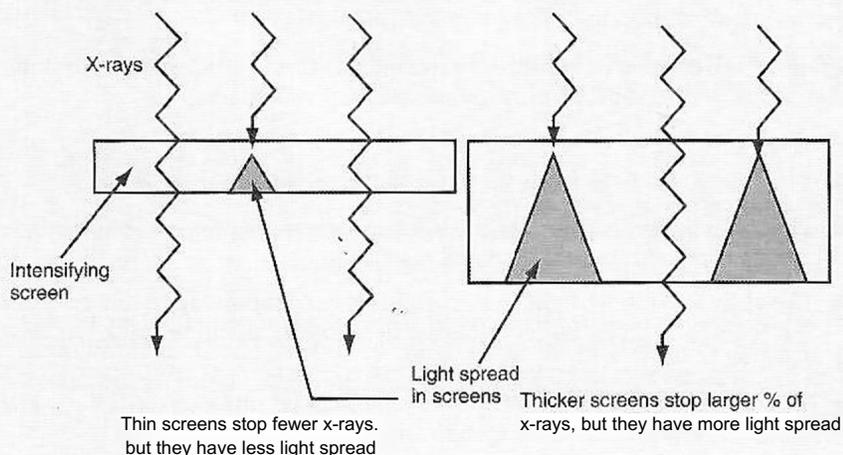


Intensifying Screens

A. Basic Concepts

1. The basic purpose of intensifying screens is to capture a large percentage of the x-rays that pass through the patient and grid and convert this radiation into light, which is then directed onto x-ray film.
 - The *advantage* of intensifying screens is that they reduce the amount of x-ray radiation to the patient in comparison with direct exposure of film without use of intensifying screens.
 - *Intensification factor* is the radiation required for direct exposure of film without intensifying screens divided by the radiation required with screens.
 - Intensification factors are usually greater than 40 to 50. This means that intensifying screens reduce the radiation dose to the patient by more than 50 times.
2. The *disadvantage* of intensifying screens is that the image quality is diminished. The reduction of the radiation dose results in increased image noise (quantum mottle), and light dispersion in the intensifying screens reduces the spatial resolution.
 - Thicker intensifying screens stop more of the x-rays and reduce the radiation dose to the patient.
 - In standard radiography, a cassette with two screens is used with a double-emulsion film. One screen is mounted to the front of the cassette, and the other is mounted to the back of the cassette.
 - The thicker screens result in more of the light diverging; thicker screens reduce spatial resolution more than thinner screens.





3. Two types of efficiency are associated with intensifying screens to produce the overall screen efficiency, E .
 - **Absorption efficiency**, μ , is the fraction of x-rays that interact with the screen.
 - **Conversion efficiency**, κ , is the fraction of the energy deposited in the intensifying screen that is converted in light.
$$E = \mu \kappa$$
 - Typical values of μ are 20% to 60%, dependent on screen composition material and thickness.
 - Typical values of κ are 5% in older calcium tungstate (CaWO_4) screens to 16% to 18% in newer rare-earth phosphor screens.
 - The overall speed of an intensifying screen depends on both good absorption of x-rays and good conversion of the energy deposited in the screens to light.

e The patient's radiation dose is directly related to the speed of the intensifying screen, the film speed, and the film processing conditions.

 - As the speed of the film-screen combination increases, the patient's dose is reduced.
4. An intensifying screen is constructed of four different layers:
 - A plastic **base material** to act as a support structure.
 - e A **reflective layer** (such as TiO_2) to reflect light back toward the film.
 - A **phosphor layer** of high atomic number (Z) material that stops the x-rays and converts the x-ray energy to light. It is the light that exposes the film.
 - Direct x-ray interactions with the film represent 1% to 5% of the total interaction with the film emulsion. More than 95% of the exposure is due to light from the intensifying screen.
 - A clear plastic **protective coating** prevents water and cleaning chemicals from affecting the phosphor crystals. Light from the phosphor crystal easily passes through the protective coating of screens.
5. The absorption efficiency of intensifying screens depends on the type of atomic elements in the phosphor material.
6. CaWO_4 has a K-edge where the x-ray absorption is greatest around 70 keV because of the tungsten material in the phosphor. It emits light in a continuous color (wavelength) spectrum in the blue region.
7. The most common rare earth phosphor is gadolinium oxysulfate ($\text{Gd}_2\text{O}_2\text{S}$), which emits light (blue, green, and yellow) in discrete wavelengths.
8. Other rare earth phosphors of intensifying screens include $\text{La}_2\text{O}_2\text{S}_7$ (blue), LaOBr (blue), $\text{Y}_2\text{O}_2\text{S}$ (blue), and YTaO_4 (ultraviolet).
9. Many of the rare earth phosphors have an absorption efficiency that changes significantly with the kVp used to take the clinical images.
10. A number of factors affect the speed of intensifying screens:
 - The thickness of the phosphor layer in the screen is important.
 - Reflective layers use more of the light and are more efficient, but the light spread is greater, reducing spatial resolution.
 - Use of dyes to absorb light reduces light spread, improving spatial resolution, but it also requires a larger radiation dose to the patient because it is less efficient.

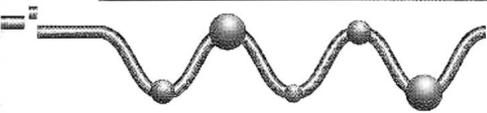
« The conversion efficiency of the phosphor converting deposited x-ray energy to light is another factor in speed.



