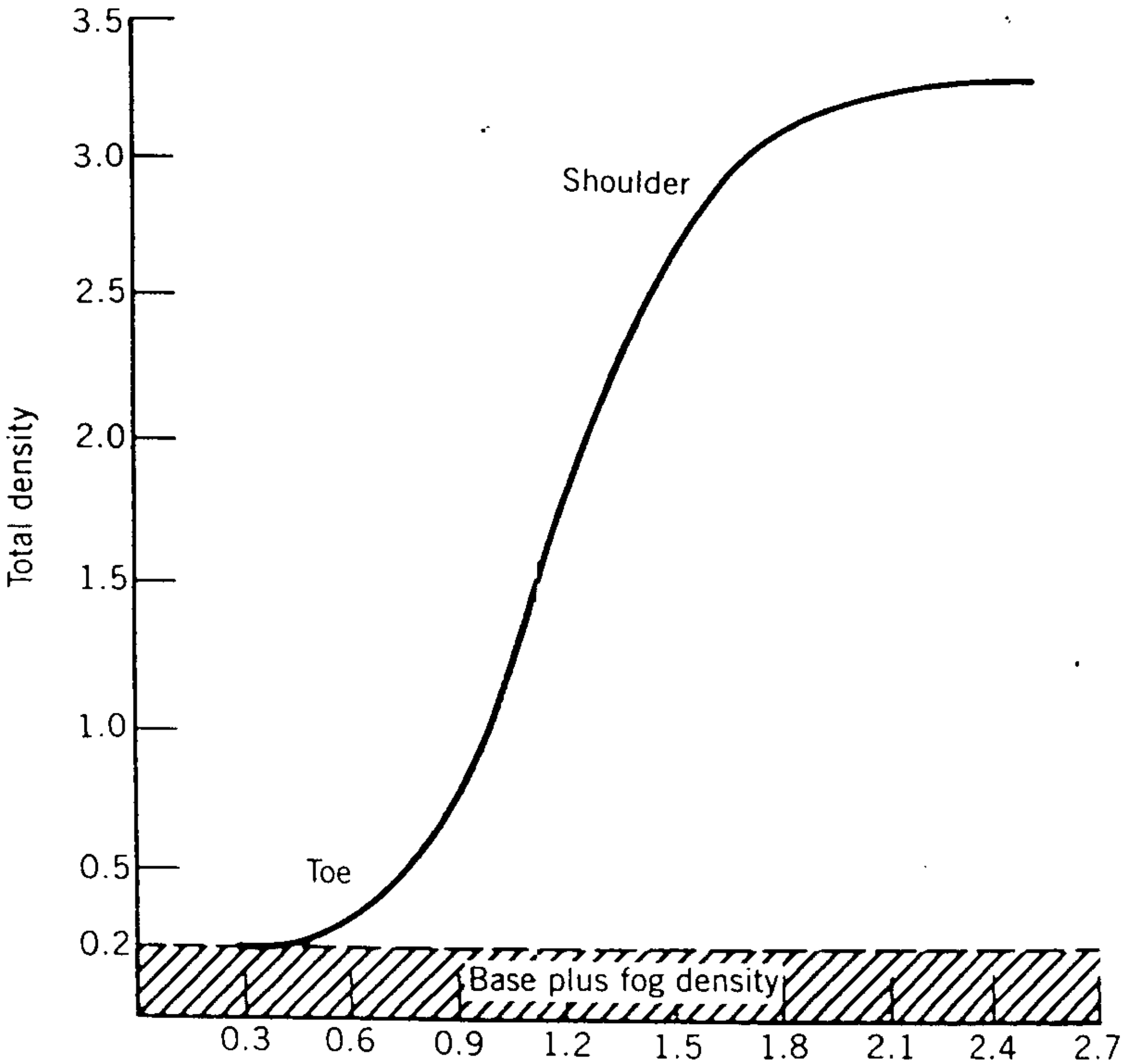
The chemical reactions of the processing are strongly dependent on:

temperature

ingredient concentrations

Processor performance

The processor performance are derived from the characteristic curve.



