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What is average gradient and should it be used as part of a quality control program? If so, how?

The 21 points from the sensitometric strip may be plotted and used to calculate average gradient. Average gradient is the slope of a straight line between two specific points of the characteristic curve, the most diagnostically useful part of a practical image (approximately the minimum and maximum useful densities in the clinical setting). For most medical x-ray films, average gradient is measured between the densities of 0.25 and 2.00 above base plus fog. It is calculated by the formula:

$$\text{Average Gradient} = \frac{(2.0 + \text{base plus fog}) - (0.25 + \text{base plus fog})}{\log E_2 - \log E_1}$$

where:

- Base plus fog is defined as the optical density of the film base plus any additional density to the emulsion coated on the film base.
- Log E_2 is defined as the log relative exposure value for the point on the curve represented by a density of 2.0 + base plus fog.
- Log E_1 is defined as the log relative exposure value for the point on the curve represented by a density of 0.25 + base plus fog.

Average gradient may also be described as the rise of a straight line between two points on the density axis over the run of the same straight line between two points on the log E axis.

Calculating the average gradient is not difficult, but it requires a precisely drawn characteristic curve and careful interpretation of the density and log E values if the results are to be meaningful and repeatable. Automatic scanning densitometers are programmed to make this calculation.

Small differences in the characteristic curve shape can result in significant differences in average gradient values. Two factors that contribute to these differences, aside from film-processing effects, are:

- Deviations from the nominal 0.15 optical density difference between the steps of a typical step tablet (installed in simulated light sensitometers).
- The assumption that the exposure difference between steps is 0.15 when characteristic curves are plotted, either manually or automatically.

To a limited extent, the plotting routines, or algorithms, in automatic scanning densitometers may also contribute to differences in curve shape.

The sensitometers and densitometers currently available do not address these variables. As a result, there are often significant discrepancies in average gradient values from one sensitometer/densitometer system to another. Therefore, it is not practical to compare average gradient values

generated with different systems.

Using Average Gradient

Average gradient is the most accurate method for determining contrast because it is derived from the relationship between two specific (optical) densities and the exposure required to produce them with any given film/developer combination.

The ways average gradient can be used include:

- Comparison of the published average gradients for films from a specific manufacturer to determine which film is higher or lower in contrast (i.e., to rank the films, all from the same manufacturer, in relation to one another). The following table gives information on KODAK Mammography Films:

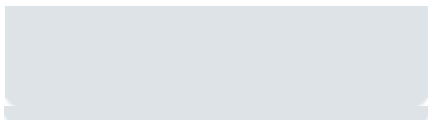
KODAK Screen	KODAK Film	Processing	Relative Speed ¹	Contrast ² RP	Contrast EX II	D-max
MIN-R 2000	MIN-R 2000	Standard	150	3.60	3.80	>4.0
MIN-R 2190	MIN-R 2000	Standard	190	3.60	3.80	>4.0
MIN-R	MIN-R 2000	Standard	100	3.60	3.80	>4.0
MIN-R 2000	MIN-R L	Standard	150	3.40	3.60	>4.0
MIN-R 2190	MIN-R L	Standard	190	3.40	3.60	>4.0
MIN-R	MIN-R L	Standard	100	3.40	3.60	>4.0
MIN-R	MIN-R M	Standard	100	2.95	3.15	3.9
MIN-R Medium	MIN-R M	Standard	170	2.95	3.15	3.9

¹ Relative speed determined from matched-density radiographs of a mammography phantom; KODAK MIN-R M Film arbitrarily assigned a relative speed of 100.

² Contrast--Measured as the average gradient between densities of 0.25 and 2.00 above gross fog.

- As a relative measure of contrast. After establishing the processor QC program, calculate the average gradient and use it as a benchmark for all future comparisons, provided the same film type, processor, chemical type, sensitometer and densitometer are used.

Average gradient should not be used to compare the contrast of different screen-film combinations.



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What is cleanup film and how is it used?

KODAK Roller Transport Cleanup Film 4955 (CAT No. 166 2303), is a specialized film designed to be used in conjunction with the processing environment. Each 14 x 17-inch (35 x 43 cm) sheet of film features a tacky, non-light-sensitive coating on both sides of the film base.

Cleanup film picks up lint, dirt and other deposits and helps carry them out of the processor. For best results, one or two sheets should be processed.

Cleanup film is particularly useful for controlling a processing artifact called delay streaks. Cleanup film may be used in all processors, except those with area replenishment, which cannot sense this clear-based film.

Fogged or expired single- or double-emulsion film that has not previously been processed may also be used as cleanup film. Note that mixing films from different manufacturers in the same environment should be avoided because undesired sensitometric changes may occur.

Any film used as cleanup film should be discarded after one use to avoid contaminating the developer solution with fixer and redepositing lint or dirt back onto the rollers in the processor.