11. Use of intensifying screens can change the relative speed of the film-screen combination by about a factor of 32 from the slowest to the fastest. Films can double or halve the speed.
12. **Mottle (image noise)** is a result of variation in density for a uniform radiation exposure of the film-screen cassette. It has three components:
- **Screen mottle** is due to variation in the thickness and density of the screen from point to point.
 - **Film (or grain) mottle** is due to variations in the silver grains from point to point on the film surface.
 - **Quantum mottle (QM)** is due to statistical variations in the number of x-rays per mm^2 of the image surface.
 - **QM is by far the most important** of the three types of mottle.
13. For film-screen combinations, the QM:
- Is higher for greater intensifying screen conversion efficiency (κ)
 - **Does NOT depend on screen thickness** or absorption efficiency (a)
 - If only the overall speed (S) is known, depends on S/a
 - Is higher for faster film speed
 - Is higher for faster processing because of higher temperature, greater developer concentration, and slower film transport speeds in the processor
14. **Film-screen contact** is important for uniformity and good spatial resolution.
- Dirt or nonuniform pressure causes “poor” film contact to the intensifying screen.
 - Clean screens regularly: weekly for mammographic units and at least quarterly for radiographic units.
 - Test contact with radiographs of uniform mesh on a cassette at a long focal spot-to-film distance (SID) that show blotches for nonuniform contact.

B. Questions

- 9-1. All of the following are typical intensifying screen phosphors, *except*. _____
- (a) CaWO_4 (b) LiF (c) $\text{Gd}_2\text{O}_2\text{S}$ (d) LaOBr (e) Y_2TaO_4
- 9-2. The intensifying screen phosphor that emits both blue and green light in discrete color lines is. _____
- (a) CaWO_4 (b) LiF (c) $\text{Gd}_2\text{O}_2\text{S}$ (d) LaOBr (e) Y_2TaO_4
- 9-3. The _____ is the intensifying screen phosphor that emits a nearly continuous light spectrum of primarily blue light without discrete lines of emission.
- (a) CaWO_4 (b) LiF (c) $\text{Gd}_2\text{O}_2\text{S}$ (d) LaOBr (e) Y_2TaO_4
- 9-4. The is the intensifying screen phosphor that emits discrete lines of emission primarily in the ultraviolet range.
- (a) CaWO_4 (b) LiF (c) $\text{Gd}_2\text{O}_2\text{S}$ (d) LaOBr (e) Y_2TaO_4
- 9-5. The intensifying screen phosphors that are classified as rare earth screens include which of the following? (i) CaWO_4 , (ii) LiF , (iii) $\text{Gd}_2\text{O}_2\text{S}$, (iv) LaOBr , (v) Y_2TaO_4
- (a) i, ii, and iii (b) ii, iii, and iv (c) Only iii (d) iii, iv, and v
(e) Only iii and iv



- 9-6. Standard radiographic cassettes have intensifying screen(s), and mammography cassettes have screen(s).
- (a) 1,2 (b) 2, 1 (c) 2,2 (d) 1, 1 (e) 2, 0
- 9-7. Radiographic intensifying screens should be cleaned at least, and mammography intensifying screens should be cleaned at least. _____
- (a) Weekly daily (b) Monthly, weekly (c) Quarterly weekly
(d) Quarterly monthly (e) Yearly quarterly
- 9-8. Qualify control tests that should be performed to evaluate film-screen cassettes include all of the following, *except*. _____
- (a) Film-screen contact (b) Uniformity (c) Light leaks (d) Dispersion
(e) Visual inspection of intensifying screens
- 9-9. Thicker intensifying screens result in. _____
- (a) Degraded spatial resolution (b) Slower speeds
(c) Less quantum mottle (d) Higher radiation doses to the patient
(e) Greater conversion efficiency
- 9-10. The main purpose of intensifying screens is to. _____
- (a) Improve resolution (b) Reduce quantum mottle
(c) Reduce radiation dose to the patient (d) Increase image contrast
(e) Increase financial cost
- 9-11. As kVp use is increased, the light production of the intensifying screens _____.
- (a) Remains constant (b) Increases (c) Decreases
(d) Depends on phosphor material and kVp (e) Is negligible
- 9-12. The QM for intensifying screens depends on. _____
- (a) Geometric efficiency (b) Absorption efficiency
(c) Conversion efficiency (d) Screen thickness (e) Screen pressure
- 9-13. To maximize the overall efficiency of a film-screen combination, it is important to match the of the film to the screen phosphor.
- (a) Contrast (b) Color sensitivity (c) Thickness (d) Spatial resolution
(e) Elasticity
- 9-14. In comparison with an image receptor composed of film alone, an intensifying screen plus film combination reduces the patient's radiation by at least a factor of. _____
- (a) 2 (b) 10 (c) 50 (d) 1000 (e) 5000
- 9-15. Behind the rear intensifying screen in a radiographic cassette is a layer of _____.
- (a) Plastic (b) Lead (c) Copper (d) Aluminum (e) Paper
- 9-16. The intensifying screen selection can affect all of the following image quality parameters, *except*. _____
- (a) Spatial resolution (b) Patient's radiation dose (c) Contrast
(d) QM (e) Unsharpness
- 9-17. The amount of QM produced by intensifying screens depends on all of the following factors, *except*. _____
- (a) Reflective layer (b) Dyes added to intensifying screen
(c) Screen thickness (d) Type of phosphor (e) kVp used
- 9-18. The spatial resolution of a film-screen combination depends on. _____
- (a) Film alone (b) Screen alone (c) Both film and screen
(d) Neither film nor screen (e) Only x-ray tube focal spot