Sensitometer

The sensitometer exposes film with a know quantity of light through two 21-step light modulators. The maximum light is emitted from step n.21. Each successive step emits 70.7% of the light emitted from the step adjacent to it (0.15 log(exposure)).

Color selection

permits to expose the film with the same color emitted from the intensifying screen (BLUE or GREEN)

Single or double exposure selection

permits to select single sided exposure (MAMMOGRAPHIC FILM) or double sided exposure (GENERAL PURPOSE FILM)

Pre-exposed strip

* Less sensitive to small changes in processing condition

* They should be stored at low temperature (refrigerator) to minimize film changes with time

* They must not be used for a period longer then that specified by the manufacturer

Exposure to X-rays must be absolutely avoided for the quality control of automatic film processor

Definition of the performance

The following parameters are relevant in order to monitor the performance of an automatic film processor:

base-plus-fog level **speed** **contrast**

Only three steps of the sensitometric strip can be utilized to obtain information on these parameters

a density step D_0 measured in an unexposed area

D_0 provides a measure of **the base-plus-fog level**

a density step D_1 in the region of density 1(above base-plus-fog level)

D_1 is adopted as **speed index**

a density step D_2 in the region of density 2 (above base-plus-fog level)

The **contrast index** C is computed as $C = D_2 - D_1$ (DIN 6868)

In other references $C = D_2 - D_3$, where D_3 is a density step closest but not lower then 0.25 (above base-plus-fog level)

Setting up an automatic film processor

1. Prepare the automatic processor unit in accordance with the recommendation of the manufacturers of the processing chemical.

2. Set the developer temperature at 28 °C.

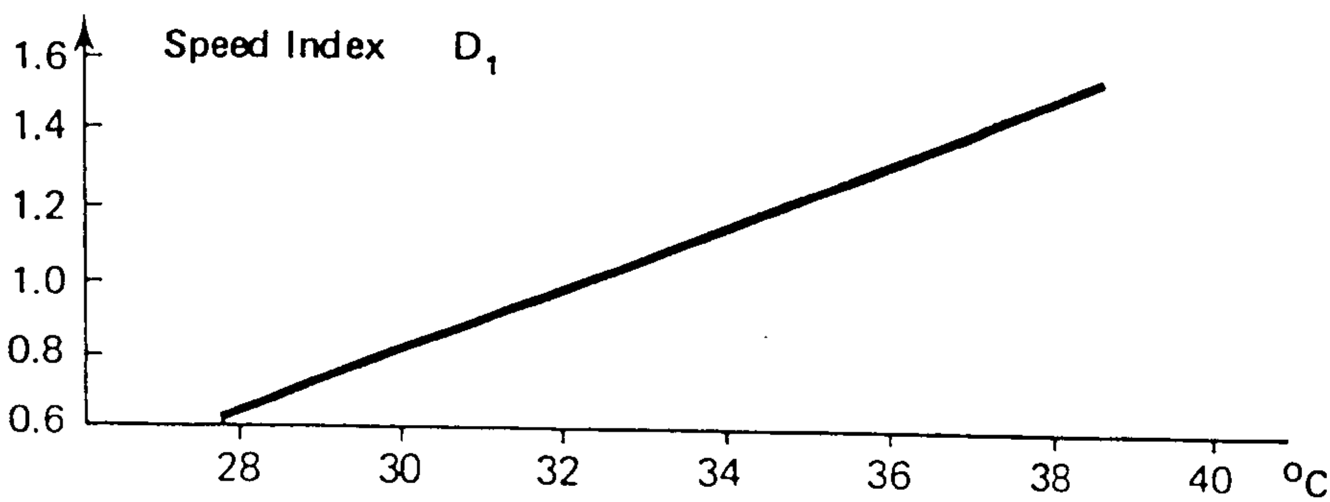
3. After 1 hour, measure the developer temperature, using a metal thermometer or thermocouple.

