

KODAK Oncology Imaging Guide

PURPOSE OF THIS GUIDE

The following information is intended to be a useful guide to understanding and optimizing the use of Kodak EC film and other films for oncology imaging. Imaging applications for Kodak EC film include both portal localization and verification imaging. For optimum results, it is recommended that Kodak EC film components be used together, along with Kodak film processing chemicals and equipment.

*If you have any questions concerning the information contained in this guide, contact your regional Kodak oncology manager or Kodak customer support for medical products (USA) at **1-800-328-2910** (USA area code **716-724-9362**). Some of the information contained in this guide can also be seen on the Health Imaging Web site: **www.kodak.com/go/oncology**.*

HOW TO USE THIS GUIDE

This Kodak guide includes the following sections to provide information and to help optimize image quality:

- **Technology & historical overview**
- **KODAK EC film design & applications**
- **Localization imaging applications**
 - For Cobalt 60, radiosurgery, radiotherapy, and intensity-modulated radiation therapy (IMRT)
- **Processing KODAK EC film**
- **Screen cleaning and antistatic treatment**
- **Compatibility of EC films with select KODAK products**
- **Technical considerations and technique recommendations for EC-L film systems**
 - Using multiple energies
 - Image geometry
 - Patient thickness
 - Field size
 - Film processing
- **KODAK EC-L film system technique charts**
- **Simulator exposure chart**
- **Artifact isolation fundamentals**
- **Questions and answers**
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 - Replenishment rates, chemistry selection, and processor selection
 - Safelights
 - When images are too light
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 - Geometric factors and intermittent density variations
- **Other KODAK oncology products**
 - SIM—KODAK simulation film
 - PPL-2—portal pack for localization
 - KODAK X-OMAT radiation therapy cassettes L and V and KODAK X-OMAT verification film (XV)
 - KODAK EDR-2 film for dosimetry/QA/equipment calibration
 - Other KODAK films for direct exposure
- **Other KODAK products**
 - Film processors
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- **KODAK EC-L and EC-V film systems catalog numbers**
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- **Information needed by Kodak to facilitate troubleshooting**
- **References**

TECHNOLOGY & HISTORICAL OVERVIEW

History of portal imaging

Some of the earliest portal images were recorded on industrial-type, direct-exposure films. These films were often placed in cardboard film holders and required special processing. In 1974, Eastman Kodak Company introduced films in light-tight (Kodak Ready-Pack) envelopes for portal localization and verification. Reasonably good quality portal images could be obtained by direct exposure using treatment machines such as Cobalt 60 units (1.2 MeV) and Van de Graff generators (approximately 2 MV). However, the image quality at higher energies was poor.

As high-energy linear accelerators were being introduced, studies by Hammoudah and Henschke and by Droege and Bjarngard showed the importance of using metal plates for portal imaging.^{1,2,3} They showed that some types of conventional medical films could be used, depending on the film's sensitivity to exposure by electrons. Droege and Bjarngard also showed that film contrast is independent of x-ray energy and metal screen composition.^{2,3} They published MTF data characterizing the spatial resolution of metal plate detectors at megavoltage energies.

Visibility of anatomical structures and landmarks has always been difficult when using conventional medical x-ray films with higher-energy portal imaging. Such films are designed for medical radiography at far lower beam energies. Most screen-type medical x-ray films, regardless of their inherent film contrast level, exhibit very similar and very low measured contrast when exposed under non-phosphor screen exposure conditions in portal localization and

verification imaging procedures. A widely used measurement of film contrast in radiographic imaging is called average gradient. As the name indicates, this measurement is an average of many individual contrast (i.e., gradient) measurements along a film's characteristic curve or H & D curve, between specified processed film densities. Most screen-type medical x-ray films will produce an average gradient measurement of approximately 1.6 when used for localization and verification imaging without phosphor intensifying screens. This contrast level is well below what is seen with typical low-contrast or "latitude"-type medical radiography films, which have average gradients in the vicinity of 2.1–2.4. This can make some measurements and appropriate placement of the treatment beam more difficult to determine accurately.

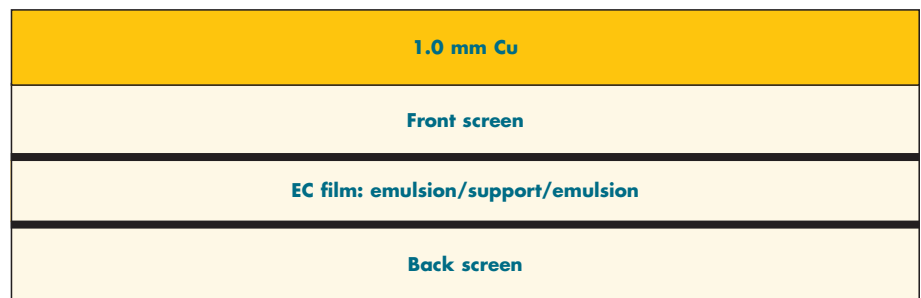
In 1981, Du Pont introduced cassettes with lead front and back plates to be used with conventional medical x-ray film. Kodak introduced cassettes in 1983 with copper front plates and lead back plates, copper front and plastic back plates, and films in light-tight (Kodak Ready-Pack) envelopes that fit inside the cassettes for portal localization and verification imaging.

These systems gave better images at the new higher treatment energies but the contrast of the final image was still low.

New thinking in portal imaging

The Kodak EC-L (enhanced contrast for localization) film system uses light instead of electrons to expose the film. Kodak EC film is not a traditional medical diagnostic x-ray film "borrowed" for use in portal imaging but a product uniquely designed for this purpose. Electrons generated within the cassette are absorbed in gadolinium oxysulfide phosphor screens and are converted into light. Light emitted from these dual phosphor-coated screens exposes the double-emulsion Kodak EC film, as can be seen in Figure 1.

Figure 1
*Kodak EC-L film system for oncology**



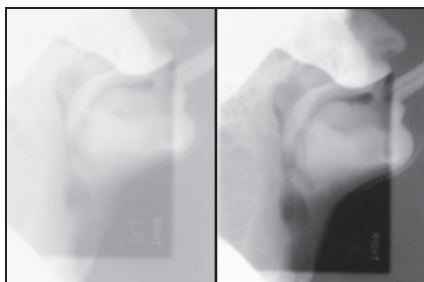
* Not to scale.

KODAK EC FILM DESIGN & APPLICATIONS

Kodak EC film has a characteristic curve designed with the unique needs of portal imaging and verification imaging in mind. Because light from phosphor intensifying screens is used to expose the film instead of a direct electron exposure to the film, a much different film emulsion can be created. Using the usual film contrast measurement called “average gradient” as our reference, the differences are immediately clear. Typical “high-contrast,” screen-type medical x-ray films have average gradient values or numbers of approximately 3.0. Very-high-contrast films designed for mammography have average gradients of approximately 3.6. The average gradient of Kodak EC film is approximately 6.0, and because light instead of electrons exposes the Kodak EC film, the characteristic curve (i.e., image contrast) is similar over energies from 6 to 20 MV. Metal ion “doping” of the silver-halide microcrystals contributes further to enabling this very high image display contrast level.

The intensifying factor delivered by the use of rare-earth screens, coupled with the high-energy exposure source, allow the design of a very slow-speed, very fine-grain film emulsion. Kodak EC film emulsion’s extremely small grain size, narrow grain size distribution, and low diffuse density variations work together to provide a very high-contrast, low-noise image (see Figure 2).