- 9-19. The image contrast of a film-screen combination depends on. _____
- (a) Film alone (b) Screen alone (c) Both film and screen
(d) Neither film nor screen (e) Only x-ray tube kVp
- 9-20. The radiation dose to the patient and the speed of a film-screen combination depend on. _____
- (a) Film alone (b) Screen alone (c) Both film and screen
(d) Neither film nor screen (e) Primarily the grid
- 9-21. The QM of a film-screen combination depends on _____. .
- (a) Film alone (b) Screen alone (c) Both film and screen
(d) Neither film nor screen (e) Primarily x-ray filtration
- 9-22. The principal factor affecting the overall image noise (mottle) is the. _____
- (a) Screen mottle (b) Silver grain mottle (c) Quantum mottle
(d) Filter mottle (e) Dielectric mottle
- 9-23. Film-screen contact is tested using a. _____
- (a) Uniform mesh screen (b) Densitometer (c) Penetrometer
(d) Step wedge (e) Spinning top
- 9-24. If two intensifying screens have the same overall efficiency (speed) and screen X has a higher conversion efficiency than Y, the screen with the better spatial resolution is. _____
- (a) X (b) Y (c) Neither; both are the same
(d) Unknown; not enough information provided
(e) Not important; question is irrelevant
- 9-25. If screen Y has 2.0 times the absorption efficiency and 0.5 times the conversion efficiency of screen X, screen has the lower radiation dose to the patient and screen has the lower quantum mottle.
- (a) Neither, X (b) Neither, Y (c) X, neither (d) Y, neither (e) X, Y



C. Answers

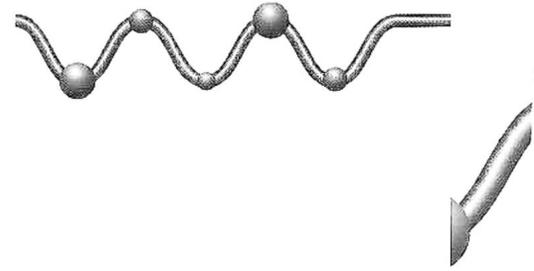
- 9-1. Answer = (b). CaWO_4 is an older type of intensifying screen phosphor that is *not* a rare earth metal. $\text{Gd}_2\text{O}_2\text{S}$, LaOBr , and Y_2TaO_4 are of the newer-type rare-earth phosphors that have a greater conversion efficiency and emit light in discrete wavelengths instead of continuous spectra. LiF is a crystal used for thermoluminescent dosimeters (TLDs), which are used in some personnel radiation badges.
- 9-2. Answer = (c). CaWO_4 emits in a continuous blue spectrum. LaOBr emits in discrete wavelengths (color fines) primarily in the blue region of the visible light spectrum. Y_2TaO_4 is a rare earth phosphor that emits discrete color fines primarily in the ultraviolet portion of the light spectrum.
- 9-3. Answer = (a). See answers to 9-1 and 9-2.
- 9-4. Answer = (e). See answers to 9-1 and 9-2.
- 9-5. Answer = (d). See notes in this chapter (A7 and A8).
- 9-6. Answer = (b). Radiographic cassettes use front and rear intensifying screens with dual-emulsion film so that an emulsion layer faces each screen. The dual screens reduce the radiation dose to the patient. However, the quantum mottle (QM) is increased, and spatial resolution is degraded. In mammography, it is important to improve spatial resolution; thus, a single intensifying screen with a single-emulsion film is used despite the fact that the relative speed is less.

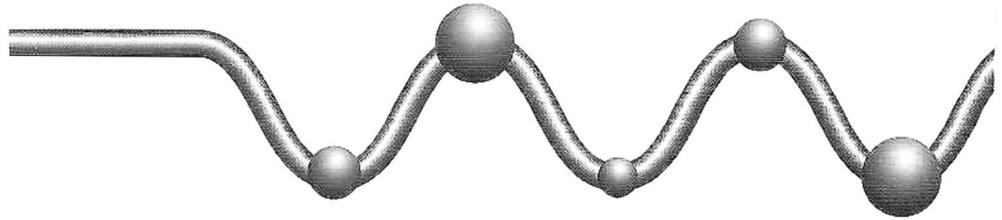


- 9-7. Answer = (c). Although the need to clean intensifying screens depends on usage, dirt, and other conditions, accreditation and regulatory programs specify that cleaning of mammography screens should take place weekly because small dust specks might create clinically unacceptable artifacts in the images. Quarterly cleaning of radiographic screens is usually the longest specified interval, and more frequent cleaning might be necessary, depending on conditions in any particular facility.
- 9-8. Answer = (d). Dispersion refers to the light spread in the screens, which is a function of design. Film-screen contact is the mesh test used to uncover warped cassettes and dirty screens. Uniformity is required for mammography film-screen cassettes to make sure that the AEC (phototimer) produces similar densities for the same phantom. Light leaks can occur with older cassettes in which fog is produced because of failure to prevent ambient light from leaking inside to the film. Visual inspection is performed to find damage to the protective coating and discoloration of the phosphor related to humidity, which causes the phosphors to change with age.
- 9-9. Answer = (a). Thicker screens have better absorption efficiency, which reduces the radiation dose to the patient and increases the speed of the system. The conversion efficiency is unaffected because it depends only on selection of the screen phosphor material. Because conversion efficiency is unchanged with screen thickness, the QM is not changed.
- 9-10. Answer = (c). Film (without intensifying screens) has better spatial resolution and less QM than film-screen systems. The film alone (of the film-screen combination) affects the image contrast; the screen has no effect on image contrast. Use of screens does increase costs, but this is not a goal, nor is it relevant to image quality.
- 9-11. Answer = (d). With all intensifying screens, the absorption efficiency depends on the K-edge of the material in the screen phosphor. With rare earth screens, the K-edge can occur at assorted energies between 17 and 50 keV, depending on the phosphor used. Moreover, the absorption efficiency changes significantly with kVp. AEC (phototimers) must have curves to compensate for this change in efficiency with kVp in order to maintain consistent film densities at all kVp values.
- 9-12. Answer = (c). Geometric efficiency is pertinent only to radiation detectors, not intensifying screens. Absorption efficiency depends on screen thickness but does not affect QM. Screen pressure is important to film-screen contact and spatial resolution and uniformity within a radiograph.
- 9-13. Answer = (b). Contrast, thickness, and spatial resolution of the film have no effect on the overall efficiency of the matching of the film to the screen. Elasticity of the film has nothing to do with speed or efficiency.
- 9-14. Answer = (c). A film-screen system of average speed would have an intensification factor of at least 50. A system with a relative speed of 400 would have a factor 4 times greater, or about 200. A value of 1000 or more is too high.
- 9-15. Answer = (b). In most radiographic cassettes, there is a thin lead layer intended to block any x-rays transmitted through the two intensifying screens of the cassette. This approach is acceptable because the AEC detector (phototimer) of radiographic units is located in front of the cassette. For mammography, this method cannot be used because the AEC detector is located behind the cassette; instead, the cassette holder assembly is shielded with a thin layer of lead.
- 9-16. Answer = (c). Contrast is controlled only by the film and film processing. Screen thickness affects light spread, unsharpness, spatial resolution, speed, and radiation dose to the patient. The selection of screen phosphor type affects the QM.
- 9-17. Answer = (c). Anything that affects the amount of light produced per x-ray interaction in the intensifying screen affects the QM. The reflective layer redirects the light and boosts the light utilization. Absorption dyes absorb some