Contact your local Kodak representative for additional information about KODAK Roller Transport Cleanup Film 4955.



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What is the crossover procedure and how should it be performed?

Perform a crossover procedure when a new box of QC film is opened to adjust the originally established parameters for speed, contrast, and base plus fog on the processor QC chart for the characteristics of the new emulsion. An adjustment is required because film used in medical imaging is produced in batches and there may be slight differences in the sensitometric characteristics from batch to batch. The conditions under which the film is stored (i.e., temperature, relative humidity, exposure to fumes from chemicals or to ionizing radiation, etc.) and the age of the film can also affect the sensitometric characteristics of film.

Performing a crossover procedure is necessary to maintain a controlled processing environment. Note the following important points:

- 1.
2. The crossover should be performed on the same day rather than over five consecutive days as when the processor QC program was initially established.
3. Expose and process all of the films required for the crossover:
 - At the same time of day that processor QC is normally performed because slight sensitometric changes due to fluctuations in film feeding patterns throughout the day are common.
 - All at the same time, without interruptions.
 - With the same delay (e.g., a few seconds) between exposure and processing that is normally used.
 - Alternating the films from the existing QC box and from the new box. Expose and process the first film from the existing box, followed by the first film from the new box, the second film from the existing box, the second film from the new box, etc. This distributes any sensitometric changes due to seasoning equally among the 10 films. The films from the existing box and new box can easily be distinguished from each other before processing by marking one set of films with a lead pencil or by cutting a corner of one set of films, etc.
 - The computations and adjustments to the control chart may be delayed until a more convenient time later in the day, if preferred.
4. The chemicals in the processor should be seasoned when a crossover is performed on a single day. Generally, for this purpose, it is important to avoid performing a crossover

immediately after a preventive maintenance procedure (PM). Monitor both the number of films remaining in the QC box and when the next processor PM will be performed so that the crossover can be performed before the PM occurs and with fully seasoned chemicals in the developer tank. A good rule of thumb is that a minimum of 10 to 15 films should remain in the existing box of QC film when beginning a crossover procedure. A piece of cardboard from the film box inserted between the last 15 films and the balance of the box makes a good divider and serves as a reminder that a crossover must be performed.

5. The processor should be in control (within the ± 0.10 control limits for speed and contrast) for crossovers performed all on a single day. It is extremely unlikely, however, that the speed and contrast of the processor will be at the operating level originally established. It will be necessary, therefore, to adjust the new operating levels (taken from the characteristics of the new film) by the difference between the originally established aims and the current box of film.
6. The developer in the processor must have reached its operating temperature before doing a crossover procedure.
7. The crossover procedure should be fully outlined in the policy and procedures manual, and all QC personnel should be trained.

Performing a Crossover

Follow these steps:

- 1.
2. Alternately expose and immediately process five sensitometric strips each from the current and new boxes of film.
3. Determine the average of the steps previously chosen for processor quality control (i.e., step 11 for speed, steps 13 and 9 for contrast, and step 1 for base plus fog for the five films from the current box and for the five films from the new box).
4. Adjust the aim operating levels on the control chart for speed, contrast, and base plus fog by the difference in the average values between the current and new boxes of film, as shown in the following equations:

Step 1:

$$\begin{array}{rcl} \text{New Box} & & \\ \text{Average} & - & \text{Current Box} \\ & & \text{Average} & = & \text{Difference} \end{array}$$

Step 2:

$$\begin{array}{rcl} \text{Original Aim} & + & \text{Difference} & = & \text{New Operating} \\ & & & & \text{Aim} \end{array}$$

Example #1: The original operating aim for speed is 1.20; the average for speed of the five films from the current QC box is 1.28; the average for speed of the five films from the new QC box is 1.32.

$$\begin{array}{rcl} \text{Step} & & \\ \text{1:} & 1.32 & - & 1.28 & = & 0.04 \end{array}$$

$$\begin{array}{rcl} \text{Step} & & \\ \text{2:} & 1.20 & + & 0.04 & = & 1.24 \end{array}$$

Example #2: The original operating aim for contrast is 1.80; the average for contrast of the five films from the current QC box is 1.75; the average for contrast of the five films from the new QC box is 1.70.

$$\begin{array}{rcl} \text{Step} & & \\ \text{1:} & 1.70 & - & 1.75 & = & -0.05 \end{array}$$

$$\begin{array}{rcl} \text{Step} & & \\ \text{2:} & 1.80 & + & (-0.05) & = & 1.75 \end{array}$$

To confirm that the correct adjustment has been made, check that the offset (or difference) between the new operating level and the point which represents the average of the five films from the new box of QC film is exactly the same as the offset (or difference) between the old operating level and the point which represents the average of the five films from the current box of QC film.

