# 4 REJECT-REPEAT ANALYSIS PROGRAM

One of the main goals of a quality control program is to reduce the number of films that are rejected and repeated. By rejects we mean all scrap film including greeen film, black film, clean-up films, and patient films. We limit repeat films to those radiographs of patients that were not accepted and required an additional exposure of the patient. This accomplishes two things—1) it reduces the amount of film and chemistry that will be needlessly wasted; and 2) it reduces the number of times patients will have to be exposed two or more times without providing additional diagnostic information. Consequently, we should consider the analysis of rejected and repeated films a key to how a radiology department is functioning. Although a Reject-Repeat Analysis Program (RAP) could be considered a measure of the effectiveness of a QC program, it should be used with caution in this vein since many other factors should be considered in determining the efficacy of such a program. The reject-repeat rate can be reduced to zero if the radiologist reads every film that comes out of the processor, but these films may not contain the necessary diagnostic information.

The steps necessary to carry out a Reject-Repeat Analysis Program are outlined in the Procedures section of this chapter, and also discussed in the literature (Goldman, 1979). However, we should look at what we can and cannot learn from such a program. First of all, we can determine what the reject rate is for a specific department and compare this to the average reject rates from around the country, as shown in Table 4.1. However, anytime you compare data from a single institution with that of others, it is important to be certain that the data were collected in the same manner and that the facilities are similar. For example, does one institution include all "green" film in the count of rejected films whereas another does not? Does one institution rely on an estimate of the number of films consumed whereas another relies on a counter attached to the entrance roller of the processor to determine the number of films processed? [This also provides an inaccurate count since small films—e.g., 8 × 10 inch (20 × 25 cm)—should be processed two at a time.] Does one institution notify the technologists that a RAP is being carried out whereas another does not? In terms of facilities, one must consider many variables—does the institution have student technologists; is the patient mix at the institution similar (e.g., all inpatients, all outpatients, mostly trauma patients); are the number of cases per technologist similar at both institutions; what is the attitude of the radiologists toward quality films (i.e., will they read anything that comes out of the processor)? All of these variables, and many more, will affect the results of a RAP, so comparison of data between two or more institutions is difficult to say the least.

The attitude of the staff technologists is very important in a RAP. If QC and the RAP are seen as policing measures, every effort will be made, intentionally or unintentionally, to thwart the RAP. Even unconsciously a technologist may pass films that he or she might normally repeat on to the radiologist to read, if a RAP is in progress, just to reduce the overall repeat rate. In some institutions, technologists have been known to take their repeat films home with them for disposal while a RAP was going on.

There are several key guidelines to carrying out a RAP. Everyone in the department should be aware

**Table 4.1.** Reject-repeat rates

| | Reject rate (%) | | Repeat rate (%) | |
|---|---|---|---|---|
| | Before QC | After QC | Before QC | After QC |
| DuPont (Hall, 1977) | 13[a] | 7 | 9 | |
| University of Connecticut | | 14.3 | 8.4 | |
| PHS Hospital (Goldman et al., 1977) | | | 8 | 6.2[b] |
| Donelson Hospital | | | 9–10 | 3–5 |
| Hammond Clinic (ACR, 1981) | 6.5–8 | 2.75–3.75 | | |
| Medical College of Virginia (ACR, 1981) | | | 8 | 3 |
| Morton F Plant Hospital (ACR, 1981) | 12.6 | 6.2 | | |
| McLaren Hospital (ACR, 1981) | | | 10 | 7.4 |
| Mercy Hospital, Baltimore (ACR, 1981) | 24 | 13.6 | 14 | 8.6 |
| Fountain Valley Community Hospital (ACR, 1981) | | | 15 | 7.7 |
| Mercy Hospital, Davenport (ACR, 1981) | | | 14 | 7.5 |

[a]Hall indicated a range of reject rates before QC from 2% to 46% over 150 facilities.

[b]After photographic processor QC only.

that such a program will be going on sometime in the future and they should be made aware of the results in a constructive manner. Individual technologists should never be identified as being at fault for the results of the RAP. Consequently, technologists' identification should be removed from the rejected films if any of them are to be used as teaching cases for in-service education.

You will find a considerable diversity of opinion in trying to determine why films were rejected. A radiologist who is involved in the analysis may find that many rejected films would have been acceptable for readings. Consequently, there should be a category on the analysis sheet for "good" films. The fact that these films were acceptable should be communicated to all of the technologists. The same people should analyze the films each time since different individuals will have different criteria for judging a good film, whether a film is too light or too dark, whether the radiograph was retaken due to motion or position, and so on.