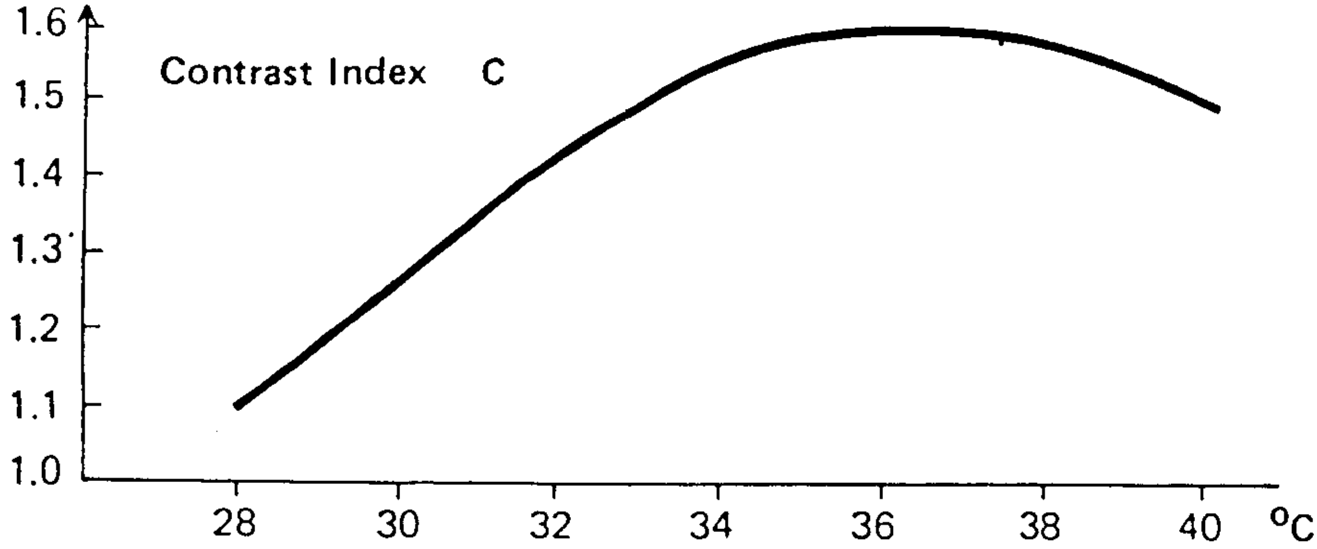
4. Expose a film with a sensitometer and process the film.