of the light produced to decrease the conversion efficiency. The change from calcium tungstate to rare earth screen phosphors results in an increase in the conversion efficiency. The kVp affects the absorption efficiency because of the K-edge of the phosphor. Also, higher energy⁷ x-rays that interact in the screen release more energy in the screen, producing more light per x-ray interaction, which increases the QM. Screen thickness affects only the absorption efficiency.

- 9-18.** Answer = (b). The film resolution is much greater than the screen resolution, so that it has little influence on the overall spatial resolution. Although other things affect image spatial resolution, such as motion blur, parallax, and focal spot blur, the question asked specifically about film-screen resolution. Of these two items, the screen is the limitation.
- 9-19.** Answer = (a). Although other things affect image contrast, such as filtration, kVp, and film processing, the question asked about film-screen contrast. Of the two items, the film is the component that affects the contrast; the screen does not affect the contrast.
- 9-20.** Answer = (c). Although the grid ratio does affect the patient's radiation dose, the grid does not affect the film-screen speed. The film has an influence of about a factor of 3, and the intensifying screens can have a much greater effect on the speed and the radiation dose to the patient. Film processing also has a major influence on the speed and radiation dose; however, film processing is not one of the answer choices.
- 9-21.** Answer = (c). The QM is affected by the intensifying screen conversion efficiency, the film speed, and the film processing conditions.
- 9-22.** Answer = (c). Filter mottle and dielectric mottle are falsified terms. Of the three sources of mottle, quantum mottle is the most significant factor.
- 9-23.** Answer = (a). The sensitometer and densitometer are used for film processor quality control, which is discussed in Chapter 10. A penetrometer is used to evaluate low contrast discrimination of fluoroscopic systems. A step wedge is a miniature aluminum staircase used to look at the contrast of film-screen systems. A spinning top can be used to measure exposure duration of some x-ray units.
- 9-24.** Answer = (a). If the overall speeds are the same and X has the higher conversion efficiency, the absorption efficiency of screen X is less. If the absorption efficiency is less, screen X must be thinner. The thinner screen has the better spatial resolution.
- 9-25.** Answer = (b). The product of absorption and conversion efficiencies is 1.0; hence, the patient's radiation doses are the same. A higher conversion efficiency means more quantum mottle and better spatial resolution for screen X.





Film Characteristics, Film Processing, and Film Quality Control

A. Film Characteristics

1. Film composition is as follows:
 - **Base** material of clear plastic (triacetate or polyester) to support the emulsion; it usually has a slight tint (blue or gray)
 - **Adhesive layer** to hold the emulsion
 - **Emulsion**, which is a mixture of gelatin plus silver halide grains
 - A **supercoat** to protect the emulsion, which softens and allows chemicals to pass through during film processing
2. X-rays either interact with the intensifying screen to produce light, which affects the silver halide grains and rearranges their structure (95% to 99%), or interact directly with the silver halide crystals (about 1% to 5%).
 - The rearranged silver halide crystals are **sensitivity specks**.
 - During film processing, the sensitivity specks serve as centers where other silver ions gather and are oxidized.
 - Oxidized silver atoms are black and block the light from the viewbox.
 - The darker portions of the processed film are where the amount of light from the intensifying screen and direct interaction with emulsion are greatest. Where the interactions are few, this portion of the processed film is relatively clear and allows the most light from the viewbox to pass through the film.
 - The film that has been exposed to x-rays but has not yet been run through the film processor is said to have a **latent image** that will appear after film processing.
 - If there is a long delay between x-ray exposure and film processing, some of the affected silver grains can recombine with electrons and no longer act as sensitivity specks. Thus, long delays between x-ray exposure and film processing result in a film with fewer oxidized silver grains, producing a lighter film; this is called **latent image fading**.



- When nearly all the silver halide grains have been affected by the x-rays, the processed film is the darkest that it can get. It blocks the most light from the viewbox. This maximum darkness of the film is called **DAIAX**. Additional x-ray exposure cannot make the film any darker.

3. **Density (D)** is defined as the logarithm (to the base 10) of the light incident upon the film from the viewbox (I_0) divided by the light transmitted through the exposed and processed x-ray film (I_T).

$$D = \log(I_0/I_T)$$

4. For each 50% reduction in the amount of transmitted incident light from the viewbox, the density increases by the addition of another 0.30 optical density (OD) units.