In **Example #1** above, the offset, or difference, between the current QC box average value (1.28) and the original operating aim (1.20) is 0.08, with the average being higher. The new QC box average value (1.32) is also 0.08 higher than the new operating aim (1.24).

In **Example #2** above, the offset, or difference, between the

current QC box average value (1.75) and the original operating aim (1.80) is 0.05, with the average being lower. The new QC box average value (1.70) is also 0.05 lower than the new operating aim (1.75).

5. Record the complete emulsion number of the new box of film on the control chart.
6. Make a notation in the "remarks" section recording the date and the fact that a crossover was performed.



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What is an emulsion number log, and how is it used for troubleshooting a suspected image quality problem?

Film manufacturers designate each box of x-ray film with a multiple-digit emulsion number. This number provides important information such as which particular emulsion batch was used as well as which roll it came from, the specific part (slit) of the roll, and which variation of emulsion was used (variation code).

Keeping track of the emulsion number of the film used for processor quality control is generally done in every processor quality control program. It is also extremely advantageous to keep track of the complete emulsion numbers of all film used clinically, especially for mammography. Doing so allows film manufacturers to make comparisons in speed, contrast, D-max, etc., between current clinical images and images taken one or more years previously. Such comparisons may assist in troubleshooting image quality concerns.

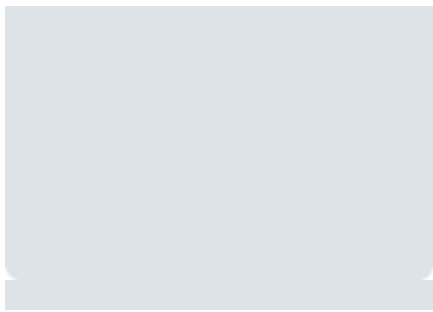
The easiest way to retain this information is to start an emulsion number log. The log should contain the following information:

- Type of film.
- Date film box was opened.
- Film size.
- Complete emulsion number, including variation code.
- Any other comments, such as which emulsions were used for processor QC or phantom images.

Refer to the example of a emulsion number log below. Every time a box of film with a different emulsion number is opened, a new entry should be made in the log.

KODAK MIN-R 2000 Film

Date Opened	Film Size	Emulsion Number	QC	Comments
7/8/2002	18x24 cm	476-016-14		
	24x30 cm	476-011-15		Phantom Image
7/15/2002	18x24 cm	479-032-14	X	
	18x24 cm	482-015-15		
7/19/2002	18x24 cm	482-031-14		



7/22/2002	18x24 cm	483-015-11		Reestablished QC
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What is flooded replenishment and how is it used?

In low volume per eight-hour situations, sufficient replenishment does not occur as films are being processed and undesired chemical components accumulate (e.g., bromide, a by-product of the development process). As a result, the processor quality control chart may indicate that the processor is "out-of-control."

To rectify the situation, it is necessary to add fresh chemicals to the processor at a rate that will assure constant chemical activity. A method first introduced in 1979, called flooded, or flood, replenishment, can be used to help stabilize the processing environment for low-volume use.

Flooded replenishment is accomplished by not only pumping fresh developer and fixer replenisher into the processor when film is fed (moving through the entrance detector crossover assembly), but also on the basis of the amount of time the processor is operational. A timer installed on the processor activates the replenishment pump periodically (e.g., 20 seconds every 5 minutes at a rate of 65 milliliters per actuation). The additional amounts of developer and fixer replenisher will help maintain the developer and fixer activity at a stable level.

If **flooded replenishment** is used, starter should be added to the developer replenisher holding tank. The typical volume of KODAK Developer Starter for all KODAK Medical X-ray Films is 3 fluid ounces (89 mL) per US gallon (3.8 litres) of developer replenisher. The typical volume of KODAK RP X-OMAT Developer Starter for KODAK MIN-R 2000 Film is four ounces [(119 mL) per US gallon (3.8 litres)/31 ml per litre]. Additional starter should not be added to the processor developer tank.

Flooded replenishment should be set up on a processor by qualified service personnel.

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How should film be selected for processor quality control (QC)?

When establishing a processor quality control program, a box of fresh film should be selected and set aside for processor QC as follows:

- For a processor dedicated to a particular type of film, such as mammography, the box of film should be the same type of mammography film (identical catalog number). Select a box of 18 x 24 cm film.
- For processors with a mix of different film types, such as mammography and general radiography, a box of mammography film must also be selected. (Ideally, processor QC should be performed using all film types in a mixed processing environment.)
- For processors with a mix of different film types other than mammography, the most process-sensitive film of the types being processed should be selected for processor QC. Because mammography film is more process-sensitive than films used for conventional medical imaging, it is not recommended for use in this situation because it may result in unnecessary control actions for the less process-sensitive films.