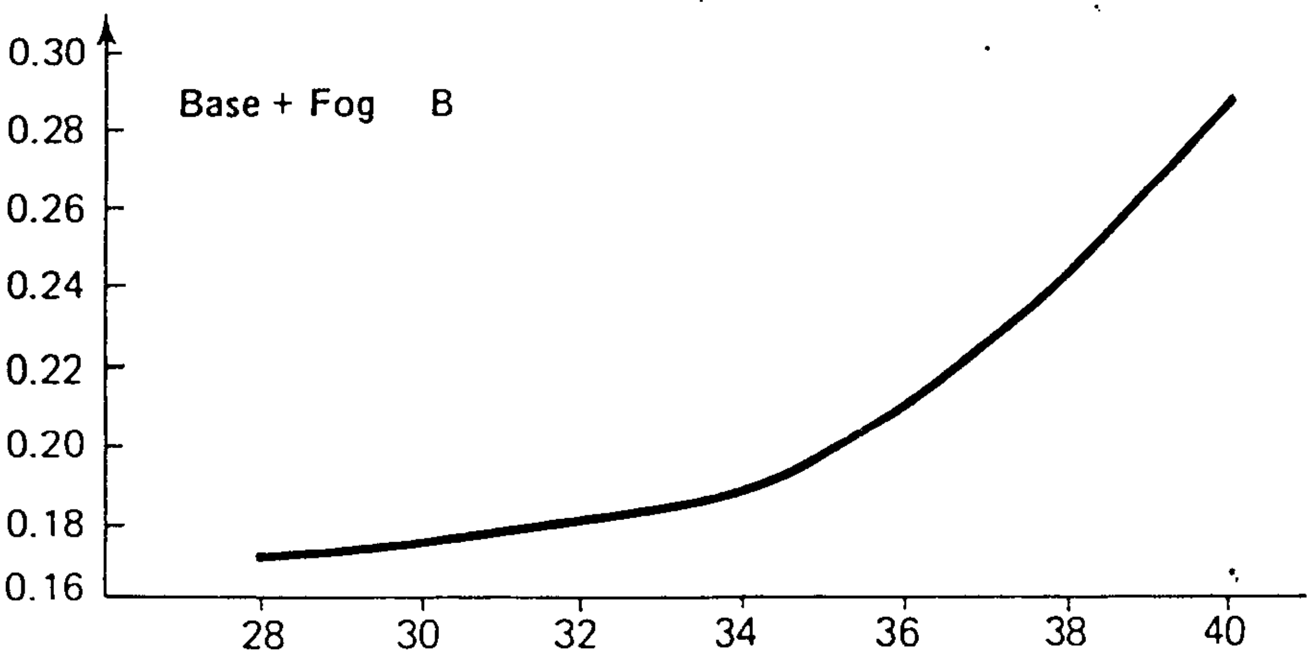
5. Measure base-plus-fog level
   speed index
   contrast index

6. Repeat steps 2 to 5, but at developer temperature of 30, 32, 34 38 °C.

7. Plot the parameters against temperature.







Tc the temperature at which C has the maximum value

Tb the temperature at which base-plus-fog-level exceed 0.22

The appropriate temperature for optimum development is whichever is the smaller of Tb and Tc

Tolerance levels

In the optimum conditions of work, expose 5 films with the sensitometer and process them.
For each film evaluate base-plus-fog level, speed index and contast index.
Calculate the mean values to provide the baseline values for these parameters.

The tolerance levels should be established in accordance to the needs of the radiological departement and in collaboration with the manufacturer of the film and processor.

Base-plus-fog level

Alarm level: *mean value* $\pm$ *0,02*

Intervention level: *mean value* $\pm$ *0,05*

Speed index

Alarm level: *mean value* $\pm$ *0,1*

Intervention level: *mean value* $\pm$ *0,15*

Contrast index

Alarm level: *mean value* $\pm$ *0,1*

Intervention level: *mean value* $\pm$ *0,15*

Daily monitoring of processor performance

Equipment required:	sensitometer (or preexposed strip) densitometer
Frequency:	daily

Expose the film with the sensitometer.
Process the film.
Read the densities levels in the three references points.
Plot the values of base-plus-fog, speed index and contrast index on the control chart.

* *The daily monitoring of the automatic processor should be performed in a systematic way, and not less than one hour after the processor as been started up*

* *When a value of the parameters falls outside the tolerance level, the cause must be identified.*

Table 1 (for processors operating at Tc)

	Parameter change	**Possible cause**
I.	B — Normal C — Decrease D_1 — Sharp increase	(a) Developer temperature too high (b) Water temperature too high (c) Water flow-rate too low (d) Transport time too long (e) New developer — too strong
II.	B — Normal C — Decrease D_1 — Sharp decrease	(a) Developer temperature too low (b) Water temperature too low (c) Transport time too short (d) Developer oxidised (reduced pH) (e) New developer — too weak
III.	B — Normal C — Gradual decrease D_1 — Gradual decrease	(a) New replenisher — too weak/contaminated (b) Under replenishment
IV.	B — Normal C — Gradual decrease D_1 — Gradual increase	(a) New replenisher — too strong (b) Over replenishment
V.	B — Increase C — Decrease D_1 — Sharp increase	(a) New replenisher — too strong (b) Over replenishment (c) Developer temperature too high (d) Increase in degree of agitation (e) Increase in development time (f) Sensitometer control strips fogged (g) No starter added to new developer (h) Contaminated developer
VI.	B — Possible decrease C — Decrease D_1 — Sharp decrease	(a) New replenisher — too weak/contaminated (b) Under replenishment (c) Developer temperature too low (d) Decrease in degree of agitation (e) Developer recirculation blockage (f) Recirculation pump failure (g) Decrease in development time (h) Contaminated developer
VII.	B — Increase C — Decrease D_1 — Sharp decrease	(a) Exhausted developer