The results of the RAP should never be used competitively between areas of a hospital, different hospitals, or different groups of technologists since such competition is not fair and the results of the RAP, under such conditions, will be less than reliable. The results of the RAP should be communicated to all of the technologists in terms of the overall reject rate at their institution, and perhaps relative to the national averages where appropriate. Such results can be used to demonstrate the effective efforts of *all* personnel in the department in reducing the number of rejected or repeated films but should never be used to demonstrate the effectiveness of the QC program to the staff technologists or radiologists since *everyone* in the department is responsible for the rejected and repeated films. The results of a RAP indicate the effectiveness of the QA program, which represents the overall quality assurance efforts of everyone.

Before a RAP can be carried out, strict guidelines must be established concerning the methods of film collection and analysis. The following guidelines are an example of the necessary "ground rules" to assure that the study is carried out in the same manner each time:

1. No copy or subtraction films should be included in the reject count or total film count.
2. "Positioning" includes any errors generally attributed to the technologist; for example, no labels on the film, snaps from patient gowns, or dual exposures.
3. Scout films, although normally rejected, will be included in the count as "Scouts."
4. Films from special procedure areas (cardiovascular and neurological) will not be included in the reject count or the total number of films used.
5. The "miscellaneous" category should be used for films that cannot be fit into the other categories. Notation should be made concerning the cause of the rejects in miscellaneous categories.
6. Examples of "good films" should be saved.
7. You should look at three separate categories: (A) total waste films—all films that are in the

scrap bin; (B) total rejects—all films except clear films and quality control films; and (C) total repeats—only those films for which you are fairly certain that an additional film was made of the patient.

The results of a *reject* analysis, based on the above guidelines, are shown in Figure 4.1, Table 4.2, and Table 4.3. There are several notable points in Table 4.2., especially the fact that the type and mixture of patients will significantly affect the results. For example, an outpatient clinic would expect to have a lower overall reject rate than a hospital general radiology department. Likewise, a hospital emergency room would be expected to have a higher reject rate than a hospital general radiology department.

Location St. Mary's General
From 12/1/81 To 12/29/81

| Cause | Number of Films | Percentage of Rejects | Percentage of Repeats |
|---|---|---|---|
| 1. Positioning | 46 | 30 | 37 |
| 2. Patient Motion | 5 | 3 | 4 |
| 3. Light Films | 21 | 14 | 17 |
| 4. Dark Films | 14 | 9 | 11 |
| 5. Clear Film | 20 | | |
| 6. Black Film | 17 | 11 | 13 |
| 7. Tomo Scouts | 12 | 8 | |
| 8. Static | — | — | — |
| 9. Fog—Darkroom | 2 | 1 | 2 |
| 10. Fog—Cassettes | 6 | 4 | 5 |
| 11. Mechanical | 6 | 4 | 5 |
| 12. Q.C. | 10 | | |
| 13. Miscellaneous (?) | 15 | 10 | |
| 14. Good Films | 9 | 4 | 7 |
| Total Waste (1-14) 7.8 % | 183 | | |
| Total Rejects (All except 5 and 12) | 153 | (6.5) | |
| Total Repeats (1-4, 6, 8-11, 14) | 126 | | 5.4 |
| Total Film Used 2354 | | | |

Figure 4.1. Worksheet for reject and repeat analysis.

**Table 4.2.** Mayo Clinic reject rates

| Section | Rate (%) |
|---|---|
| Clinic (outpatients) | 3.1(weighted average) |
| Heads | 6.6 |
| General | 2.8 |
| Mammography | 1.8 |
| Pediatrics | 8.6 |
| Community Medicine | 5.8 |
| Methodist Hospital | 6.4 |
| St. Mary's Hospital—General | 6.5 |
| St. Mary's Hospital—ER | 7.7 |
| Weighted average | 5.2 |

Even within one type of facility there will be a diversity of reject rates depending on the type of examinations. For example, in an outpatient facility the highest reject rate is found in pediatrics, not surprising since one would expect problems with patient motion. (The reject rates shown in the breakdown of the outpatient clinic exams are statistically significant since they are based on the analysis of over 8,000 *processed* films.)

The next aspect to consider in a RAP is that of the percentage of rejects by category (Table 4.3). In this analysis, you take all of the *rejected* films and determine what percentage of the total number of rejects fall into each of the categories. The results of this analysis can be used to guide the efforts of the quality control program.