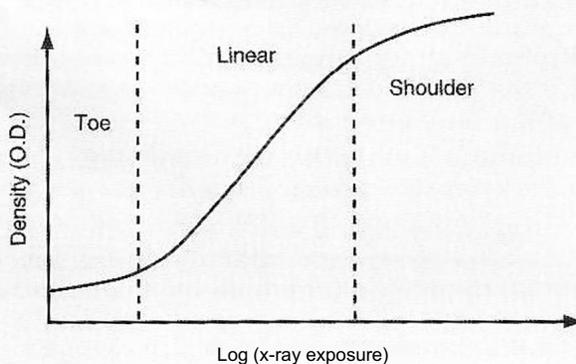
(I_0/I_T)	DENSITY (OD)
1.0	0.0
0.5	0.30
0.25	0.60
0.125	0.90
0.0625	1.20

5. For each reduction in the amount of transmitted incident light from the viewbox by a factor of 10, the density increases by the addition of another 1.0 OD.

(I_0/I_T) DENSITY (OD)

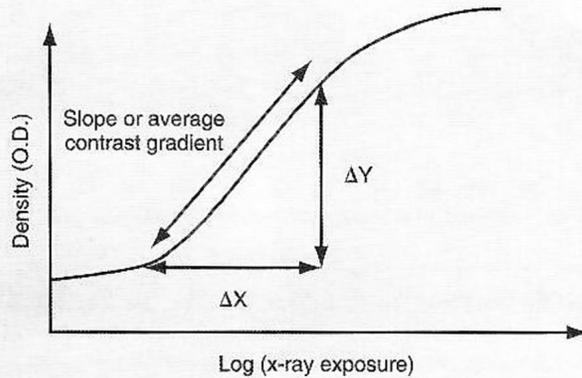
1.0	0.0
0.10	1.00
0.01	2.00
0.001	3.00
0.0001	4.00

6. Useful radiographic densities are usually defined to be in the range of 0.50 to about 2.5 OD because higher densities transmit too little light to be seen. However, in mammography, which uses viewboxes with a high light level and "hot lights," densities up to 3.5 may be seen.
7. Each film-screen combination has a distinctive **characteristic curve**, which plots the film density versus the logarithm of the radiation exposure used to obtain that density. This curve is also called the **H&D curve**.
 - The shape of the curve depends on the film selected, the intensifying screen selected, and the film processing conditions.
 - All curves have three different regions, called the toe, the linear portion, and the shoulder.





8. The *toe* is not a useful region because changes in the radiation exposure levels do not cause much of a change in film density. The *shoulder* is not a useful region because the film is so dark and most of the silver grains have been used. Additional radiation in the shoulder region does little to increase the density.
9. In the *linear region*, every increase in radiation causes a linear increase in density. The slope at every portion of the characteristic curve is called the gamma (γ) and the average slope of the curve between densities of about 0.50 and 2.50 OD is called the average contrast gradient (γ).



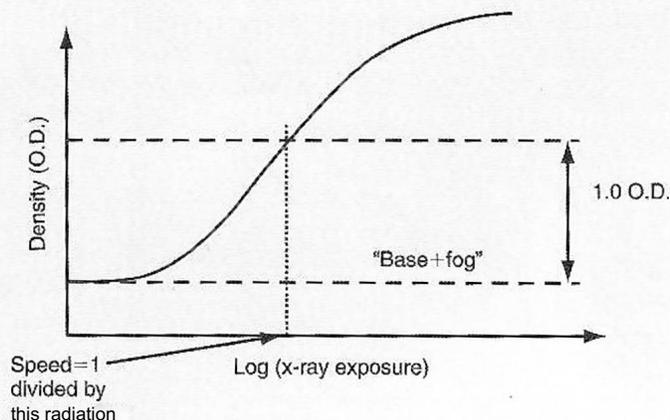
10. The change in density divided by the change in log (x-ray exposure) in the linear portion of the characteristic curve is the *average contrast gradient* of the film.
 - Values < 2.50 are seen with *latitude film*, which does not show much contrast.
 - Values > 3.0 are seen with *contrast film*.
 - *The intensifying screen choice does not affect the average contrast gradient.*
 - The film processing conditions do affect the average contrast gradient and can either increase or decrease the value.
11. *Base + fog* level is the density of the film in the toe region of the characteristic curve.
 - The density is a combination of the tint of the film and the exposure to cosmic rays, background radiation, light leaks, and heat, which cause the film grains to change without direct x-ray exposure,

@ Base + fog densities should be less than 0.25 OD for radiographic film and less than 0.20 OD for mammography film.
12. *Speed* is related to the radiation level required to darken a film-screen combination to a density of 1.0 OD greater than the base + fog density. For example, if the base + fog density is 0.20 OD, the speed is 1.0 divided by the radiation (in roentgens), which results in a density of 1.20 OD.
 - This definition is *absolute speed*.
 - There is also *relative speed*, which compares a film-screen combination with an older "par speed" film-screen system that is arbitrarily assigned a value of relative speed = 100.
 - Other film-screen combinations that require less radiation to achieve a density of 1.0 OD above the base + fog level would have a relative speed proportionally greater than 100, and systems that require more radiation would have a relative speed proportionally less than 100.
 - For example, a combination that requires 25% of the radiation of a par speed combination would have a relative speed of 400.



TYPE	EXPOSURE FOR 1.0 OD ABOVE BASE + FOG	ABSOLUTE SPEED	RELATIVE SPEED
Extremity	4.0 mR	250 R ⁻¹	50
Par	2.0 mR	500 R ⁻¹	100
Rare earth	0.5 mR = 0.0005 R	2000 R ⁻¹	400

- *Higher speed values mean less radiation to the patient for equivalent film densities.*



- Differences in film types have only a minor influence on the overall film-screen speed—a factor of about two times or half the speed. The screen selection has the greatest impact on the overall speed of the combination.
- The *spatial resolution* of plain film without an intensifying screen is very high, at about 50 to 100 line pairs per millimeter (LP/mm). Hence, it is the intensifying screen that limits the overall spatial resolution of the film-screen combination; the film selection does *not* limit the spatial resolution of the combination.