It is important that the emulsion number of the box of film be noted on the processor control chart. If an emulsion number log is maintained, also record the number there. The emulsion number can usually be found on the front and side of each box of film.

The box selected for processor QC should be clearly labeled "QC." As with all film, it should be protected from sources of radiation, light, chemical fumes, and should be stored within the recommended temperature and relative humidity ranges recommended for film (50° to 75° F [10° to 24° C] and 30 to 50 percent relative humidity).

If the box of film (100 sheets) is used to monitor a single processor in a single darkroom, and films are processed at least five days per week, the box will typically last approximately three months. If environmental temperature and humidity cannot be controlled 24 hours/day, 7 days/week, film aging and sensitometric changes may be accelerated, and it may be necessary to select a new box of film for processor QC at shorter intervals. In this case, the balance of the film in the box can be used for other purposes (e.g., other quality control tests).

It has been common practice in medical imaging facilities to reserve a large quantity of film with the same emulsion number (i.e., an entire case [500 sheets], or enough to last for 6 to 9 months) for processor QC. Such facilities usually have a large number of processors that are controlled with the one type of film, and they primarily wish to avoid having to do crossovers frequently.

A large supply of film should be reserved only if the film is kept frozen at an approximate temperature range of 0° to 32° F (-18° to 0° C). Before opening a new box of film that has been kept in the freezer for QC, the box should be removed from the freezer and allowed to remain, unopened, at room temperature (68° to 70° F [approximately 20° C]) for a minimum of 24

hours. A crossover should be done when the next supply of film is selected.

An alternative for large facilities with many processors using the same type of diagnostic film would be to select a large quantity of film with a single emulsion number and provide a box of QC film for each individual processor. This would limit having to do a crossover to approximately four times per year. Note that all processors should be at the same operating levels.

For mammography facilities, a crossover procedure should be performed with each new box of film selected, regardless of whether the emulsion number is the same as the current box or a different number.



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When is it appropriate to restart the processor and processor quality control program?

After a processor QC program has been initially established, it may be possible to proceed for a long period of time (i.e., a year or more) using the original operating aims if the processing environment is well controlled and all personnel operate in a consistent manner.

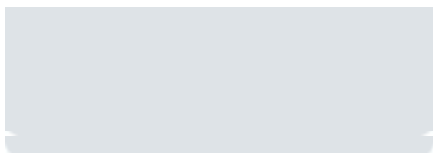
Most facilities, however, will benefit from a periodic reevaluation and reestablishment of the processor QC program. This might be done on, at least, an annual basis. Some facilities are hesitant to re-establish a processor quality control program. If you do reestablish your program, be sure to make a notation in the "remarks" section of the processor QC chart that the program was re-established and the reason why (e.g., annual reestablishment, etc.).

There are also a number of other events that dictate the reestablishment of the processor QC program. These include:

- A change of film type in a dedicated processor.
- A change of film mix in a non-dedicated processor.
- When a film manufacturer makes a change to a film currently in use (e.g., increases the D-max) and recommends that the processor QC program be reestablished.
- A change in film volume.
- A change of brand(s) of chemicals used.
- A change of chemical form used (e.g., switching from premixed solutions to concentrates used in an automixer).
- A change in replenishment rates.
- A change in the settings on a specific gravity automixer.
- A change in the average optical density of the films being processed (e.g., the level of exposure on mammographic images is increased).
- Using a different sensitometer and/or densitometer.
- Running out of film or having less than five sheets of film in the QC box, thus preventing a crossover from being done correctly.
- A change in the way the crossover procedure is done. Note that it is particularly important to first re-establish the processor QC program (over five consecutive days), and then, upon opening the next new box of QC film, implement a new way of doing the crossover.

In addition, over time, the values for speed and contrast on particular steps may no longer be consistent with the guidelines for establishing processor QC (the speed step closest to 1.20, and the two steps used to calculate the density difference closest to 2.20 and closest to, but not less than 0.45) due primarily to adjustments from the crossover procedure. If the step chosen to monitor speed, in particular, is now lower than 1.0 (down in the toe, not on the straight-line portion of the characteristic curve), the control chart will be relatively insensitive to processing changes that could affect clinical films. If the step chosen to monitor speed is now higher than 1.50, the control chart will be hypersensitive to processing changes and it may be difficult to maintain a controlled environment.

The reestablishment of the processor QC program, including changing the step numbers used, if appropriate, is recommended.



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What is replenishment, how should replenishment rates be set and under what circumstances should they be changed?

As exposed film is processed, the chemicals in the processor (developer and fixer) gradually weaken, and their effect on film (activity) slows down. To compensate for this progressive loss of activity, chemicals must be replenished. This occurs automatically in automatic roller-transport processors as film passes the entrance detector crossover assembly.