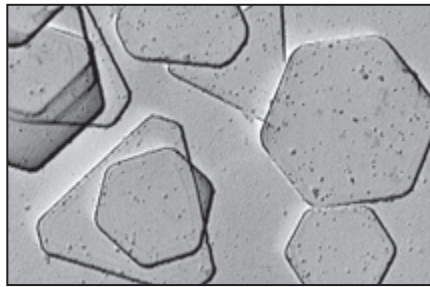
Figure 2



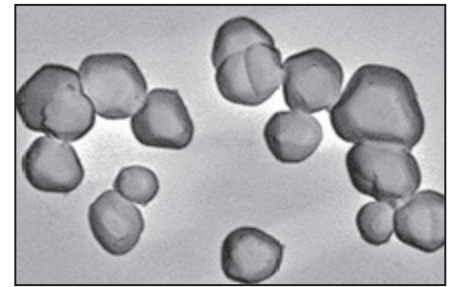
Conventional film

Kodak EC-L film system

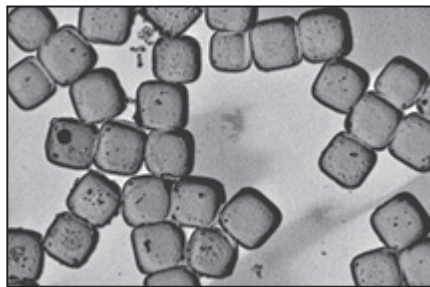
Figure 3



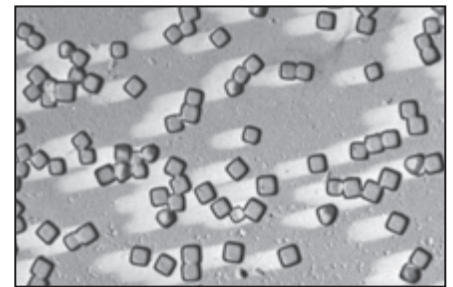
Tabular grain emulsion



3-dimensional grain emulsion



Conventional micro-cubic grain

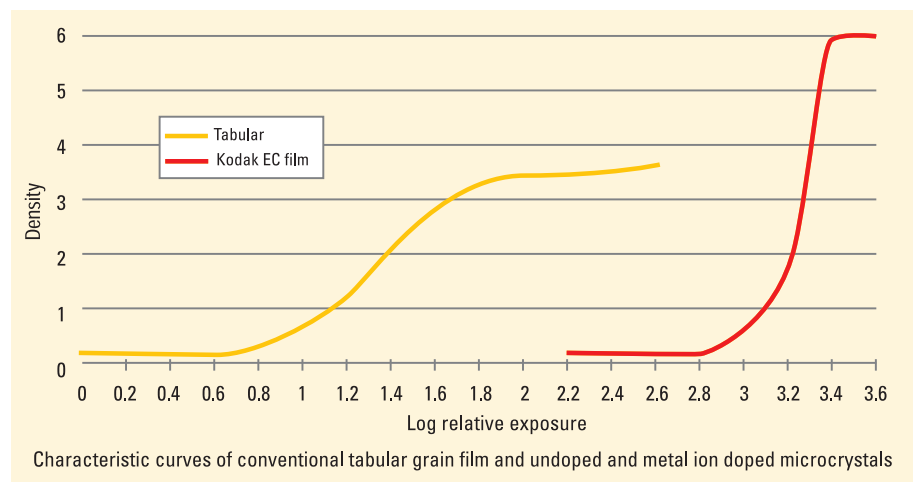


Kodak EC film emulsion

This very small grain size and much narrower distribution of grain sizes can be seen in the comparison electron microscopy photographs in Figure 3. Three different emulsion designs are shown: conventional 3-dimensional grains, tabular grains, and micro-cubic grains. Note the relative size differences

in the two micro-cubic grain photomicrographs. The difference in film contrast is evident in Figure 4, where comparison H & D curves for conventional tabular-grain film and Kodak EC film are shown.

Figure 4



KODAK EC FILM DESIGN & APPLICATIONS *(continued)*

Localization imaging applications

Through the use of different phosphor screens with varying speeds, Kodak cassettes designed for localization imaging are available to fit a wide range of equipment types, energy levels, and patient body part treatment areas. Faster cassette/film systems are ideal for fields such as the lateral pelvis, for example. Slower-speed cassette/film combinations may be appropriate to compensate for beam energies higher than 6 MV, particularly 18 MV or higher (see Table 1).

Using KODAK EC FILM with Cobalt 60 sources

Kodak EC film can be used with Cobalt 60 sources for better visualization of key landmarks near the center of the treatment field. However, because of the high contrast of this film, the penumbral region may be more difficult to image with Kodak EC film.

Using KODAK EC FILM for stereotactic radiosurgery and radiotherapy patients

The Kodak EC-L film system allows unprecedented verification and enhanced quality assurance of stereotactic radiotherapy and radiosurgery. The very low image noise and high-contrast characteristics of Kodak EC film allow for high-resolution, digitally scanned images, vital to this application. Visualization of the small localization markers used in stereotactic procedures can be seen more easily. The low image noise of a digitized EC film allows clinicians to utilize software tools identifying the 3-D position of the patient and the treatment beam.

Using the KODAK EC-L FILM SYSTEM for intensity-modulated radiation therapy (IMRT)

In IMRT, reproducible positioning of the patient can be even more important versus traditional radiotherapy. The smaller field sizes allow less inclusion of anatomy for orientation purposes and for confirmation of treatment of the same location identified in simulation. Portal imaging with the Kodak EC-L film system can significantly increase the confidence in knowing that the immobilization system is working accurately, due to the significant increase in image contrast. Such improved clinical visibility can mean a reduction in patient positioning errors, thus improving control of tumors and reducing the risk of healthy-tissue complications.

Verification imaging applications

The Kodak EC-V verification system builds upon the innovative technology introduced with the Kodak EC-L film system for portal localization imaging.

The difference between localization and verification cassettes is the exposure required to produce an image. This is underlined by the intended application. In verification, the imaging system will be exposed for the entire prescribed dose for a specific treatment field, compared to localization that involves a short collimated exposure and a short open field exposure, to confirm patient positioning. Thus the verification systems must necessarily be much slower than localization systems—hence slower screens (less light output) are used.

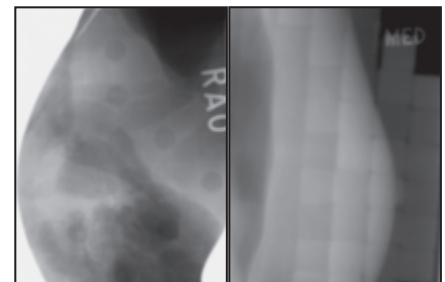
To use the EC-V system, therapists position the Kodak EC-V verification cassette before beginning a patient's treatment. The Kodak EC film records the radiation delivered during the treatment. This provides an accurate record of the irradiated area, because the film is exposed by the treatment beam.

There is also typically a 2- to 5-minute reduction in the treatment process, due to the elimination of technologist travel into and out of the treatment room to prepare the field for the double exposure. This streamlining of the treatment process offers radiation therapy departments an opportunity for improved productivity. It also can mean the elimination of non-prescribed radiation from double-exposure localization, which may not be counted in treatment prescriptions.

The Kodak EC-V verification system works particularly well for breast, whole brain, and head and neck images (see Figure 5).

There are two different cassette offerings: an EC-V regular (90 cGy) and an EC-V fast (45cGy) cassette. The regular cassette contains a single phosphor intensifying screen; the fast cassette has a pair of screens. Both use the Kodak EC film (see Table 2).

Figure 5
Oblique lung view (left) and breast view (right) using Kodak EC film



Benefits realized from using KODAK EC FILM

For localization and verification imaging include :

- More than 3X improvement in contrast over conventional portal imaging systems (see Figure 6)
- Reduction in time required to image one treatment field, resulting in an average of 2 minutes' savings per film. This can deliver increased capacity without adding resources (EC-V verification system)
- An image record of the entire treatment dose (EC-V verification system)
- Elimination of non-prescribed radiation (EC-V verification system)
- One film for both localization and verification imaging

- Fast and easy processing in a conventional film processor

Kodak cassette configurations for portal localization and verification are seen below (Tables 1 and 2).

Different variations of Kodak localization and verification cassettes are available to provide flexibility in matching the exposure to the imaging application. With the Kodak EC film's very high contrast, achieving the appropriate exposure is very important. The average exposure must be in the high-contrast part of the film response to achieve a high-contrast image on the viewbox. The different cassette/screen offerings represent a choice of different system speeds (similar to what is commonly seen in conventional x-ray imaging).

A practical example of the use of different Kodak oncology cassettes: the exposure to the patient in the localization for a lateral pelvis procedure can be reduced 30% by using the EC-L fast cassette configuration.

Figure 6
Comparison of the Kodak EC-L film system and conventional film images
AP Lung Portal Localization

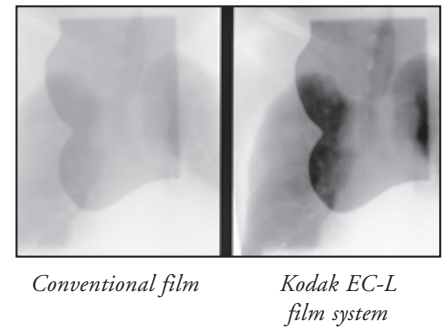


Table 1

Localization Cassettes	Metal Screen	Front Phosphor*	Back Phosphor†
EC-L fast	1.0 mm Cu	Kodak Lanex fast back screen	Kodak Lanex fast back screen
EC-L regular	1.0 mm Cu	Kodak Lanex fast front screen	Kodak Lanex fast back screen
EC-L slow	1.0 mm Cu	Kodak Lanex fast front screen	Kodak Lanex fast front screen

* Phosphor coating coverage of Kodak Lanex fast front screen is approximately 44.5 g/sq ft or 48 mg/cm².

† Phosphor coating coverage of Kodak Lanex fast back screen is approximately 124 g/sq ft or 133 mg/cm².

NOTES:

- Kodak Lanex screens are composed of gadolinium oxysulfide: terbium doped or activated
- The Kodak Lanex fast back screen has higher coverage (i.e., thicker phosphor layer) than the Kodak Lanex fast front screen

Table 2

Verification Cassettes	Metal Screen	Front Phosphor	Back Phosphor
EC-V fast	1.0 mm Cu	Phosphor screen‡	Phosphor screen‡
EC-V regular	1.0 mm Cu	Phosphor screen‡	(no screen)

‡ The same screen is used in all Kodak EC-V cassettes. This is basically a Kodak Lanex fine screen, modified to reduce the light output—this screen is slower than the screens in the EC-L system. Phosphor coating coverage in the Kodak EC-V verification system screen is approximately 31.5 g/sq ft or 34 mg/cm².

PROCESSING KODAK EC FILM

The film-processing stage in the creation of the final image is critically important in diagnostic and therapeutic imaging. Inattention to processing conditions can reduce image quality.

The micro-cubic grain emulsion technology used in Kodak EC film provides highly stable sensitometric response in varying processing environments, which is very important with this film's uniquely high average gradient. In addition, it has excellent drying characteristics. It is best suited for processing in standard 90-second or equivalent cycles. For optimum results, Kodak recommends the use of Kodak RP X-Omat Developer and Replenisher and Kodak RP X-Omat LO Fixer and Replenisher. Kodak EC film can be handled under

safelight illumination. A Kodak GBX-2 safelight filter or equivalent is recommended.