able 2 (for processors operating below [illegible])

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	B — Normal C — Increase D_1 — Sharp increase	(a) Developer temperature too high (b) Water temperature too high (c) Water flow-rate too low (d) Transport time too long (e) New developer — too strong
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Additional practical factors

Specific gravity and pH

Useful to identify changes in chemistry or replenishment rate

Use pH papers:

1) in the range 8 to 13 to measure the pH of the developer and developer replenishment

2) in the range 3 to 6 to measure the pH of the fixer and the fixer replenishment

Temperature

The most critical temperature is that of the developer (the density of processed film would increase by approximately 0.1 for each °C increase in developer temperature).

The temperature should be:

within 0.5°C of the optimum setting for the temperature of the developer;

within ±1°C of that specified by the manufacturer for the temperature of the fixer;

within ±2°C of that specified by the manufacturer for the temperature of the dryer.

The use of unprotected mercury thermometer must be absolutely avoided).

Residual hypo testing

The test indicates inadequacy of the washing and fixing of the processed film.

It should be perfomed once every mounth, using hypo estimator and test solution.

Silver recovery

The test permits to estimate the silver levels in the fixer and in the solution from the silver recovery unit and it is used to check if the fixer replenishment rate is correct.

Use estimating papers in the range 0-10 gl^{-1}. The optimun value depends on each processsor's workload, but should be within the range 4-6 gl^{-1}.

Transport speed

Total transit time of a film through an automatic processor.

Using a stop watch, verify that the variation in the measurements not exceed ±5% of the time specified by the manufacturer.

Replenishment rates

The correct replenishment rates should be determined observing the trends of base-plus fog level D_0, speed index D_1 and contrast index C, obtained daily with the sensitometric strips.

A steady increase in D_0, D_1 and C means a developer replenishment rate too high.
A steady decrease in D_0, D_1 and C means a developer replenishment rate too low.

The value of these factors should be measured when the automatic processor unit has been set up, in order to establish the baseline level of performance against which subsequent measurements can be compared.