If replenishment did not occur, or if the replenishment rate is too low, the gradual reduction in chemical activity will cause a loss of quality in the processed radiographs -- the grays become softer and blacks become lighter. In addition, it will be necessary to increase radiation exposure to patients to achieve the proper film optical density.

Replenishment is important for maintenance of stable developer and fixer activity. Proper replenishment provides stable sensitometric results (film contrast, film speed, and base plus fog), reduces processing artifacts, and provides archival keeping.

Replenishment Rate Guidelines

Film and chemical manufacturers provide extensive replenishment rate guidelines. Eastman Kodak Company publishes guidelines for all Kodak film and processor types in [Service Bulletin No. 30](#) (September 2001 update), Processing Recommendations for KODAK X-OMAT Processors, publication no. N-923.

Published replenishment rate guidelines are sometimes categorized based on daily film volumes (high, medium, and low) in an eight-hour day, film types (general-purpose films, mammography, etc.), number of films fed at a time, and whether the processor is dedicated to a particular film type, such as mammography, or whether the processor is used for all film types (intermixed).

A low film volume processed in an eight-hour day requires higher replenishment per sheet of film. Processors with very low film volumes (such as operating rooms) are very difficult to stabilize and achieve consistent image quality. A method, called **flooded replenishment**, is recommended under these conditions.

A high film volume per eight-hour day requires lower replenishment per sheet.

Note that published replenishment rate guidelines should be used as initial starting points only. It may be necessary to set higher or lower rates based on a number of factors, such as the type of chemicals used, whether or not the target film volume is spread throughout the day, if films are processed every day, if one or two 18 x 24 cm mammography films are typically fed at the same time, etc.

Once replenishment rates have been set and the processor quality control

program has been established, the goal is maintenance of a controlled processing environment while minimizing chemical use (for lower costs) and the impact on the environment. It may be possible to systematically reduce the rates as long as the processor remains in control, a regulatory requirement in many cases.

Additionally, it is important that facility personnel responsible for overseeing the processor be in close communication with the representatives of the processor service company concerning changes in film volume. As film volume decreases, it may be necessary to increase the replenishment rates; as film volume increases, it may be necessary to decrease the replenishment rates. Such communication is frequently overlooked and changing the volumes without a corresponding change in replenishment rates may be the source of an upward or downward trend and an "out-of-control" processor.

It is also important to note that different films may require different replenishment rates.

Defining Replenishment Rates

Replenishment may be defined as the amount of fresh developer and fixer replenisher that is added to the processor at a set rate, called the replenishment rate. Replenishment rates are commonly noted as a certain number of millilitres of developer and fixer. Because it is very easy to miscommunicate regarding replenishment rates and because replenishment is often an important consideration when troubleshooting an "out-of-control" processing environment, rates should be fully defined in terms of the number and size of films and length of film travel.

For intermixed general-purpose films, a 35 x 43 cm sheet of film is usually the benchmark. The length of travel is either 35 cm for a processor with a 17-inch (43 cm) feed tray, or 43 cm for a processor with a 14-inch (35 cm) feed tray. Using the high-volume replenishment rate information below, the developer replenishment rate is 50 mL and the fixer replenishment rate is 70 mL per 35 x 43 cm film. The length of film travel could be either 35 cm (14 inches) or 43 cm (17 inches) depending upon the processor model used.

General Purpose Films, Standard-Cycle Processing

Processed Film	Volume (Use)	Sheet Film Volume in 8 hours	Replenishment Rates mL per 35 x 43 cm, for 35 or 43 cm of film travel	
			Developer	Fixer
Intermixed film sizes	High	115 or more	50	70
(18 x 24 cm	Medium	40 to 115	54	85
to 35 x 43 cm)	Low*	40 or less	80	100

*If sensitometry does not stay within control limits, **flooded replenishment** may be needed.

For mammography films, typically one or two 18 x 24 cm films are processed. The length of film travel is 24 cm.

Using the medium- to high-volume replenishment rate information in the following table for KODAK MIN-R 2000 Film, the developer replenishment rate is 25 mL and the fixer replenishment rate is 30 mL per one 18 x 24 cm film fed singly, for 24 cm of film travel. In other words, 25 mL of developer and 30 mL of fixer should have been pumped into the processor after an 18 x 24 cm film fed with the short dimension as the leading edge was fed into the processor.

KODAK MIN-R 2000 Film

Processed Film	Volume (Use)	Sheet Film Volume in 8 hours	Replenishment Rates mL per 18 x 24 cm, for 24 cm of film travel	
			Developer	Fixer
Intermixed film sizes (18 x 24 cm to 24 x 30 cm) Single film feeding	Medium - High	60 sheets or more	25	30
	Low*	60 sheets or less*	Flooded	Flooded
Intermediate film sizes (18 x 24 cm to 24 x 30 cm) Double film feeding	Medium - High	60 sheets or more	50	60
	Low*	60 sheets or less	Flooded	Flooded

*If sensitometry does not stay within control limits, **flooded replenishment** may be needed.