Replenishment rate suggestions for processing Kodak EC film are the same as those rates recommended by Kodak for processing most Kodak medical x-ray films for general radiography. Kodak service bulletin #30 gives detailed information on setting replenishment rates for various films, film volumes, and Kodak processor types. Note that for lower-volume-processing circumstances, higher replenishment rates are recommended. Often the daily film processing volume in an oncology imaging department may suggest setting higher replenishment rates. The CAT No. for this service bulletin is 835 7923. It is also

cross-referenced by a Kodak part #632661 or Kodak publication number N-923. There is no charge for this service bulletin.

The automated Health Imaging fax back system can also be accessed 24 hours a day to send this document to the receiver's fax machine. The USA toll-free number is 1-800-336-4722 and the 6-page service bulletin #30 is document #800210. The Kodak fax back system can also be accessed by dialing USA area code (716) 781-8473. A touch-tone phone is required to use this system.

Some data from Kodak service bulletin #30 can be seen in Table 3 below.

Table 3

Recommended replenishment rates for length processors

- KODAK X-OMAT processor models M35, M35A, M35-M, M35A-M, Clinic 1, M7B, M7B-E, M6A-N, M6AW, M6B, 1000, 1000A, 1000J, 2000, 2000A
- KODAK MIN-R mammography processor
 - Replenishment takes place whenever film is in the entrance rollers
 - Replenishment rates must be set according to usage and film size(s) fed
 - Film should be fed as recommended in the processor Operator Manual/User Guide

Film Size Processed	Use Condition	Average Number of Films per 8 Hours of Processor Operation	Developer Replenishment Rate (mL per 35 x 43 cm)	Fixer Replenishment Rate (mL per 35 x 43 cm)
Average size intermix film	High	115 sheets or more	50	70
	Medium	40–115 sheets	65	85
	Low	40 sheets or less*	80	100
35 x 43 cm film (only)	High	75 sheets or more	60	85
	Medium	25–75 sheets	80	100
	Low	25 sheets or less*	100	120

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

“Chemistry matters”

Different types of films respond differently in different types of processing chemicals. This variation can occur among different processing chemistry types from the same manufacturer, or from manufacturer to manufacturer. In some cases, just switching to the chemistry made and recommended by the film manufacturer can yield visible changes on the viewbox. In other words, there can be a difference between “changing chemistry” from old solutions to fresh solutions and “changing chemistry” from one type or brand to another.

Positively affected aspects can include increased speed (i.e., reduced monitor units), improved image contrast, possible reduction in dryer artifacts, and “cooler” image tone. With the knowledge that portal imaging by nature does not offer an abundance of image contrast, it makes sense to review the film manufacturer’s recommendations for processing chemistry.

The special sensitometric characteristics and performance of Kodak EC film are optimized when proper attention is given to processing conditions. Many common problems with image quality stem from the processing environment. The typical sources for many of these imaging concerns include insufficient chemistry replenishment, chemistry type and condition, processor type and condition, and safelighting.

Poor processing conditions can undermine the best efforts of the radiation therapist in exposure selection, and possibly result in higher exposures than necessary. Inconsistent film densities over time can be another consequence of a less well-controlled processing environment.

The film processor

The general *condition* of the film processor and/or the *type* of film processor can influence the performance of Kodak EC film as well. As a group, the so-called “shallow tank” or “tabletop” film processors have internal roller path and “roller strike” designs which necessarily differ in many aspects from those seen in larger processors. These design differences tend to produce more processing artifacts on Kodak EC film. There can also be differences in chemical oxidation rates among these small processors. Smaller internal tank volumes can sometimes mean that smaller amounts of chemistry contamination and replenishment irregularities will produce visible density differences in films. For these reasons, processing Kodak EC film in “shallow-tank” automatic film processors is not encouraged.

In some situations and environments with shallow tank-type processors (and with larger film processors too), it is useful to set the recommended processor up for what is called “flooded replenishment.” Flooded replenishment is typically recommended for low-volume processing conditions. In such conditions, there is a greater chance of chemical oxidation and resulting impaired image quality/consistency over time. Flooded replenishment is a practice where chemistry replenishment is delivered regularly via a timer mechanism, whether or not film is being processed. In conjunction with this, there is usually a change to the normal routine of adding “starter” solution to the developer tank inside the processor upon a chemistry change. With flooded replenishment, the addition of starter solution is omitted, so both the internal

processor tank and the external replenisher tank contain the same identically prepared developer. Many film processors today have built-in electronics to allow quick setup for flooded replenishment if this is needed.

There is additional discussion on selected “processing” topics in this guide in the “Questions and Answers” section.

Safelight recommendations

It is wise to check safelight performance/integrity semi-annually, or as needed. Small cracks can develop in the filter material over time, allowing white light to strike the film, and this can cause intermittent, irregular artifacts that are sometimes hard to trace. Use the right type of safelight filter along with the proper type and wattage light bulb. Kodak recommends the Kodak GBX-2 safelight filter or equivalent for Kodak EC film. Maximum bulb wattage should be 15 watts for direct illumination and 25 watts for indirect illumination. If direct illumination is used, the safelight(s) should be at least 4 feet (1.22 meters) from the film-handling area(s).

Even the way a safelight filter is installed in the fixture, i.e., its orientation front vs. back, may be specifically indicated. With the Kodak GBX-2 safelight filter, the filter should be oriented so that a person looking at the installed filter can read the lettering on the filter glass.

PROCESSING KODAK EC FILM *(continued)*

You can also perform the following “quick” test if the Kodak safelight test kit is not available:

1. Place a loaded cassette on top of the treatment table and expose a 35 x 43-cm field to 2 MU for Kodak EC film. Turn off all lights and safelights in darkroom.
2. Remove the film and cover half the exposed film area with an opaque cover (film box, film box stiffener board, etc.)
3. Turn on safelight(s) and allow the uncovered half to remain exposed to the safelight for 2 minutes.
4. Turn off safelight(s) and process the film.
5. Using a densitometer make two optical density readings near the middle of the film; one on the covered and one on the uncovered side.
6. The optical density of the uncovered half of the film should be between 1.0 and 1.4. Consider adjusting the exposure if the optical density is not in this range.
7. If there are differences in optical density greater than 0.05, safelight integrity, bulb wattage, or safelight location(s) should be checked.

To check for white-light leaks in the darkroom, it is useful to go into the darkroom, turn ALL lighting off, and remain in the darkroom for several minutes to allow vision to adjust. (Lights on energized processors or other darkroom devices are typically OK.) Small white-light leaks around doors or around cutouts in walls for processors are easier to detect after the eyes have some time to adjust to total darkness. Remember that not all light leaks might be seen from an upright, standing height, so move around in the darkroom and examine the darkroom from different angles and heights.

Film storage and handling recommendations

Ideally, all packages of film should be stored in an area properly shielded from penetrating radiation at a temperature of 50 to 70 degrees F (10 to 21 degrees C). Store opened packages at 30% to 50% relative humidity. Store processed images at 60 to 80 degrees F (15.5 to 26.5 degrees C) and 30% to 50% relative humidity.

Each package of film should be placed on edge to avoid pressure marking the film. Use older dated film first. Handle film carefully to avoid physical strains caused by pressure, creasing, buckling, and friction. Film should not be drawn rapidly from the box or the cassette, or be handled in any way that would cause static electricity discharges.

SCREEN CLEANING AND ANTISTATIC TREATMENT

The phosphor screens in Kodak film system cassettes can be cleaned using Kodak intensifying screen cleaner and antistatic solution. Here are the Kodak-recommended screen-cleaning and antistatic application instructions:

Cleaning intensifying screens:

1. Dampen a clean, lint-free gauze pad or sponge with the solution. Use the minimum amount of screen cleaner needed to moisten the cotton ball or gauze. Excess screen cleaner will not improve screen cleanliness, nor will this facilitate rapid air-drying of the screen(s).

2. Wipe one screen at a time. After cleaning, wipe each screen again with a dry, clean, lint-free gauze pad or sponge.

3. Allow screens to air dry completely before returning them to service.

Antistatic treatment (if this is necessary or desired):

1. Clean screen(s) as recommended above.
2. Apply a second application of the solution to the screen(s) with a clean, lint-free gauze pad. DO NOT WIPE THE SCREEN(S) DRY. Set the screen(s) aside until thoroughly dry.
3. When dry, return cassette and screens to service.

If Kodak intensifying screen cleaner and antistatic solution is not available, a mild soap-and-water solution may be used following the procedure given in steps 1 through 3 in the screen cleaning instructions in this section. Do not use soaps or detergents containing brightening agents. Denatured ethyl alcohol may also be used, but only in small amounts and confined to the screen surface. Avoid excessive pressure and rubbing that may damage the screen surface.

The use of any cleaning agents other than those specifically suggested for cleaning Kodak intensifying screens is not recommended.

COMPATIBILITY OF EC FILMS WITH SELECT KODAK PRODUCTS

Kodak EC film and EC-V verification system cassettes use the Kodak X-Omat and X-Omatic cassettes that are fully compatible with Kodak multiloader units models XML 7000, ML 700 plus, XML 300 plus, and XML 300.

The Kodak multiloader ML 700 utilizes infrared film sensors that may not reliably detect the almost transparent Kodak EC film at some points during film transport within this particular model.