B. Film Processing

- Film processing consists of four stages in automated units:

- **Development** softens the supercoat and wets the film, then oxidizes the silver grains that have been exposed to light or x-rays but does not affect unexposed silver grains.

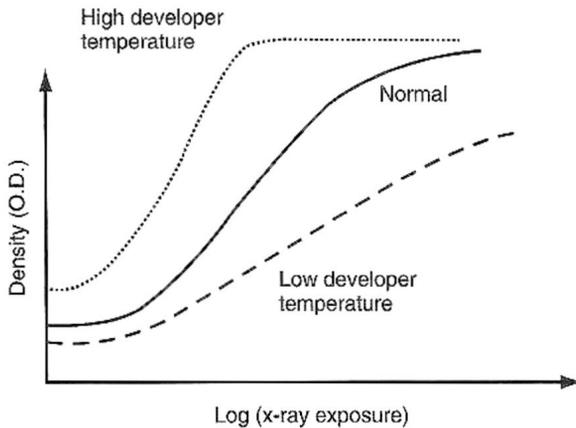
- **Fixation** washes off unaltered and unoxidized silver grains and stops the development process.

- **Washing** washes off the chemicals from the film.

- **Drying** dries the film.

- Problems with the developer section can affect the film speed, contrast gradient, and base + fog.
- Problems with the fixer section can affect the archival storage. Incomplete fixing causes the film to darken with age of storage.
- Problems with the wash section leave spots on the film.
- Excessive heat in the dryer section causes the film to wrinkle, and too little heat results in wet films.
- Too much heat in the developer section (or slow transport speed or chemicals that are too concentrated) results in more base + fog density, a higher average contrast gradient, and a faster speed. A low temperature of the developer solution (or fast transport speed or low chemical specific gravity) results in low

base + fog density and lower average contrast gradient and requires more radiation to darken the film (low film speed).



7. Typical developer temperatures range from 92° F to 95° F (34.0° C).
8. Silver removed from the film goes into the fixer solution. Because silver is toxic and valuable, it is then usually electrolytically **reclaimed** from the solution.
9. Automated film processors often measure the amount of film being processed and add a small amount of chemical in the developer and fixer to replace the amount being depleted. This is called **replenishment**.

C. Film Processor Quality Control

1. A **sensitometer** is an electronic device that exposes a QC film to 21 different levels of light to produce a latent image with 21 different levels of density.
2. A **densitometer** is an electronic device that measures and digitally displays the darkness of a processed film in units of OD (optical density).
3. Once a film processor has been optimized and stabilized, a sensitometer is used to expose a film from a QC control box, and the film is processed.
 - § The density step closest to 1.20 OD is selected as a **speed step** to be monitored on a daily basis. This density must be within ± 0.15 OD of the established aim value.
 - The density step that is closest to 2.2 OD above base \pm fog is selected as the high-density (HD) step. The density step that is closest to 0.4 OD but greater than 0.4 OD is selected as the low-density (LD) step. The density of these steps is measured daily. The difference in density between HD and LD steps is calculated; this is called the **contrast index**. It is determined daily and should be within ± 0.15 OD of the established value.
 - e The density of the **base -fog** level on the daily QC film is also measured. The base + fog density must be less than the values listed.
 - e A digital thermometer is used to measure the **developer temperature**, which should be within $\pm 1.0^\circ$ F of the recommended value.
4. **Darkroom fog** of film related to light leaks must be assessed. A sensitometer is used to expose a film on both edges. Half the film is covered and placed in the darkroom for 2 minutes. It is then processed, and the density of the speed step is measured on both sides of the film. The uncovered speed step should not be more than ± 0.05 OD higher than the covered speed step. If the density exceeds this level, methods to lessen light leaks in the darkroom must be employed.
5. Film can be sensitive to different wavelengths (colors) of visible light. Standard silver halide film is sensitive to blue light. To obtain sensitivity to green light,



orthochromatic film is needed. Special dyes are used to improve sensitivity to other wavelengths of light. Panchromatic film is sensitive to even longer wavelength visible light.

D. Questions

- 10-1.** An exposed and developed radiographic film that transmits only 3% of the incident viewbox light has a density of OD. _____
 (a) 0.5 (b) 1.0 (c) 1.5 (d) 2.0 (e) 2.5
- 10-2.** The range of exposure values that produce acceptable densities of the exposed and processed film is called the. _____
 (a) Speed (b) Base + fog (c) Average contrast gradient
 (d) D_{MAX} (e) Latitude
- 10-3.** The is equal to 1.0 divided by the radiation in roentgens needed to produce a density of 1.0 OD above the background levels of the unexposed and developed film.
 (a) Speed (b) Base + fog (c) Average contrast gradient
 (d) D_{MAX} (e) Latitude
- 10-4.** The density of an unexposed and processed film is called. _____
 (a) Speed (b) Base + fog (c) Average contrast gradient
 (d) D_{MAX} (e) Latitude
- 10-5.** The is the highest density that can be obtained on an exposed and processed film.
 (a) Speed (b) Base + fog (c) Average contrast gradient
 (d) D_{MAX} (e) Latitude
- 10-6.** The average slope of a film characteristic curve is called the. _____
 (a) Speed (b) Base + fog (c) Average contrast gradient
 (d) D_{MAX} (e) Latitude
- 10-7.** If the film is not sensitive to the wavelength (color) of light emitted from the phosphors in the intensifying screens, the decreases. _____
 (a) Spatial resolution (b) Speed (c) Contrast (d) Latitude
 (e) Exposure time
- 10-8.** The selection of the film can affect all of the following imaging quality parameters, *except*. _____
 (a) Patient's radiation dose (b) Image contrast (c) Spatial resolution
 (d) Quantum mottle (noise) (e) Base + fog levels
- 10-9.** Increasing the developer temperature in the film processor can cause all image changes, *except*. _____
 (a) Increased quantum mottle (noise) (b) Increased base + fog
 (c) Greater average contrast gradient
 (d) Reduced radiation dose to the patient (e) Improved latitude
- 10-10.** The ideal film processor developer temperature for most radiographic film, chemicals, and processors is approximately. _____
 (a) 85°F (b) 90°F (c) 95°F (d) 100°F (e) 105°F
- 10-11.** Film processor performance is monitored by QC systems that use a(n) _____.
 (a) Dosimeter (b) Sensitometer (c) Photometer (d) Strain gauge
 (e) Interferometer