When a QC program is first initiated, it will usually be found that a large percentage of the rejected films falls into the categories of light films and dark films. After a good QC program has been in effect, you will find that the percentage of films in these categories *decreases* but that the percentage in other categories such as positioning and patient motion *increases*. This is to be expected since the total number of rejected films is decreasing and the number in the light and dark film categories is decreasing. Consequently, if the *number* of films in the positioning and motion categories stays the same the *percentage* of these films relative to the total number of rejected films must increase.

**Table 4.3.** Percentage of rejects by category, St. Mary's Hospital—general radiology

| | Rejects (%) |
|---|---|
| Positioning | 30 |
| Patient motion | 3 |
| Light films | 14 |
| Dark films | 9 |
| Black films | 11 |
| Tomo scouts | 8 |
| Static | — |
| Fog—darkroom | 1 |
| cassette | 4 |
| Mechanical | 4 |
| Good films | 6 |
| Miscellaneous | 10 |

There is a wealth of useful information in the results of a RAP. However, the data must be collected with extreme care and the results must be analyzed with great caution to assure that the conclusions drawn from the study are correct and meaningful.

# PROCEDURES

## 4.1. REJECT-REPEAT ANALYSIS PROGRAM (RAP)

### Purpose

To provide a method for the analysis of the rejected radiographs in a radiology department. The results of such an analysis will provide information concerning those aspects of radiologic imaging that need the most attention. If you plan to initiate a quality control program then you should carry out an analysis of your rejects before starting the QC program so you will have some idea of the impact of your quality control efforts.

### Equipment Needed

1. Rejected radiographs and a count of the total number of films consumed during the survey period
2. A QC technologist and, preferably, a radiologist

### Procedure

1. Clean out all rejected film bins throughout your departments.
2. Establish a method to accurately determine the amount of raw film consumed starting on the day that you cleaned out the reject bins.
3. After at least 1 week, or the period of time that it takes to produce about 1,000 radiographs, collect all rejected radiographs and determine the actual number of radiographs exposed (i.e., the number of sheets of raw films consumed) during this period.
4. Analyze, with a radiologist if possible, all of the rejected films and determine the reason that they were probably rejected.
5. Record these numbers on a tally sheet (see the examples in Figure 4.1 and Appendix A) as you are reviewing the films. (Don't be surprised if there are many radiographs for which you can't determine the cause of rejection.)
   [***Note:*** It will be difficult to determine if a light or dark radiograph was rejected because of poor technique or improper processing. Consequently, these must be classed simply as "light" or "dark."]
6. Determine the overall reject rate. For example, if there were 153 rejected films and a total of 1225 films produced, then the overall rate is

$$\frac{153}{1225} \times 100\% = 12.5\%$$

7. Now determine the percentage of rejects from each of the categories. For example, let's say that 49 films fell into the category labelled "too dark." The percentage of rejected films falling into this category is then

$$\frac{49}{153} \times 100\% = 32\%$$

### Problems and Pitfalls

1. Many technologists regard a reject analysis program as a means of "checking up on them." Consequently, you should not use the reject analysis program to determine which technologist is producing the most rejected radiographs.
2. If possible, it would be better not to let your technologists know when you are collecting the rejected films. If they know you are collecting rejects, they will often pass more radiographs through to the radiologists or throw rejected films in the trash can rather than the reject box. In fact, in one institution, the technologists actually carried rejected films home with them to avoid having their supervisors find out how many films were not acceptable.
3. Once you have completed the reject analysis, share the results of your study with the radiologists and technologists, explaining to them what these results mean and how you plan on reducing the number of rejects. Remember to point out to them that reducing the number of rejects will reduce the technologists' work load and frustrations and will save the department money in terms of reduced film and chemical consump-

tion, while higher patient throughput may be realized. Also, the radiation exposure to the patients and staff will be reduced.

4. One problem in this type of analysis is the "acceptance level" of the radiologist. We all know which radiologist in our department will "accept anything." Consequently, if the department has become accustomed to poor and variable quality radiographs and the radiologists accept them, the overall reject rate may be quite low. However, this does not mean that a quality control program is not needed. It does mean that the technologists are not exhibiting pride in their work, and the radiologists are not providing the best medical care possible to their patients. This, of course, means a QC program is needed to improve image quality and consistency. Once the radiologists start reading good quality, consistent films they will appreciate the need for QC and the efforts of their technologists while having more confidence in the diagnostic information content of the images.
5. In general, special procedures should not be included in the overall departmental reject analysis but should be analyzed separately.