Kodak EC film can be used with the Kodak x-ray film identification printer, model B. The X-Omatic identification camera, model 2, can be modified to be compatible with

Kodak EC film. This modification will provide the ability to record patient information on both EC and conventional films. Contact your regional Kodak oncology manager to receive further information on this modification package. These units are operated in full roomlight.

The Kodak x-ray film identification printer, model B, can also be used for exposing patient identification on this and all film. This is a small, darkroom-operated device that can be ordered through your dealer. Designed for use in a darkroom setting, the model B printer is a cost-effective solution to data-recording needs.

A longer exposure is necessary to record patient information on Kodak EC film with the model B printer, necessitating a slightly different operation of the printer in practice. The model B printer is also compatible with Kodak simulation film and most other general-purpose x-ray films.

TECHNICAL CONSIDERATIONS AND TECHNIQUE RECOMMENDATIONS FOR EC-L FILM SYSTEM

Technical considerations for EC-L film system

Kodak EC film and Kodak EC-L cassettes have been specifically designed to produce high-contrast images at the megavoltage energies of therapy radiation. The high contrast enables greater visualization of anatomical structures, which can help in ensuring the appropriate placement of the treatment beam in a portal localization procedure.

With high contrast, the latitude of the film is reduced. This puts greater emphasis on careful control of the exposure conditions to create a consistent image. The consistent production of high-quality EC-L images requires careful consideration of all the factors affecting exposure.

An estimation of the amount of radiation to expose the Kodak EC film/EC-L cassette is based on the following factors:

- Energy of the radiation beam
- Geometry
- Patient thickness or separation
- Field size
- Film processing

Following a few simple steps will ensure optimal EC-L system images, and lead to greater confidence in therapy localization. At the end of a brief discussion on the factors listed above, technique charts that can be developed and used to estimate the exposure for

Kodak EC film and EC-L cassettes are presented.

In these charts, a double exposure is specified in the form of $x+y$. The first number refers to the exposure to the treatment field and the second number to the exposure to the secondary or open field. Note that in these tables, only 1 MU is typically specified to the treatment field. The rationale is that this minimizes the difference between the treatment exposure relative to the total exposure and works to ensure that the treatment field is not too dark relative to the secondary or open field.

If it is necessary to manipulate the exposures specified in these charts, always add or subtract exposure from the secondary or open field. Additional exposure to the treatment field should be considered only in situations where very large exposures are necessary.

Using multiple energies

Many modern treatment machines can operate at multiple energies. The lowest energy available should be used for port filming, because the contrast between structures (i.e., the subject contrast) will be greatest at lower energies. This will result in better visualization of structures in the image. When high energies are used, in addition to lower contrast, there is greater transmission through the patient, and more energy reaching the receptor. As a result, less exposure is

required. The techniques included at the end of this discussion have been separated according to the energy of the radiation beam. Note that less total exposure is required at higher treatment energies.

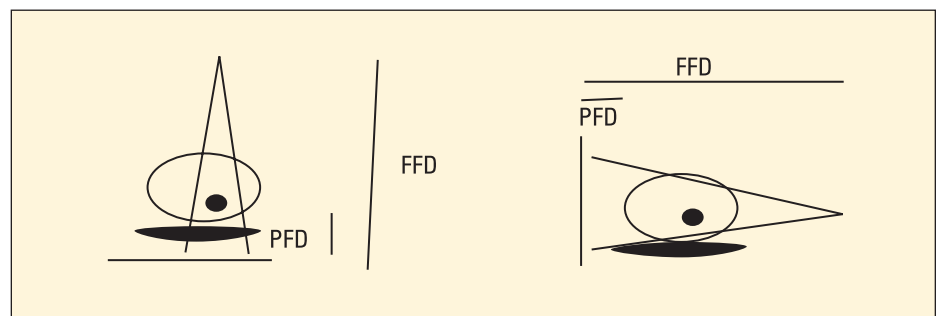
Image geometry

Geometry is an important consideration in determining the exposure for any radiographic procedure. Factors influencing geometry of the source relative to the patient and the film (image receptor) are the location of the disease, the orientation of the beam, and the access around the patient.

Typically the target volume is positioned so that it is at the isocenter of the treatment device, which is commonly 100 cm from the source. The position of the image receptor relative to the source is referred to as the focal-film distance, or FFD. This distance is influenced primarily by the orientation of the beam and the access around the patient. Another important distance is the separation between the exit of the patient and the film, referred to in the figure as the PFD (Figure 7).

The distance from the source to the film is important, because the intensity of a projection beam, which diverges from a small source of radiation, diminishes according to the square of the distance from the source (inverse square law). Practically speaking, then, a receptor placed farther from the source (larger

Figure 7



FFD) will require the specification of a higher exposure technique in order to achieve adequate darkening of the film.

If the radiation originating at the source of the treatment machine were the only radiation, then the FFD would be the only important geometric consideration impacting technique. However, the intensity of radiation behind the patient has been observed to fall off more rapidly than would be predicted by the inverse square of the FFD. A dependence that is roughly related to the inverse cube of the FFD has been measured empirically. This dependence is understood in terms of two additional factors: electrons originating from interactions within the patient, and the proximity of this patient source of radiation to the image receptor.

At megavoltage energies, photons that interact within the patient produce electrons. Some of the electrons created close to the exit of the patient can escape into the gap between the patient and the image receptor. Some of these will reach the receptor and interact to expose the film. These electrons effectively act as a second source of radiation. There is a greater impact associated with the receptor placement relative to the radiation from the patient than the therapy source, due to the fractional distances involved. The prediction, which has been verified empirically, is that the optical density falls (due to the drop in intensity) much faster than would be predicted by the inverse square of the FFD alone.

Understanding the implications of the distance between the patient and the receptor (PFD) is extremely important in ensuring consistent results with the high contrast and narrow latitude of

EC-L exposures. For optimal image quality, the distance between patient and cassette should be reduced as much as is reasonably possible. As the distance between patient and cassette increases, density decreases, following the inverse square law. Kodak EC film will amplify this effect due to its considerably higher film contrast vs. conventional films. If distance increases, a compensating increase in monitor units will need to be made.

This should be remembered if and when the cassette is placed at different distances from the patient each time the patient is treated. Changes in density due to the contrast characteristics of the Kodak EC film should be anticipated, and proper exposure techniques for each situation should be noted. The distance between the patient and the film is more important than the distance between the source and the film for predicting the appropriate exposure technique.

How is geometry reflected in the specification of the technique charts? In the AP projection, where the image receptor is placed beneath the patient, the cassette is commonly rested on supports beneath the patient couch. This is very desirable, as the cassette is placed at a fixed and reproducible distance relative to the source and the patient.

In other projections, the beam may traverse a greater distance across the patient, and the patient couch may prevent getting the image receptor close to the patient. In this case, much greater distances would be involved and exposures would be expected to increase. This is reflected in both the geometry and the recommended exposures specified in the technique charts for AP vs. lateral procedures. The increase in the

exposures for the lateral geometry is due to both the increases in radiation from the source (FFD) and radiation from the patient (PFD).

The charts provided in this section are for use with the geometry specified. Other geometries are possible; however, it will be necessary to customize the techniques accordingly. The discussion above should be used as a guide: pay close attention to the PFD. Using a smaller PFD will minimize the exposure required. As PFD increases, an increase in exposure will be required (i.e., add exposure to the open field of 1 MU for each additional foot of PFD).

It is very important to note that once a geometry is chosen, the reliable production of consistent high-quality EC film images requires careful attention to and consistent use of that geometry. Many facilities have improved their consistency by using a short ruler or piece of string to ensure a consistent separation between the patient and the film.

Patient thickness

The thickness of the patient will affect the amount of radiation reaching the image receptor. As patient thickness increases, more exposure is needed to compensate for the increased attenuation. This is reflected in the technique charts in this guide, in that the techniques for some anatomical parts have been divided according to patient profile: small, medium, and large. Note that exposure has been added to the open field as the patient thickness increases. In situations where the patient is either very thick or very thin, consider adding or subtracting exposure from the secondary or open field.

TECHNICAL CONSIDERATIONS AND TECHNIQUE RECOMMENDATIONS FOR EC-L FILM SYSTEM *(continued)*

Field size

The field size is not specified in the technique charts. It is important to note that field size can affect the technique selection, because the amount of scattered radiation will increase as field size increases. This will cause the overall density of the image to increase. If large fields are being used, then the exposure should be reduced in the secondary or open field.

This relationship between field size and image density is more apparent with imaging systems that use intensifying screens, such as the Kodak EC-L film system, coupled with the approximately 3X contrast amplification delivered by Kodak EC film. Small adjustments or changes in radiation intensity are translated into more pronounced image density changes, due to the combination of intensifying screens and the very-high-contrast film.

This same principle operates to a lesser extent among the typical choices of low-contrast, medium-contrast, and

high-contrast general radiographic films in conventional medical radiography. The very-high-contrast films currently used in film-screen mammography imaging also place similar demands on the accuracy of exposure parameters, attention to body part thickness, field size, and collimation.

The size of the treatment field will be determined in the treatment plan. Some additional consideration should be given to the size of the secondary or open field. Using a large secondary field in the hopes of seeing more anatomical landmarks will increase the scatter, and reduce the contrast of the image. The secondary or open field should be defined according to a fixed increment from the dimensions of the treatment field, rather than using a very large field, or one corresponding to the maximum opening of the port. A 5-cm increment is recommended to allow increased visualization of the regional anatomy, without excessive increase in the amount of scattered radiation.