Error most frequently occurs for mammography processors if the replenishment rates are set based on 35 or 43 cm of film travel, rather than 24 cm, or on an incorrect number of films typically fed.

In the above mammography example, if two 18 x 24 cm films are usually processed at one time, an initial developer replenishment rate of 50 mL and a fixer replenishment of 60 mL would be required. Note that feeding two 18 x 24 cm films at a time is the norm. However, single film feeding is recommended for some processors with narrower film feed trays. Processor modifications may be available to widen the film feed tray so an adequate space separates two 18 x 24 cm mammography films fed at the same time.

In addition, for mammography, film feeding protocols should be posted in the darkroom, and all personnel who process film should be trained to process film the same way. Processing mammography film consistently is

important to help standardize replenishment rates.



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What is the difference between "fresh" and "seasoned" chemicals? What are "seasoning effects?"

Newly mixed chemicals are frequently referred to as "fresh." Fresh chemicals should be used in the replenisher holding tanks or automixer for the initial startup of a processor, especially when first establishing a processor quality control program, and after a complete chemical change during the performance of a preventive maintenance procedure.

For best results, it is important to follow the manufacturer's recommendations by:

- using the proper chemicals;
- mixing to the correct concentrations;
- adding the appropriate amount of starter solution.

"Seasoning" refers to the changes that take place in the developer solution as films are processed after fresh chemicals have been added to the processor.

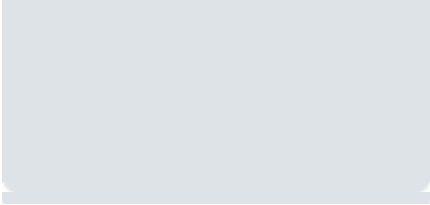
The developer is considered fully seasoned when the developer tank in the processor has "turned over" three times. In other words, an amount of fresh developer replenisher equal to three times the volume of the developer tank has been pumped into the processor.

The time required to go from a fresh to fully seasoned state in a particular processor will vary depending upon the number of films processed and the amount of fresh developer replenisher (developer replenishment rate) pumped into the developer tank as each film passes through the entrance detector crossover of the processor.

The time can be calculated by knowing the volume of the developer tank in millilitres, the developer replenisher rate (also in millilitres), and the number of films processed in a given period of time.

The occurrence of seasoning is the basis for averaging the sensitometric values from five processor quality control films, one per day. Averaging is necessary to reflect a meaningful processor quality control baseline against which the values (speed and contrast) from all daily sensitometric films will be compared to determine if the processor is in control.

As film development occurs, developing agents are consumed, and bromide ions and other by products are released into solution. As more of the developing agents are consumed, the sensitometry of processed films and developer activity changes. Slight changes in speed and contrast occur; developer activity decreases. The sensitometric effect of seasoning is very dependent upon the type of film being processed, the chemicals in use, and whether correct replenishment rates are set and adjusted for changes in film volumes.



At some point in a seasoned process, film speed and contrast will stabilize, provided everything is balanced. Balance is best achieved by following the manufacturer's recommendations, as previously discussed.

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What is the split phantom test and how is it used to test sensitometric differences between different emulsions or batches of film?

A split phantom test should be performed to radiographically determine relative speed differences between two different boxes of film, one of which is suspected of being much faster or slower than the film in current use for either clinical films or for processor quality control. Speed comparisons made using a sensitometer may not accurately reflect the differences in speed between two films exposed by light from an intensifying screen.

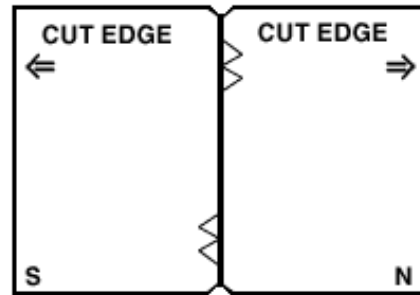
The procedure is as follows:

- 1.
2. Assemble the tools that are needed for the test:
 - A phantom used for mammography quality control testing
 - The 18 x 24 cm mammography cassette normally used for the phantom test
 - A piece of cardboard from the film box cut in half to use as a guide
 - A pair of scissors
 - A lead pencil

The mammography x-ray unit and the processor will also be used for this test.

3. In the darkroom (in total darkness to reduce any additional density added to the films due to long safelight exposure) cut a sheet of film from the current or "normal" box in half by using the cardboard as a guide. (This can be done by lining up the 18 cm edges of the cardboard and film so that the film is closest to the countertop and the cardboard half is on top. Be careful cutting the film in the dark.)
4. Place the film--emulsion side up--in the cover of the opened cassette with the film on the right side and the cut edge toward the right edge of the cassette; use a lead pencil to mark the corner "N" for normal.
5. Cut a sheet of film from the "suspect" box in half by using the cardboard as a guide.