**Acceptance Limits**

1. The overall reject rate should be less than 10%. Ideally, you should attempt to get the overall reject rate down to about 5%. This depends not only on a good QC program but on a good rapport between the radiologists and technologists, as well as an understanding between them as to what constitutes a good radiograph and what should be rejected.
2. Compare your percentage of rejects (from Procedures Step 7) to those from other institutions (Tables 4.1, 4.2, and 4.3; Hall, 1977). Those categories that contain the highest percentage of rejects should receive the most attention. For example, Hall (1977) showed that before the initiation of a QC program the combination of light and dark films accounted for 73% of all rejects. After the QC program had been in operation, this percentage dropped to 32%.

**Corrective Action**

1. If your overall reject rate is in excess of 10%, you are desperately in need of a good quality control program.
2. If your reject rate is between 5% and 10%, then you may be in one of two situations:
   a. The quality of your radiographs is good. If you don't presently have a QC program, you should initiate one to assure that you maintain the present quality of your radiographs.
   b. Your radiologists are accustomed to accepting poor quality radiographs since they can "read through" the poor quality films (Goldman et al., 1977). In this case you should work closely with your radiologists to establish a QC program and demonstrate to them the difference quality can make.
3. Remember, as your QC program becomes effective the overall reject rate should decline. Likewise, you should see a decrease in percentage of rejected films that are due to faulty equipment, processing, and so on—such as films that are too light or too dark. However, as the percentage of rejects due to a specific cause decreases, this means that the *percentage* due to the other causes will increase, but you should not see an increase in the total *number* of rejected films due to the other causes. The percentage of rejects should be used only as a guide to direct your efforts to those areas needing the most attention. The effectiveness of your quality control program should only be judged from the overall repeat rate.

# 5 PHOTOGRAPHIC QUALITY CONTROL

Of all of the areas requiring quality control in medical imaging photographic processing equipment is probably the one that demands the most attention, most frequently, and with the most care, since the photographic film is quite sensitive to changes in the processing system. All of the efforts expended in QC in other areas can be quickly negated if the processor is not well controlled.

There have been several studies made throughout the nation indicating the difficulties with photographic processing, but the study by Suleiman et al. (in press), conducted in New Jersey, is the most recent and provides excellent documentation of these problems. They evaluated 479 film-chemistry-processor systems in medical x-ray facilities. The results indicated that variations in relative speed of the same radiographic film processed in the various processors ranged from 35 to 210 (with 100 being the "normal" speed). This is a sixfold variation in film speed from processing alone! More significantly, the 245 processors producing speeds from 35 to 100 required an increased exposure to the patient to produce a radiograph—that's more than half of the processors.

The base-plus-fog levels on the films (the density of the unexposed portion of the film after processing) from all of the processors ranged from 0.09 to 0.53 with a range of about 0.15 to 0.20 being considered optimum. This is particularly important since increased fog decreases contrast and reduces diagnostic information content.

Fog can also be caused by the improper use of safelights in the darkroom or by light that is "unsafe," i.e., light that can fog the film, such as white light. Of the darkrooms studied, only 48% did *not* significantly fog the film in 1 minute (Suleiman, personal communication).

Obviously, a large portion of the darkrooms in the country are producing less than optimal results in terms of speed variations due to processing (contrast is also affected by improper processing) and in terms of light fog on the films. Consequently, we recommend that the first efforts of a quality control program should be directed at the photographic processing and darkroom aspects of the medical imaging department.

We have adopted the term "mechanized processors" as opposed to "automatic processors" in this book for a specific purpose. We would like to dispell the idea that processors are "automatic." In fact, processors are merely a mechanized method for processing film. They need a considerable amount of attention to assure that they function in the way the manufacturer intended and to maintain the activity of the chemistry at the intended levels.

A caveat is required at this point. You should not cut corners when purchasing a processor since it is the last element in the imaging chain, and perhaps the most important one. Many cardiac catheterization labs purchase an inexpensive processor with no recirculation, no chemical filtration, and no replenishment system to save a few dollars, after spending in excess of $500,000 to $700,000 for the x-ray equipment in the lab. [It is recommended that at least 2–3% of the cost of a cardiac catheterization lab be spent for a cine film processor (Inter-Society Commission for Heart Disease, 1976).] Likewise, many inexpensive conventional film processors do not come with the necessary controls to produce consistent, high-quality radiographs.

It might be argued that for small offices or radiology departments a large "expensive" processor cannot be justified. However, a mechanized processor will *not* operate properly unless at least 25 to 50 14 × 17-inch (35 × 43-cm) films, or the equivalent number of square inches of smaller sizes, are processed daily. Unless this quantity of film is processed, replenishment will be insufficient, the developer will quickly oxidize, and the processed films will become degraded, producing lower contrast. This requires the technologist to modify the techniques, with a resulting increased exposure to the patient and a decrease in diagnostic information content. It might sound like a step backward but, in most situations where low-volume processing is necessary, hand processing will provide better overall quality at a lower cost as long as the technologist processes all films at the proper temperature and for the correct time. If it is essential to use mechanized processors with low volumes, then a flood replenishment system which we describe in this chapter must be installed.