Film processing

Proper film processing is important with any medical imaging film. Processing conditions can change exposures by as much as 50 to 100%. The technique charts listed on the following pages assume that Kodak recommendations for processing of EC film are being followed. These recommendations are summarized in Kodak service bulletin #30. Local processing conditions can influence the speed and contrast. If speed is affected (the images are dark or light), manipulate (reduce or increase exposure) the exposure recommended for the secondary or open field to achieve the desired appearance.

KODAK EC-L FILM SYSTEM TECHNIQUE CHARTS

• Using the charts

1. First, identify the energy for which filming will be performed (remember, the lowest energy available will produce the best results).
2. Pay particular attention to the distance between patient and film. If this distance needs to be increased due to the access of the cassette and holder around the patient, then it will be necessary to add exposure to the secondary or open field. If different distances are used, then the techniques may have to be adjusted.
3. Next, refer to the anatomical area to be imaged. The technique indicated is based on standard considerations for thickness and field size. If the patient thickness differs from a standard thickness, add or subtract exposure from the open field accordingly. For particularly large treatment fields, decrease the exposure in the open field to account for increased scatter.

• Customizing the charts

1. The charts are presented here as a guide. The previous discussion in this section describes how geometry and the local processing conditions can impact the exposure required for Kodak EC film in Kodak EC-L cassettes. The exposures in the secondary or open field should be modified to account for local preferences in these factors. Once a technique is worked out, new charts should be produced, and careful attention to using those techniques consistently is recommended.
2. Unlike imaging at diagnostic energies, there is not a substantial difference in tissue attenuation at megavoltage energies. For this reason, the biggest factors affecting the exposure required are not specifically dependent on the anatomy. Once the energy and geometry have been determined, patient thickness and field size would be the important factors. As an alternative to the technique charts presented here which provide exposure recommendations according to anatomy, a technique chart based on thickness and field size for a given geometry and energy could be created.

• Fractional MUs

The charts provided express exposures in integer increments (MUs). Integer increments are common on most machines. Some manufacturers have provided for fractional increments of exposure. If this is available, then techniques can be fine-tuned for even greater optimization of exposure. The points raised in this discussion can be used to guide the fine-tuning according to patient thickness, field size, geometry, and processing.

KODAK EC-L FILM SYSTEM Technique Chart

Common Techniques for 6-MV Beams

Assumes source-to-film distance of: 105–115 cm for AP/PA; 100 cm SAD
 115–125 cm for Obliques; 100 cm SAD
 130–140 cm for Laterals; 100 cm SAD

LUNG/CHEST		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+3	
OBLIQUE	Most	1+4	or 1+3
PELVIS		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+3	
OBLIQUE	Most	1+4	
LATERAL	Small	2+7	1+5
LATERAL	Most	2+8	1+6
LATERAL	Large	2+10	2+7
BREAST		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
TANGENTS	Most	1+3	
TANGENTS	Single Exposure	4	
HEAD/NECK/BRAIN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+3	
LATERAL	Most	1+3	
SHOULDER/CLAVICLE		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+3	
ABDOMEN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+3	
OBLIQUE	Most	1+5	1+3
LATERAL	Most	2+8	1+6

Technique Tips:

- Generally, adjust the technique to darken or lighten films by adding or subtracting to the 2nd number (e.g., if an oblique pelvis is too light at 1+4, change technique to 1+5).
- Increasing the distance between patient and cassette will require additional MUs (e.g., a lateral lung at an angle of 270° will require more MUs than an oblique lung [1+4] at 210°).
- Poor processing conditions affect image quality and decrease image contrast and density. Recommended replenishment rates for EC film: 100 ml of developer and 120 ml of fixer.
- The dimensions of the surrounding (i.e., open) field can affect image quality.

KODAK EC-L FILM SYSTEM Technique Chart

Common Techniques for 4-MV Beams

Assumes source-to-film distance of: 105–115 cm for AP or PA; 100 cm SAD
130–140 cm for Laterals; 100 cm SAD

LUNG/CHEST		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+4	
OBLIQUE	Most	1+6	
PELVIS		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Small/Medium	1+4	1+3
AP/PA	Large	1+6	1+4
LATERAL	Small		1+7
LATERAL	Medium		1+9
LATERAL	Large		1+10
LATERAL	Small/Medium (Single Exposure)		9
LATERAL	Large (Single Exposure)		10
BREAST		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
TANGENTS	Small	1+3	
TANGENTS	Medium/Large	1+4	
TANGENTS	Single Exposure	4 or 5	5
HEAD/NECK/BRAIN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP	Most	1+3	
LATERAL	Most	1+4	
SHOULDER/CLAVICLE		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+4	
ABDOMEN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
LATERAL	Medium	2+12	2+10
OBLIQUE	Medium	2+6	2+5

KODAK EC-L FILM SYSTEM Technique Chart

Common Techniques for 10-MV Beams

Assumes source-to-film distance of: 105–115 cm for AP or PA; 100 cm SAD
130–140 cm for Laterals; 100 cm SAD

LUNG/CHEST		EC-L Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+2	
OBLIQUE	Most	1+4	
PELVIS		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Small/Medium	1+2	
AP/PA	Large	1+3	
LATERAL	Small		1+4
LATERAL	Medium		1+5
LATERAL	Large		1+6
LATERAL	Small/Medium (Single Exposure)		6
LATERAL	Large (Single Exposure)		7
BREAST		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
TANGENTS	Small	1+2	
TANGENTS	Medium/Large	1+3	
TANGENTS	Single Exposure	3	
HEAD/NECK/BRAIN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP	Most	1+2	
LATERAL	Most	1+3	
SHOULDER/CLAVICLE		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+2	
ABDOMEN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
LATERAL	Medium		1+5
OBLIQUE	Medium	1+3	

KODAK EC-L FILM SYSTEM Technique Chart

Common Techniques for 18-MV Beams

Assumes source-to-film distance of: 105–115 cm for AP or PA; 100 cm SAD
130–140 cm for Laterals; 100 cm SAD

LUNG/CHEST		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+2	
OBLIQUE	Most	1+3	
PELVIS		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Small/Medium	1+2	
AP/PA	Large	1+3	
LATERAL	Small		1+2
LATERAL	Medium		1+3
LATERAL	Large		1+4
LATERAL	Small/Medium (Single Exposure)		4
LATERAL	Large (Single Exposure)		5
BREAST		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
TANGENTS	Small	1+2	
TANGENTS	Medium/Large	1+2	
TANGENTS	Single Exposure	3	
HEAD/NECK/BRAIN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP	Most	1+2	
LATERAL	Most	1+3	
SHOULDER/CLAVICLE		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
AP/PA	Most	1+2	
ABDOMEN		EC-L Regular Cassette	EC-L Fast Cassette
	Patient Profile	Monitor Units	Monitor Units
LATERAL	Medium		1+3
OBLIQUE	Medium		1+2

ARTIFACT ISOLATION FUNDAMENTALS

This section provides a brief review of selected classes of artifacts, their causes, and corrective measures. Artifacts are unwanted defects on the processed film. Both the types of possible film artifacts and the possible sources of such artifacts are numerous. The sources for film artifacts are not limited to the film processor. A more comprehensive, 72-page spiral-bound Kodak publication, *Film Artifact Diagnostics Guide*, is available for further study. This publication is CAT No. 132 7246. The cost is approximately \$30.00 (US), and it can be ordered through any dealer of Kodak health imaging products or by calling your local Kodak office directly. For example, in the USA, the Kodak number to call is 1-800-677-9933. This publication is a good “reference manual” to identify many different types of image artifacts, learn their cause(s), and obtain corrective suggestions.

There is another 28-page Kodak publication, called *Identifying and Correcting Processing Artifacts*, which discusses a dozen of the most common processor-related film artifacts. The CAT No. for this publication is 192 8324. The cost is approximately \$6.00 (US).

When trying to identify the cause(s) of film artifacts, there are some basic observations that are important to note, including:

Characteristics of the film:

- Note leading film edge entering the processor and trailing film edge
- Does the artifact go away when a different size film or film from a different emulsion batch is tried?

Characteristics of the artifact(s):

- Is the artifact plus-density (dark) or minus-density (light)?
- Where does it occur on the film in relation to the direction of film travel (i.e., parallel to the direction of film travel or perpendicular?)
- Does the artifact repeat on the film? If so, what is the spacing between artifacts?
- Is the artifact seen using transmitted light or reflected light?
- Does the artifact occur randomly on the film? (e.g., static, surface scratches, kink marks)

Generally, there are six basic guidelines to follow when evaluating

process-related artifacts:

1. Artifacts that appear on the upper emulsion surface of the film result from the upper components in the processor.
2. Artifacts that appear on the lower emulsion surface result from the lower components in the processor.
3. Plus-density artifacts are most likely caused by problems in the film development stage or by pressure on the film after exposure. With some films, pressure exerted on the film prior to exposure can also result in plus-density artifacts.
4. Minus-density artifacts are most likely caused by problems with the fixer, with pressure on the film before exposure, and/or by dust and dirt in a cassette.

5. Generally, reflected light reveals wash- or dryer-created artifacts. Locating and viewing these flaws in the surface quality of a film is usually easier with reflected light vs. transmitted light. However, very severe wash- or dryer-created artifacts can often be seen using transmitted light as well.
6. Transmitted light generally reveals other types of artifacts than those discussed in guidelines 1 to 5.