6. Place the film--emulsion side up--in the cover of the opened cassette with the film on the left side and the cut edge toward the left edge of the cassette; use the lead pencil to mark the corner "S" for suspect.
7. Before closing the cassette, make sure the film edges in the center of the cassette are directly adjacent to one another and not overlapping.



8. Place the cassette with the two film halves in the grid of the mammography x-ray unit.
9. Place the phantom on top of the grid in the standard location used for mammography quality control testing.
10. Position the photocell beneath the center of the phantom (standard location), assuming the phantom exposure is always made using the phototimer.
11. Select the same technique factors usually employed when imaging the phantom (same kVp, etc.).
12. Make the exposure and immediately process the two film halves in the same manner (e.g., emulsion side up and on the right side of the processor).
13. Use a densitometer to take two optical density readings in the center of the phantom, just to the right and left of the cut edges (one on the "normal" and one on the "suspect" film).
14. Calculate the density difference by subtracting the optical

density value of the "suspect" film from the optical density value of the "normal" film.

If the density difference is a negative value and the "suspect" film is darker than the "normal" film, the "suspect" film is faster. If the density difference is a positive value and the "suspect" film is lighter than the "normal" film, the "suspect" film is slower.

According to the American College of Radiology in ***Recommended Specifications for New Mammography Equipment*** :

- "A density difference of 0.30 between any two films of the same type from the same manufacturer, exposed and processed together, is a reasonable maximum to be expected from manufacturing variability for films of roughly the same age and storage conditions."
- "If the difference between the two film densities exceeds 0.30 at a density of approximately 1.25, then the film supplier should be contacted to determine the source of the problem."

Note that a difference of 0.30 at a density of approximately 1.25 may translate into a bigger difference for clinical films exposed at a greater optical density. For example, high-contrast mammography films, such as KODAK MIN-R 2000 Film, are frequently exposed at an optical density between 1.50 and 2.00 in order to maximize contrast. The density difference at this optical density level will be greater due to the increased contrast.



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What is starter and how is it used for processing medical radiographs?

The addition of starter solution, a clear, odorless liquid, begins the seasoning process, mainly by adding bromide ions to the developer.

Because film and chemical formulations vary significantly from manufacturer to manufacturer, the starter solution sold by the chemical manufacturer should be used. Eastman Kodak Company manufactures KODAK *RP* X-OMAT Developer Starter, CAT No. 133 2642. One bottle of starter is sufficient to start 8 gallons (30.3 litres) of KODAK *RP* X-OMAT Developer Replenisher for all KODAK Medical X-ray Films; or one bottle will start 4 gallons (15.2 litres) for KODAK MIN-R 2000 Film.

Additionally, a graduated cylinder with millilitre markings is recommended to ensure adding the correct amount of starter solution specified for the developer tank volume.

After a complete chemical change, the correct amount of starter should be added to a half-filled developer tank. The balance of the developer may then be added. (Note that the fixer tank should first be filled and the fixer rack replaced before refilling the developer tank; additionally, a splash guard should be used.)

If **flooded replenishment** is used, starter should be added to the developer replenisher holding tank. The typical volume of KODAK Developer Starter for all KODAK Medical X-ray Films is 3 fluid ounces (89 mL) per US gallon (3.8 litres) of developer replenisher. The typical volume of KODAK *RP* X-OMAT Developer Starter for KODAK MIN-R 2000 Film is four ounces [(119 mL) per US gallon (3.8 litres)/31ml per litre]. Additional starter should not be added to the processor developer tank.

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How important are environmental temperature and relative humidity to image quality?

Storage of Unprocessed/Unexposed Film

Most medical x-ray films come in a sealed, moisture-proof inner wrap, which is packed in an outer cardboard box. Sealed packages of film are affected by heat; open packages are affected by both heat and humidity.

All packages of film should be stored away from heat sources: store in a cool, dry place at a temperature between 50° and 70° F (10° to 21° C). The National Council on Radiation Protection and Measurements (NCRP) Report No. 99 recommends that photographic material be stored at temperatures less than 75° F (24° C).

Keep open packages of film at a relative humidity between 30 and 50 percent. An inexpensive instrument called a sling psychrometer can be used to measure relative humidity. This instrument is commonly available through precision instrument supply houses. Hygrometers may also be used to measure relative humidity. Check the accuracy of the instrument under consideration before purchasing it.

Consult your film manufacturer(s) for temperature and relative humidity recommendations for the specific type(s) of film used in your facility.

Also keep in mind that temperature and relative humidity values frequently fluctuate throughout medical facilities from season to season. Year-round tight control of temperature and relative humidity should be the goal to achieve and maintain high quality and stable radiographic images.