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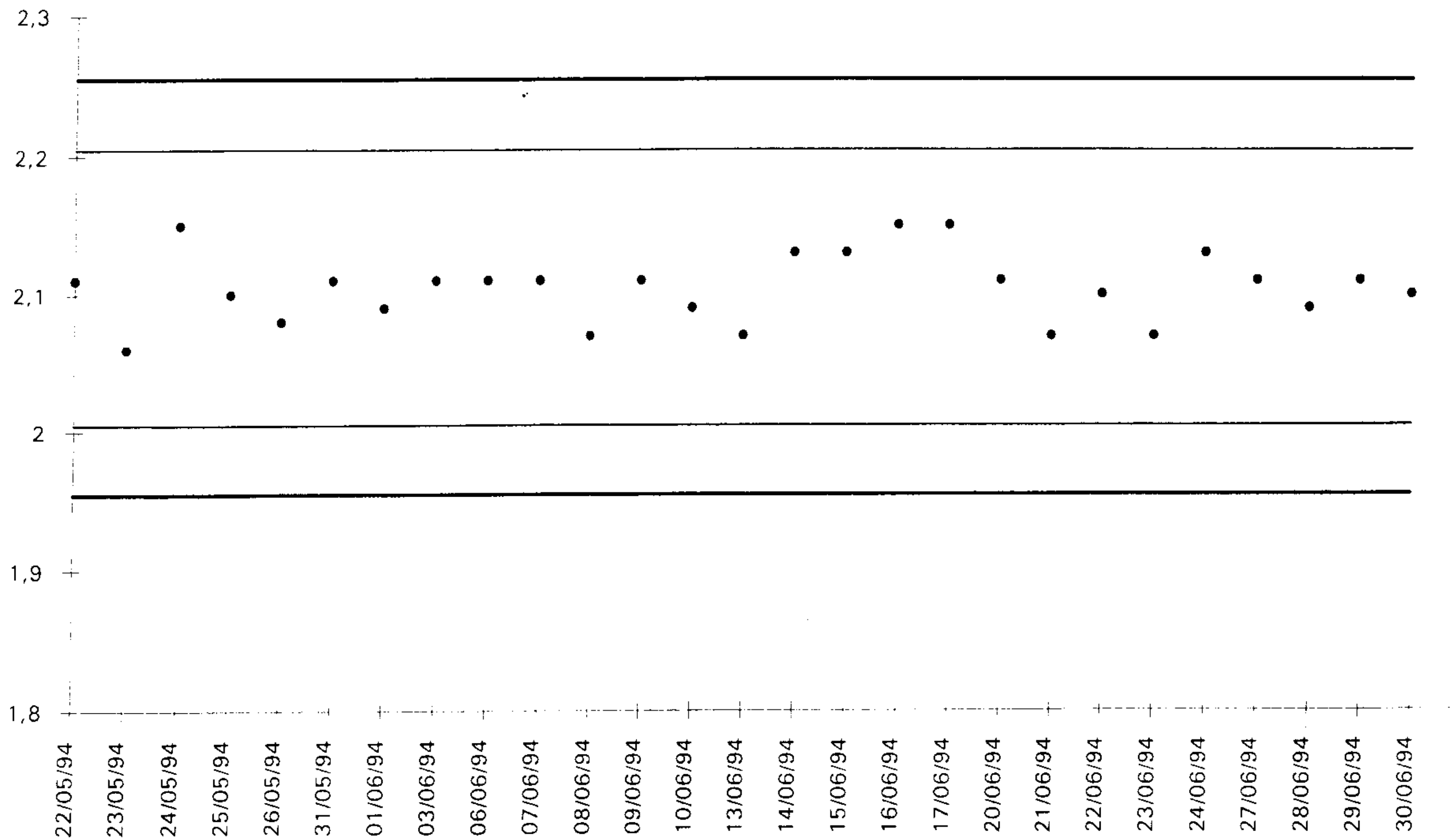

Film storage checks

Equipment required:	thermometer (range 0 to 40°) hygrometer
Frequency:	annual (or seasonal)

* Temperature ***not > 22°***

if film are stored at low temperature (< 15°) they must stand for a few hours to return to room temperature

* Relative humidity ***50 - 60%***

* Rotation ***first in - first out***

Film must be be stored separately from:

radioactive materials
chemical products (developer and fixer)

Mechanical stress must be avoided

Correct position of films should be vertical

Darkroom checks

Equipment required:	densitometer
Frequency:	annual

* Darkroom safelight

1. Expose a film to X-rays to give a uniform density around 1. Place the film on the darkroom bench and expose different strips of the film to the safelights respectively for 0, 1/2, 1, 4, 8 minutes. Process the film.
   No visually increase in density should detectable on the film.
2. Place a film not exposed to X-rays on the darkroom bench for 10 minutes. Process the film.
   The base-plu-fog level should not exceed 0.25

* Light leaks into the darkroom

* Radiation protection of the darkroom

Background radiation should not exceed 7 μRh^{-1}($2 \cdot 10^{-5} \mu Ckg^{-1}h^{-1}$)

Sparking of electric motors and luminous clocks and watches can produce film blackening