There may be similarities among film processors and perhaps processing chemistry in the same institution or across different diagnostic imaging departments.

Artifacts from other sources can include:

- Static marks
- Shadow images
- Kink marks
- Bent corners

QUESTIONS AND ANSWERS

Selected product usage recommendations

Can I use Kodak EC film in metal-screened cassettes for portal localization and/or verification imaging?

No. This combination is not recommended for patient imaging. The main reason is the very slow film speed of Kodak EC film. This would make the system speed too slow for use with patients.

Can I use conventional medical x-ray film(s) in Kodak EC-L or EC-V film system cassettes?

No. This is not recommended, because the higher speed of most medical x-ray films would make the resulting combination too fast for patient use. A fraction of 1 MU might be required, and delivering this amount of exposure is typically difficult with most equipment.

With the availability of the Kodak EC-L or EC-V film systems for localization and verification imaging, are Kodak therapy cassettes L and V still available?

Yes. Those who decide to use conventional screen-type medical x-ray films with metal-screened cassettes will be able to purchase these cassettes. Some recommended films for use with the Kodak therapy cassette L and therapy cassette V are Kodak PPL-2 or Kodak X-Omat K film for the L cassette and Kodak X-Omat V film for the V cassette.

Replenishment rates, chemistry selection, and processor selection **What are the recommended replenishment rates with Kodak chemicals for processing Kodak EC film?**

Radiation oncology centers and processing environments tend to have relatively

low-volume film-processing demands. Each site or situation should be analyzed individually to determine the optimal chemistry replenishment rates needed to produce consistent, high-quality images. Kodak service bulletin #30 provides the latest film replenishment recommendations for a variety of films and conditions.

See Page 6 in this Guide for some replenishment rate recommendations. For many sites, 100 mL of developer and 120 mL of fixer provide a good starting point for setting replenishment rates.

Does the brand and/or type chemistry I use affect the image quality?

Yes; particularly with the developer solution. There are many choices of x-ray film developer solutions on the market today, and the performance of each can yield visible differences on the viewbox. Image contrast is a particularly important aspect in oncology imaging. Select your developer brand and type carefully so that the film interpreter's ability to see important clinical details and anatomical landmarks is not compromised.

Fixer solutions can also affect different films in different ways. Fixer brand and/or type can affect performance characteristics such as film drying. Physical characteristics such as susceptibility to certain film processor artifacts can change with different fixer types. Even viewbox characteristics such as image tone can be affected by different fixer formulations. These examples illustrate that the selection of fixer solution should be made with the Kodak recommendations in mind.

Some chemicals, in concentrate and/or in mixed form, exhibit better chemical stability and sensitometric

consistency over time. These can be important performance characteristics to consider in oncology film-processing areas, which might not always see high volumes of films processed daily.

For optimal image quality, we recommend the use of Kodak RP X-Omat developer and replenisher and Kodak RP X-Omat LO fixer and replenisher.

Does the automatic film processor I select affect image quality?

Yes, in at least a couple of ways. The film processor's internal design and chemicals circulation systems provide agitation to the film's surface. Proper agitation and "flexing" of the film as it transports through the processor is a very precise science. This emulsion flexing combines with chemistry recirculation system design to provide specific benefits in a number of areas. Not all film processors do this equally. Some smaller automatic film processors with "shallow-tank" designs can affect important performance parameters, including contrast and speed. In addition, a film processor's design in the "wet tanks" as well as in the film-drying section can cause artifacts or imaging "noise" that interfere with the visibility of clinical information.

We recommend a number of Kodak X-Omat processors for optimal processing of the broad variety of Kodak films for oncology imaging, including:

- Model 2000 RA
- Models 5000 RA and 3000 RA
- Models 480 RA and M6B
- Models M7B and M35

QUESTIONS AND ANSWERS *(continued)*

Safelights

Can my safelight(s) affect image quality?

Yes. With improper safelighting conditions or damaged safelights, you may see increased image density, lower image contrast, increased gross fog levels, and possibly other image artifacts as well. Reduction in image contrast is particularly detrimental in oncology imaging, where the typically lower-contrast images may make it more difficult to recognize any image contrast loss due to the lack of safelight integrity.

When images are too light

Light images are typically the result of processing and exposure.

Processing

Check the working chemistry inside the processor for possible oxidation. If oxidized solutions exist, replace with fresh chemistry. If chemical replenishment rates are insufficient for the film type, volume, and/or film mix, processed films can appear to have a green tint. Certain types of processing chemicals can sometimes produce similar shifts in image tone with some films. Insufficient fixer strength and/or under replenishment can also affect the image tone of processed films, giving films a milky or greenish appearance. In addition, film drying can be adversely affected in such circumstances, and there can be an increased propensity for film artifacts due to insufficient emulsion “hardening” in the fixer stage.

It is not unusual to add 1 MU to the larger field because the processing chemistry is not optimized. This can be more obvious on the lesser-exposed projections. In some cases, a change to fresh chemistry can bring an immediate change. In other cases, a change in

chemistry brand or type could bring about similar improvements.

Exposure

If you are exposing two fields on one film and the treatment field is too light, then the secondary field should be too light as well. Increasing the monitor units on the secondary field also darkens the treatment field. Adding one or two units to the technique, using the charts provided in this publication, should be all that is required to account for differences in normal chemistry and film fluctuations.

If the exposure guidelines in this publication do not provide satisfactory results, you should seek help from your regional Kodak oncology manager. Do not add monitor units to the treatment field. This will only make the secondary field appear lighter. Single-field users should never require an increase of more than one or two MU from the exposure guidelines recommended in this publication.

When images are too dark

Dark images are often the result of processing chemistry, safelight, and film storage technique.

Processing, chemistry, and safelight(s)

Chemistry, processing, and darkroom “basics” can be the cause or contributing factors when images are determined to be too dark. Potential causes can include:

- Developer temperature higher than recommended
- Chemistry activity higher than normal (improper mixing, “starter” solution omitted)
- Chemistry changes from fresh to “seasoned” conditioning process

- Improper safelight conditions—the accompanying image density increase, image contrast decrease, and higher gross fog may be less easily or quickly noticed on many oncology localization and verification images. This is because these images typically have lower image contrast overall. In addition, typical patient images may have areas of higher density where added density may not be perceived as readily.

Placement of loaded cassettes in the treatment room

Films exposed to scatter radiation either pre- or post-exposure will appear to be darker and/or lower in overall contrast. Kodak EC-L and EC-V system cassettes have intensifying screens that very efficiently convert the scatter radiation energy to light. This light can add additional exposure to the film, giving the processed image additional density.

Putting loaded cassettes aside in the treatment room during a treatment is not recommended. Besides the effects of altered image density and/or image contrast, other aspects, including potential time savings and convenience, can be negatively affected as well. Sometimes the apparent mystery of density differences in films on the same patient, using the same exposure, can be quickly solved by proper film/cassette storage.

Geometric factors and intermittent density variations

Does field size affect image density?

Yes. There is a direct relationship between field size and image density. The underlying cause is scatter energy. The larger the field size, the more scatter is created. This invites added density to the image, particularly with the knowledge of the high inherent contrast of Kodak EC film. The significant increase (over 3X) in image receptor contrast provided by the Kodak EC-L film system “amplifies” exposure differences into more pronounced density differences.

The practice of enlarging the field size to facilitate visibility of anatomic landmarks can introduce less desirable image results, including variable densities and reduced image contrast. The significantly higher image contrast level of Kodak EC film should help decrease or even eliminate this behavior in many instances, providing improved image quality.

What about intermittent density shifts or density variations on films?

This can happen for multiple reasons, including:

- Processing
- Scatter radiation exposure
- Loss of safelight integrity
- Inconsistent cassette-to-patient distance

Looking at inconsistent cassette-to-patient distance more closely, we recognize that different distance positioning in reverse PA views, oblique views, and tangent views can produce density variations that may not initially be thought of as traceable to this cause. Differences in image magnification on comparison films should alert the film interpreter to inconsistent geometry as a possible reason for image density variations.

OTHER KODAK ONCOLOGY PRODUCTS

SIM—KODAK SIMULATION FILM

Kodak simulation film and Kodak Lanex regular screens are designed to work together to deliver excellent image quality. The system speed of this combination is 400. If Kodak Lanex fast screens are used instead of Lanex regular, the system speed is approximately 600. In addition, this screen-film combination may allow lower exposure techniques compared to many existing simulation imaging systems.

The wide exposure latitude of Kodak simulation film is useful when

exposure settings are difficult to control, and this characteristic provides better visualization of the full range of anatomical landmarks, including:

- Skin line and the chest wall on breast simulations
- Soft tissues of the neck and the bony details of the cervical spine
- Lung markings
- The heart and mediastinum

The film is a green-sensitive film with highly stable sensitometric properties over a wide range of processing conditions. If you currently have Kodak

Lanex regular screens or other green-light-emitting screens, this film is a “drop-in.” No changes are required to existing film processors or chemistry.

Kodak simulation film is compatible with virtually all darkroom film I.D. printers or the Kodak X-Omatic identification camera, model 2. It can be used with a Kodak GBX-2 safelight filter or equivalent, and it is available in 2 quantities in the 35 x 43 cm size: a 20-sheet “demonstration package” or 100-sheet box.