- 10-12.** The parameters typically measured in most film processor QC programs include all of the following items, *except*. _____
 (a) Temperature (b) Speed point (c) pH levels (d) Contrast index
 (e) Base + fog densities
- 10-13.** Parameters that can affect film processor performance include all of the following, *except*. _____
 (a) Developer temperature (b) Replenishment rates
 (c) Specific gravity of chemistry (d) Fixer temperature
 (e) Bromine content
- 10-14.** The darkroom-light fog levels should cause the speed point density to increase less than OD for a 2-minute exposure.
 (a) 0.02 (b) 0.05 (c) 0.10 (d) 0.15 (e) 0.20
- 10-15.** The base 4- fog level for radiographic film should be less than OD. ____
 (a) 0.05 (b) 0.10 (c) 0.15 (d) 0.20 (e) 0.25
- 10-16.** The useful density range for most radiographic film is usually considered to be between OD and OD. _____
 (a) 0.2, 1.2 (b) 0.3, 1.8 (c) 0.4, 2.2 (d) 0.5, 2.5 (e) 0.6, 3.0
- 10-17.** In the linear portion of a film characteristic curve, a density increase from 1.2 to 1.8 OD (for an average contrast gradient of 3.0) requires a radiation increase of about%. _____
 (a) 20 (b) 40 (c) 60 (d) 80 (e) 100
- 10-18.** A film-screen combination has a density of 1.50 OD for an incident radiation level of 1.0 mR. If the incident radiation is increased to 2.0 mR, the density increases to 2.31 OD. The average contrast gradient of this film-screen combination is. _____
 (a) 2.00 (b) 2.35 (c) 2.70 (d) 3.00 (e) 3.33
- 10-19.** All of the following improvements to film have contributed to better image quality, *except*. _____
 (a) Tabular silver grains (b) Activator dyes (c) Anticrossover layers
 (d) Asymmetrical emulsion layers (e) Thicker supercoats
- 10-20.** Delays in the processing of exposed film cause. _____
 (a) Increased contrast (b) Loss of film density (c) Increased base + fog
 (d) More scatter radiation (e) No effect at all
- 10-21.** Long-term archival storage of exposed and developed film depends on _____.
 (a) Proper development temperature (b) Adequate fixing
 (c) Proper washing (d) Proper film dryer temperatures
 (e) Flood replenishment
- 10-22.** In matching a film with an intensifying screen cassette, one should consider all the following characteristics of the film, *except*. _____
 (a) Contrast (b) Color sensitivity (c) Speed (d) Spatial resolution
 (e) Tint
- 10-23.** The film characteristic curve (H & D) plots versus _____.
 (a) P radiation, contrast (b) Contrast, latitude (c) Density, resolution
 (d) Density, log (exposure) (e) Speed, temperature
- 10-24.** The speed point step of most film processor QC programs is usually chosen around a density of OD. _____.
 (a) 0.50 (b) 1.00 (c) 1.20 (d) 1.50 (e) 2.00

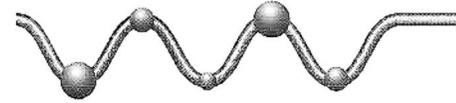


- 10-25. Film processor OC programs usually require both the speed point and the contrast index to vary less than ± 0.05 from the established aim values.
- (a) 0.05 (b) 0.10 (c) 0.15 (d) 0.20 (e) 0.30

E. Answers

- 10-1. Answer = (c). Each reduction of one half in light intensity adds a density of 0.30 OD. Hence, 50% = 0.30 OD; 25% = 0.30 + 0.30 = 0.60 OD; 12.5% = 0.30 + 0.30 + 0.30 = 0.90 OD; 6.25% = 0.30 + 0.30 + 0.30 + 0.30 = 1.20 OD; and 3.125% = 0.30 + 0.30 + 0.30 + 0.30 + 0.30 = 1.50 OD.
- 10-2. Answer = (e). The latitude of the film is the range of exposures that produce acceptable film densities. Also, latitude refers to a film that is the opposite of a contrast film; the film shows more shades of gray rather than a sharp difference of dark and clear densities.
- 10-3. Answer = (a). This is the definition of the absolute speed of a film-screen combination.
- 10-4. Answer = (b). An unexposed and processed film has density related to the film base tint and silver grains that have been affected by cosmic rays, background radiation, light leaks (such as darkroom fog), and thermal effects.
- 10-5. Answer = (d). When almost all the silver grains are oxidized, the highest density is obtained, which is called density maximum (D_{MAX}).
- 10-6. Answer = (c). See the definition of average contrast gradient (point 9 under "Film Characteristics").
- 10-7. Answer = (b). The spatial resolution, contrast, and latitude do not change when the film and intensifying screen are color mismatched. The mismatch results in more light being required to create a sensitivity speck because the light is not of the optimal wavelength (color) to transfer its energy to the silver grains. Hence, more light and more radiation are required. The radiation dose to the patient and the exposure time also increase.
- 10-8. Answer = (c). The film selection affects the overall film-screen speed (although not as much as the intensifying screen), the contrast, the latitude, the base + fog level, and the D_{MAX} . Because the spatial resolution of film is about 10 times better than that of the intensifying screen, the film does not affect the overall resolution of the combination. The intensifying screen is the "weak link" that dominates the overall spatial resolution.
- 10-9. Answer = (e). Higher developer temperatures increase the speed, contrast gradient, and base + fog levels. The higher speed of the system means that the patient's radiation dose is less. Moreover, the higher speed is equivalent to a more efficient film-screen system, which increases the quantum mottle. Because contrast and latitude are opposites, increasing contrast reduces latitude.
- 10-10. Answer = (c). The ideal temperature for most developer solutions is between 92° F and 95° F, with 95° F being the most common temperature.
- 10-11. Answer = (b). A dosimeter is used to measure radiation exposure levels. A photometer is used to measure light intensity levels. A strain gauge is used to measure mechanical pressures and forces. An interferometer is used to measure small distance differences according to shifts in wavelengths of light. Film processor QC is done with a sensitometer to expose the film to difference steps of light intensity, and a densitometer is used to measure the density differences on the processed film.
- 10-12. Answer = (c). Although the pH of the developer solution does have an effect on film processing, the relation is complex and depends on many other factors.