It is also important to avoid storing film near chemical fumes, which can fog film. Film may also be damaged by exposure to radiation from x-ray machines or radioactive materials.

In addition, packages of sheet film should be stored on edge (like the books in a library). This allows for easy rotation of inventory. Always use older films first. The film's expiration date is generally printed on both the box's front and side panels, so the date is visible when the boxes are stored on edge.

Boxes of film should never be stacked horizontally because film at the bottom may show pressure artifacts by being weighed down by other boxes or cases of film.

Storage of Processed Film

Proper storage and handling of processed film is imperative for stability of the radiographic image. It is especially important to treat

single-emulsion mammography film with great care, the same care you would give to your most treasured family photographs.

Film must be thoroughly washed during processing to remove residual fixer, which can cause staining and fading. Tests for fixer retention should be done at least every three months.

Since all films contain gelatin as one of the principal ingredients of their emulsion, it is important to maintain a constant temperature at about 70° F (21° C) and 40 to 60 percent relative humidity.

Subjecting radiographs to humidity below 30 percent and/or high temperatures can occasionally lead to emulsion cracking, an artifact that appears as a series of parallel lines in a D-max area of the film. This artifact can be avoided by storing film at constant temperatures and humidity, not overexposing film to "hot-lighting," and using only the recommended bulb wattage for hot lights.



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Should single-emulsion mammography film be processed emulsion side up or down?

Each processor used for mammography film (manually fed) should be evaluated before establishing the processor quality control (QC) program to determine whether single-emulsion mammography film should be processed emulsion side up or emulsion side down. The decision should be based on which orientation provides the best uniformity and the fewest processor-induced artifacts. There are no regulations that require a specific film orientation. Room-light processing systems are excluded from this evaluation because film orientation during processing is fixed.

Initially, it is necessary to assess whether any artifacts are being caused by the x-ray equipment, especially the grid(s). Both the 18 x 24 and 24 x 30 cm grids should be evaluated. This procedure (Artifact Evaluation) is discussed in the 1999 American College of Radiology's *Mammography Quality Control: Medical Physicist's Manual*.

Then follow this procedure:

1. Select a 24 x 30 cm mammography cassette that is known to have good screen-film contact.
2. In the dark, load a sheet of film into the cassette so that the film notch is positioned at the lower right corner or the upper left corner. The emulsion is upward facing if the notch or notches are located as described.
3. Place the cassette in the non-grid cassette holder or on top of the grid. A uniform sheet of acrylic (1-inch [2.54 cm]) thick may be placed on top of the cassette.
4. Select an exposure technique that will provide an optical density of 1.10 to 1.50 on the processed film.
5. In the darkroom under safelight illumination, remove the exposed film from the cassette. Lay the film on the film feed tray so that :
 - The widest dimension of the film is the leading edge.
 - The emulsion side is up.
 - The film edge is along the guide on the right side of the film feed tray.

Using a pencil, mark "↑UR" on a corner of the film nearest the film guide immediately before processing. The leading or trailing film edge corner may be used, as desired, as long as consistency is employed. The "↑" indicates the direction of film travel, "U" indicates that the emulsion side is up, and "R" indicates that the right hand side of the processor was used.

6. Repeat the above steps for three additional films, all processed with the widest dimension of the film as the leading edge, and as follows:
 - o Process film #2 emulsion side up on the left side of the film feed tray; mark the film "↑UL."
 - o Process film #3 emulsion side down on the right side of the film feed tray; mark the film "↑DR."
 - o Process film #4 emulsion side down on the left side of the film feed tray; mark the film "↑DL."

7. Place the four films on a view box and evaluate. Careful analysis will indicate whether emulsion up or down gives the best overall processing results. All clinical and QC films should then be processed in the same orientation.

It may also be possible to determine if one side of the processor is significantly different than the other in terms of artifacts. If so, it may signal a need to have one or more rollers replaced. It is important to check whether any film feeding practices (e.g., all single films habitually fed on the right side) may be accelerating roller wear on one side of the processor versus the other. Clinical films should be processed on both sides of the processor to prolong roller life. All QC films, however, should be processed consistently on only one side.

Note that while the above evaluation should take place in all processors used for mammography film, many processor manufacturers do recommend a particular orientation. Information on specific processors may be obtained by consulting the processor manufacturer.

It is also generally considered that processing mammography films with the emulsion side up will provide the best overall results. Notable exceptions include the recommendation that KODAK MIN-R EV, KODAK MIN-R 2000 and MIN-R L Films should be processed emulsion-side down in KODAK MIN-R Mammography or KODAK M35 or M35A-M X-OMAT Processors. It may be necessary to install smooth guide shoes to minimize guide shoe marks.