Simulator Exposure Chart

These are reasonable exposure techniques for the “400 speed” Kodak Lanex regular screens with Kodak simulation film, for average-sized patients. With other similar-speed, appropriately matched screen-film systems (i.e., Green-Green, Blue-Blue), these techniques may be an appropriate starting point.

BODY PART/VIEW	NO GRID		WITH 8:1 GRID		SEPARATION
	KVP	MAS	KVP	MA	
LUNG/CHEST					
AP/PA	70	40	80-85	60-65	22CM
LAT	75	60	90	100	
OBLIQUE	70	75	95	85	
PELVIS					
AP/PA	80	40	85	95	23CM
LAT	90	150	90	170 (2 Exp.)	36CM
BREAST					
TANGENTS	70	10	75	35	
HEAD/NECK					
AP	75	20	80	35	
LAT	75	120	80	45	14CM
SKULL					
AP	75	25	85	45	
LAT	75	20	75	35	15CM
SPINE					
AP/PA	70	50	85	70	20CM
LAT	75	120	95	200	

PPL-2—Portal pack for localization (PPL)

Kodak portal pack for localization is available in “Ready-Pack” packaging in two sizes: 33 x 41 cm and 10 x 12 inches. The 33 x 41 cm film size allows the Ready-Pack envelope with film to fit neatly inside a 35 x 43 cm

Kodak X-Omatic L radiation therapy cassette. The Ready-Pack is a sealed envelope containing film that can be used with or without a metal-screened cassette. This packaging offers great convenience in handling and can eliminate carrying heavy cassettes from treatment room to darkroom and back.

CAT Nos. for PPL are 801 3963 for the 33 x 41 cm size and 801 5059 for the 10 x 12 in size.

KODAK X-OMAT RADIATION THERAPY CASSETTES L and V and KODAK X-OMAT VERIFICATION FILM (XV)

The Kodak X-Omat L radiation therapy cassette contains a 1.0-mm-thick copper-front screen and a 0.25-mm-thick lead-back screen. Its size is 35 x 43 cm. The 1.0-mm copper-front screen:

- Prevents electrons generated within the patient from reaching the film
- Generates electrons, which are the primary source of film exposure. Because these electrons are much closer to the film emulsion than those generated within the patient, image blur is reduced and resolution is improved

- Intensifies primary radiation to a greater extent than scattered photons of lower energy, resulting in improved subject contrast

The 0.25-mm lead-back screen:

- Serves as an intensifier that provides additional exposure to the film due, in large part, to the back-scattering of electrons. This reduces the required number of monitor units by a factor of approximately 2

Typically, conventional blue-sensitive medical x-ray films are used with this cassette, as well as certain films in Ready-Pack packaging and size to fit inside this cassette. Tests have shown that there is minimal resolution loss when film is exposed in a ready pack as opposed to direct contact film-(metal) screen exposure.

A slightly different cassette designed for verification imaging is the Kodak X-Omat V radiation therapy cassette. Its size is 35 x 43 cm. This cassette has the same 1.0-mm copper-front screen as the Kodak X-Omat L radiation therapy cassette, but instead of the lead-back screen it has a lightweight 0.4-mm thermoplastic polymer back screen. This system is paired with Kodak X-Omat V film packaged in Ready-Pack format, a slow film capable of recording exit doses resulting from many radiation treatments.

KODAK EDR-2 FILM for dosimetry/QA/equipment calibration

EDR-2 film is a new addition to the Kodak Ready-Pack product family. Kodak now offers EDR-2 film as well as PPL and XV in Ready-Pack format.

EDR-2 film is a convenient means for calibration and monitoring of exposures.

- Two sizes available: 35 x 43 cm and 10 x 12 inches
- Widely available through distributors of Kodak medical imaging products
- Excellent for relative dosimetry (e.g., field uniformity, equipment characterization: field shapes, port openings, MLCs)
- With appropriate calibration, film may be applicable to absolute dosimetry (e.g., high-dose treatment strategies such as IMRT)

EDR-2 is intended for direct exposure applications only. Its features include:

- Wide response range
- Approximately linear (see graph)
- Robust processing
- Available in convenient Ready-Pack format

Dose response evaluation

Exact dose responses depend on processing conditions (processing time, processing temperature, processing equipment, processing chemistry); the density sampling (digitizer equipment and calibration) and exposure monitoring equipment. The exact response relationship should be measured and verified for the local conditions.

OTHER KODAK ONCOLOGY PRODUCTS *(continued)*

Measurement technique

The dose response of a film should be measured using appropriate amounts of buildup and backscatter material, with a range of field sizes and energies. The films should be processed using the conditions given in Kodak's service bulletin #30.

Dose response

The curve in Figure 8 shows the approximate relative dose response for EDR-2. The curve is representative only—the exact results will depend on the exposing, processing, and scanning conditions at each facility. EDR-2 film will saturate in direct exposure at ~700 cGy.

Other KODAK FILMS for direct exposure

The selection of the appropriate film depends on the application, particularly the exposure range of interest. The following films are commonly used in the oncology environment for portal simulation, localization, and verification imaging. The table below summarizes the approximate active ranges and saturation for direct exposure with commonly available films in the oncology department (Table 4). This table may be helpful when considering their use in relative and absolute dosimetric measurements.

Figure 8

Kodak extended dose range film (EDR-2)

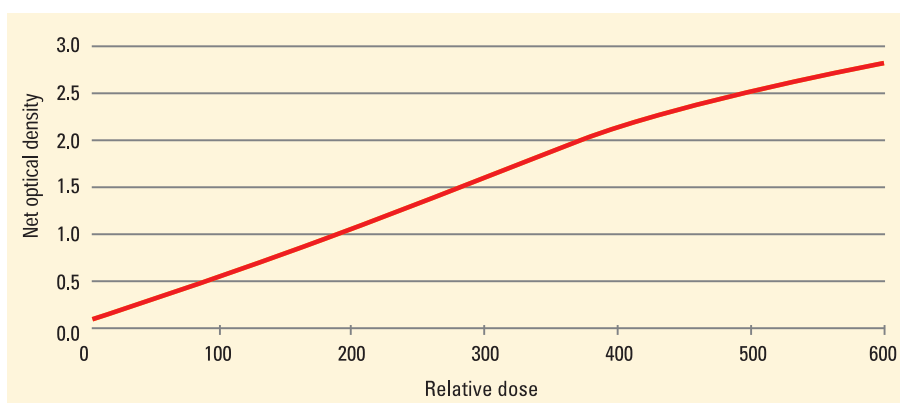


Table 4

Film	Responsive Range	Approximate Saturation Exposure
General (e.g., SIM film)	0.5–10 cGy	20 cGy
PPL-2	0.25–5 cGy	10 cGy
XV-2	5–100 cGy	200 cGy
EDR-2	25–400 cGy	700 cGy
XTL-2	1–15 cGy	30 cGy

OTHER KODAK PRODUCTS

Film processors

- Kodak X-Omat 2000 processor

The Kodak X-Omat 2000 and 2000A processors offer the proven reliability of Kodak M35 and M35A processors plus rapid-cycle processing capability, to deliver 34% higher throughput for medium- to low-volume processing needs. Key features include:

- Automatic standby control
- Ambient temperature wash water
- Developer temperature control to ± 0.5 degrees F (± 0.3 degrees C)
- 220-volt or 110-volt models; either can be installed for through-the-wall operation using an installation kit provided with the processor
- Designed to minimize service time through ease of installation, ready service access, and readily available Kodak M35/M35A processor parts
- Can process up to 100 35 x 43-cm sheets of film/hour in standard cycle (120 sec. leading edge in/out)
- Can process up to 125 35 x 43-cm sheets of film/hour in rapid cycle (90 sec. leading edge in/out)

- Kodak X-Omat 3000 RA processor

The Kodak 3000 RA processor is designed for medium-volume film processing needs. It can process up to 150 35 x 43-cm sheets of film per hour in standard cycle. Rapid and kwik/RA processing cycles are also built into this processor to allow higher film throughput and increased productivity. The Kodak 3000 RA processor offers all of the features listed for the Kodak 5000 RA processor in a mid-volume footprint or size. If automatic cassette loading and unloading with an integrated film

processor is desired, the Kodak multiloader 300 plus contains the Kodak 3000 RA processor in a single, space-saving 33 in. W x 34 in. D x 51 in. H (83 cm W x 86 cm D x 128 cm H) size. This same processor is also incorporated into the Kodak X-Omat multiloader 7000.

- Kodak X-Omat 5000 RA processor

The Kodak 5000 RA processor is designed for high-volume film processing. Three processing speeds are available: standard, rapid, and kwik/RA. In standard cycle, up to 245 sheets of 35 x 43-cm film can be processed per hour. This number increases with rapid and kwik/RA cycles to 355 35 x 43-cm films/hour and 485 35 x 43-cm films/hour, respectively. Cassette loading and unloading in full roomlight is possible if the processor is docked to the Kodak multiloader 700 plus.