Moreover, pH is difficult to measure properly. Hence, pH is usually not included in the QC program.



- 10-13. Answer = (d). Developer temperature directly affects the chemical reaction rates and film density. Fixer solution affects only archival storage of the film. Replenishment is needed to replace depleted chemicals as the film interacts with the solutions. Specific gravity determines whether the chemical is diluted with water, which reduces its potency. Although not mentioned in the notes, bromine content is important to the reaction rates of the development process. In any event, the correct answer could have been narrowed to (d) or (e) by eliminating the answers known to be incorrect.
- 10-14. Answer = (b). The darkroom fog caused by stray light must be less than an increase of 0.05 OD in 2 minutes, as stated in the notes.
- 10-15. Answer = (e). Base + fog on radiographic film should be less than 0.25 OD, and less than 0.20 OD for mammography film.
- 10-16. Answer = (d). Film densities of less than 0.5 OD are in the toe of the characteristic film curves, with diminished contrast, and are too light to use. Film densities of more than 2.5 OD transmit less than 0.25% of the incident light. Unless the film is linear in this region, the viewbox has high-intensity light, and the viewing room is very dark, it would be difficult to visualize details on the film because of the low light transmission through this level of film darkness.
- 10-17. Answer = (c). In the linear portion of the characteristic curve, the density (D) is related to the radiation exposure (Ex) by the average contrast gradient (y).
- $$D = y \log(\text{Ex}) + (B + F)$$
- This equation can be rearranged to solve for density differences, $\Delta D = D_2 - D_1$.
- $$\Delta D = y \log(\text{Ex}_2 / \text{Ex}_1)$$
- $$[\text{Ex}_2 / \text{Ex}_1] = 10^{(\Delta D / y)}$$
- A simple generalization usually gives approximate answers for normal film with an average contrast gradient of about 3.0. **The rule is that each 0.10 OD change requires about a 10% change in radiation exposure to the film-screen cassette.**
- 10-18. Answer = (c). The radiation is double, and $\log(2.0) = 0.30$. The difference in film density is 0.81 OD. Average contrast gradient is the difference in density divided by the log of the ratio of the radiation exposures:
- $$0.81 / 0.30 = 2.70.$$
- 10-19. Answer = (e). Tabular silver grains are flat and allow better packing and coverage of the film surface. Activator dyes enable the incident light from the intensifying screens to be better absorbed by the film and to transfer the energy to the silver grains. Anticrosslayer is a special light-absorbing coating that is placed behind the silver grain layer; it prevents light from the front screen from passing through the adjacent silver emulsion layer of film and exposing the rear film emulsion layer on double-emulsion-layer film. Because of the divergence of light from the screen and parallax of front and rear emulsion layers, crossover degrades image quality by making edges of objects unsharp. Asymmetrical coating of a different front and rear emulsion layer permits the film characteristic layer to be shaped with a dual slope that is useful for certain clinical studies (e.g., chest radiographs). Thicker supercoats on the film would allow more light divergence and light scattering, which would reduce spatial resolution and make edges unsharp.
- 10-20. Answer = (b). Delays in the processing of exposed film cassettes or even computed radiography (CR) cassettes for periods of time of 60 minutes or longer cause the densities on the processed image to be less. This is known as **latent image fading**. With film, the delays allow the ions created by the x-ray exposure to migrate and repair the latent specks.



- 10-21'** Answer = (b). Developer temperature affects the speed, contrast, and density of the film. Failure to wash film properly can leave spots and a white coating on the film. Too high a dryer temperature causes the film to wrinkle, and too low a temperature leaves a wet film. Flood replenishment constantly adds small amounts of chemical to the developer and fixer tank: it is used in film processors that process very few films per day. Chemicals not only are lost in processing the films but also deteriorate because of heat, evaporation, and oxidation after being unused for long periods of times. Fixer is supposed to remove unexposed silver grains; dilute fixer solution leaves the unexposed silver grains on the film, which then change because of the heat and ambient light over long periods of time. Thus, films that are not properly fixed darken over time.
- 10-22.** Answer = (d). It is important to select film that provides the proper contrast, radiation dose to the patient (speed), and tint needed for clinical studies. To utilize the light from the intensifying screens efficiently, the film should be sensitive to the same color of light as emitted by the intensifying screens. Because the spatial resolution of almost all film is much greater than that of the intensifying screens, film selection does not affect spatial resolution limitations.
- 10-23.** Answer = (d). See the graphs on pages 78 and 79.
- 10-24.** Answer = (c). Traditionally, the speed point is usually 1.0 OD above the base + fog density (which is usually 0.15 to 0.25 OD). The useful range of film densities is between 0.50 and 2.5 OD and is also the linear range. Hence, a density of 1.20 OD is near the center of this range.
- 10-25.** Answer = (c). See the notes and state and local regulatory requirements as well as American College of Radiology accreditation requirements.