Key features include:

- It offers “intelligent” replenishment based upon film area
- Selectable flooded replenishment mode for low-activity periods
- Microprocessor control allows easy front-panel adjustments to film transport speed, replenishment rates, solution and dryer temperatures
- “Custom” processing cycles can be programmed for special circumstances or to meet technological advances
- Usage log keeps track of the number and sizes of films processed as well as chemical consumption; built-in printer interface allows printing of hard-copy logs and reports
- Processor monitoring systems report operational status, changes

in progress, signal operator error, and identify service needs

- Programmable 7-day automatic startup and shutdown times
- Automatic crossover rack cleaning and roller activation
- Automatic fill mode eliminates manual filling of processing tanks
- Auto-dimming front-panel display adjusts to ambient lighting conditions
- Display messages in choice of 12 languages; display temperatures in either degrees Fahrenheit or degrees Centigrade

Patient identification devices

- Kodak x-ray film identification printer, model B

This is a darkroom printer that transfers printed or typed information from a paper card to the film. If used with Kodak EC film, the operator usage of this device is slightly modified vs. the normal operating procedure. It can also be used with most other films for portal localization and verification imaging. It comes supplied with a 7-watt bulb and an 8-foot cord, for 110-125V AC operation.

- Kodak X-Omatic identification camera, model 2 (110V) and 2L (220V)

This is a roomlight identification device that photographically records typed or printed information from a paper card to the film. In addition, the time and date are recorded digitally on the film with each exposure. This device is compatible with either Kodak X-Omatic or Kodak X-Omat cassettes, in all cassette sizes and screen complements. Due to the very slow film speed of Kodak EC film, this identification device cannot be used without modifications to allow a higher-density image imprint.

OTHER KODAK PRODUCTS *(continued)*

Film-handling equipment

- Kodak X-Omat multiloader 7000

The Kodak X-Omat multiloader 7000 offers a very small “footprint,” similar to the Kodak X-Omat multiloader 300 plus, and adds the option to accommodate from three up to seven film magazines. This unit is only about 5 inches (approximately 12.5 cm) taller than the Kodak X-Omat multiloader 300 plus. The integrated film processor is the Kodak X-Omat RA 3000 processor.

Print options

With widespread use of computers and the increased utilization of digital image and data sources, printing is a growing need in oncology. The wide-ranging potential applications for printing in the radiation oncology environment include (but are not limited to):

- Digitally reconstructed radiographs for comparison with port films and/or treatment plans
- Images from electronic portal imaging devices (EPIDs)
- Images from other digital sources (CT, MRI, ultrasound, CR, and film digitizer)
- Treatment plans (both two- and three-dimensional plans)

Kodak offers multiple options for printing which covers a wide range of usage factors and needs.

Laser imagers

Kodak offers a variety of DryView™ laser imagers, all of which eliminate chemical processing and darkroom activities. The small size of the DryView imagers ensures ease of location and operation. Together with Kodak DryView laser imaging film, these laser imagers provide high-quality output for diagnostic applications. The image quality and convenience of dry laser imaging can enhance the printing of digitally reconstructed radiographs and electronic portal images, as well as images from other DICOM sources.

- Kodak DryView 8700 laser imager

The Kodak DryView 8700 laser imager offers exceptional speed (up to 120 films per hour), true dry laser technology, and diagnostic image quality with 4,096 laser gray level reproduction. The patented Automatic Image Quality Control ensures the contrast and density of each film meets user preferences and requires no interaction or manual procedure. The DryView 8700 has PACS Link interface to send images over a network for soft-copy viewing, archiving, or printing.

- Kodak DryView 8100 laser imager

The Kodak DryView 8100 laser imager, with a throughput of up to 55 films per hour, delivers diagnostic-quality images and film-to-film consistency with 1,024 laser gray reproduction. The patented Automatic Image Quality Control automatically calibrates the DryView 8100 to maximize image quality. With PACS Link connectivity, images can be sent over a network for soft-copy viewing, archiving, or printing.

Desktop medical imagers

Kodak desktop medical imagers offer versatility and cost-effective grayscale and color printing. Leveraging expertise in medical image processing with inkjet technology, quality images are printed in either grayscale or full color at a resolution up to 1200 x 1200 dpi on either paper or film media. Kodak's MedPage software formats pages and sizes images. Connectivity to a DICOM modality (with a Kodak distributed medical image spooler) eliminates the need for film processing.

- Kodak 3600 desktop medical imager

The Kodak 3600 desktop medical imager supports multiple operating systems (Windows NT 4.0 and 95/98, Mac OS and UNIX—and PostScript level 2 for high-level graphics and non-medical applications). The 3600 prints sheet sizes up to 11 x 14 in. and has two supply trays to allow printing on paper or film or different sheet sizes without reloading.

- Kodak 1200 desktop medical imager

The Kodak 1200 desktop medical imager is compact and supports Windows NT 4.0 and 95/98 operating systems. The 1200 prints from a single source with sheet sizes up to 8 x 10-in. film or 8.5 x 11-in. paper.

KODAK EC-L AND EC-V FILM SYSTEMS CATALOG NUMBERS

KODAK EC-L and EC-V FILM SYSTEMS

for localization and verification

imaging

Kodak EC-L and EC-V film systems for portal localization and verification imaging are composed of one film and different cassettes. The cassettes differ in the speed of the intensifying screen pair in each.

Product	Description	Size	CAT No.
Kodak EC film	100-sheet box, non-interleaved	35 x 43 cm	871 5757
		35 x 35 cm	884 2213
		11 x 14 in	885 5728
		10 x 12 in	895 5254
		8 x 10 in	896 7424
Kodak EC-L regular cassette, C-1	Regular	35 x 43 cm	193 7960
		35 x 35 cm	811 4415
		11 x 14 in	166 3236
		10 x 12 in	888 2086
		8 x 10 in	124 5018
Kodak EC-L fast cassette, C-1	Fast	35 x 43 cm	879 8092
		35 x 35 cm	873 8874
		11 x 14 in	105 4501
		10 x 12 in	852 5149
		8 x 10 in	850 9572
Kodak EC-L slow cassette, C-1	Slow	35 x 43 cm	873 7736
		35 x 35 cm	197 5523
		11 x 14 in	859 6330
		10 x 12 in	184 9579
		8 x 10 in	891 0648
Kodak EC-V regular cassette, C-1	Regular	34 x 43 cm	854 0999
		35 x 35 cm	162 6696
		11 x 14 in	115 7759
		10 x 12 in	873 2729
		8 x 10 in	887 7128
Kodak EC-V fast cassette, C-1	Fast	35 x 43 cm	110 1898
		35 x 35 cm	194 1913
		11 x 14 in	117 5397
		10 x 12 in	877 0083
		8 x 10 in	115 1406

KODAK EC-L AND EC-V FILM SYSTEMS CATALOG NUMBERS *(continued)*

Using different KODAK EC-L SYSTEM cassettes: slow, regular, & fast

Slow

The Kodak EC-L slow cassette consists of a 1-mm copper-front screen and two phosphor-coated intensifying screens inside a Kodak x-ray cassette. This cassette may be appropriate to compensate for beam energies higher than 6 MV, particularly 18 MV and higher. Using the same Kodak EC film in all three cassettes, this slow cassette requires approximately 30% more exposure vs. the Kodak EC-L regular cassette described next.

Regular

The Kodak EC-L regular cassette consists of a 1-mm copper-front screen and two phosphor-coated intensifying screens. This cassette is designed for the majority of treatment images.

Fast

The Kodak EC-L fast cassette differs from the slow and regular cassettes in its complement of phosphor intensifying screens. These screens offer increased speed, allowing a reduction in exposure of approximately 30% vs. the Kodak EC-L regular cassette. This can be particularly useful when imaging lateral pelvis fields and when dealing with large patients.

KODAK EC-V verification system for verification imaging

The Kodak EC-V verification system for verification imaging is composed of one film and two cassette/screen combinations.

All Kodak oncology film system cassettes utilize the new Kodak X-Omat cassette, which offers reduced total cassette weight while providing equal durability. As an example, the current 35 x 43-cm Kodak EC-L regular cassette weighs approximately 8.3 pounds (3.8 kg). The same product in the new Kodak X-Omat cassette weighs approximately 7.1 pounds (3.2 kg). No change in current monitor unit settings should be required and the new cassette can be used interchangeably with existing cassettes.

FOR MORE INFORMATION

- The Kodak Web site is another source for more information on Kodak oncology products. The URL is www.kodak.com/go/oncology.
- Health Imaging Customer Support Operations can be reached at 1-800-328-2910; Outside the USA, call USA Area Code (716) 724-9362.
- Health Imaging automated fax back service is available 24/7 by calling 1-800-328-2910. Outside the USA, the number is USA Area Code (716) 724-9362. An index of available fax back documents (over 200) can be ordered using the system.
- Kodak Environmental Services is a resource for health, safety, and environmental questions and concerns with Kodak products. Technical information is available by calling USA Area Code (716) 477-3194. The URL is www.kodak.com/go/kes.

INFORMATION NEEDED BY KODAK TO FACILITATE TROUBLESHOOTING

When contacting Kodak for assistance with image-quality concerns, having as much of the following information as possible will facilitate all troubleshooting efforts:

- Make and model of processor.
- Mix of film types processed.
- Volume of film (number of sheets per typical eight-hour day).
- Brand of chemicals (developer and fixer).
- Type of chemicals (e.g., premixed, automixed, or facility mixed).
- Replenishment rates (milliliters of developer and fixer, fully defined in terms of number and size of film, and length of film travel, e.g., 80 milliliters of developer and 100 milliliters of fixer per one 35 x 43-cm Kodak EC film, 35 cm of film travel).
- Dates last and previous preventive maintenance (PM) of processor performed.
- Developer temperature.
- Current and previous emulsion numbers.
- Date the change or problem was noticed.
- Description of change (what was observed and who noticed it).
- Description of any unusual circumstances (e.g., films processed only two days per week, etc.).
- Technical factors used.

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