## IS YOUR DARKROOM IN A FOG?

As we noted before, 52% of darkrooms fog film. The basic reasons are quite simple (Gray, 1975):

1. Either faded or improper safelight filters are being used (in some cases the filters must be placed in the safelight filter holder so that the lettering can be read from the outside).
2. The light bulb in the safelight is of too high a wattage for the conditions being used.
3. "Unsafe" light is reaching the film.

Safelights fade and age with time. If the safelights are left on 24 hours a day, the filters should be replaced every year. If they are on 12 hours a day, the maximum life should be 2 years. The date of the last filter change should be indicated on the safelight. In addition, if a higher wattage bulb has been used with a safelight then the chances are that the filter is already faded and should be replaced. Be sure to check with the manufacturer of your film to determine what filters you should be using with the films you use in your darkroom and remember that not all films can be handled under the same safelights.

In an effort to increase the brightness of darkrooms many people install higher wattage bulbs. No more than a 15-watt bulb should be used in the small "beehive" safelights, and no more than a 25-watt bulb in the large square safelights used for *indirect* lighting. Darkrooms can still be well illuminated and easy to work in with a few considerations. First of all, no surfaces in the darkroom need to be black. The walls can be painted white or a light pastel color, and countertops can be white or light colored. Just changing to light-colored surfaces in the darkroom will make a major difference and you will be able to see much better. Next, a sufficient number of safelights should be used. One or more of the large rectangular safelights should be aimed at the ceiling to provide overall illumination. Each work surface should have about two of the small circular safelights (at least 4 feet above the surface), and there should be a safelight directly over the processor feed tray that turns off automatically when film is feeding into the processor (this safelight also provides a visible indication of when additional film can be fed into the processor).

"Unsafe" light can cause a major problem in darkrooms. Darkrooms with maze entrances, i.e., without a double or revolving door system, are not acceptable in any medical imaging darkroom. Neither can one accept anything other than dual door pass boxes with an interlock so that both sets of doors cannot be opened at the same time.

Other sources of "unsafe" light include white light leaks and "unsafe" indicator lights and luminous panels. To look for white light leaks, go into the darkroom and, with all of the lights turned off, allow your eyes to dark adapt for at least 5 to 15 minutes and then start looking for light leaks. Any white light leaks that you can see will fog film. Be particularly observant around door frames, where the processor abuts to the darkroom, around pass boxes and anywhere there is a break in the wall (around light switches, for example). Also, look very closely at the ceiling. Many suspended acoustical tile ceilings will allow light to leak into the darkroom from adjacent areas—the ceiling looks like a starry night sky.

Indicator lights, although they appear red, may actually be emitting light that can fog your film. Also, luminous panels or clock dials will fog film since they emit light in the region of the spectrum where the film is sensitive. One other potential problem area is in room lighting. Fluorescent lights should never be installed in a darkroom since some of these produce an afterglow when they are turned off. Some of the afterglow may be in the ultraviolet region, which will fog your film but is not visible to the human eye.

The methods of testing your darkroom for fog are described in the Procedures section of this chapter. Every darkroom should be checked for fog using this technique every 6 months or at any time you suspect there might be an increase in darkroom fog.

The technique for testing for darkroom fog requires that you preexpose the test film and then test

for fog. This is extremely important since unexposed film is much less sensitive to fog light. This applies in both ways: if the film is fogged before exposure the film is more sensitive to the regular exposure it receives; and if the film is fogged after exposure the film is more sensitive to the fog light.

This difference in sensitivity is due to the nonlinear nature of the photographic film. Each grain of the silver halide in the film must be "hit" with several light photons before it becomes developable. If a few hits occur during a fog exposure then it will take fewer hits to make the grain developable and, hence, the film is more sensitive.

Figure 5.1 is an excellent example of the effect of the increased sensitivity of exposed film as compared to unexposed film. A radiograph was made of an aluminum step wedge using a conventional x-ray system and a screen-film system. Half of the film was then covered with opaque paper in the darkroom and remained on the counter for 4 minutes so that one half of the area of the step wedge was fogged. It is easy to see that there is no apparent fog in either the radiographically unexposed area of the step wedge or the dark portion of the step wedge, but in the intermediate densities the effect of the fog is quite apparent.

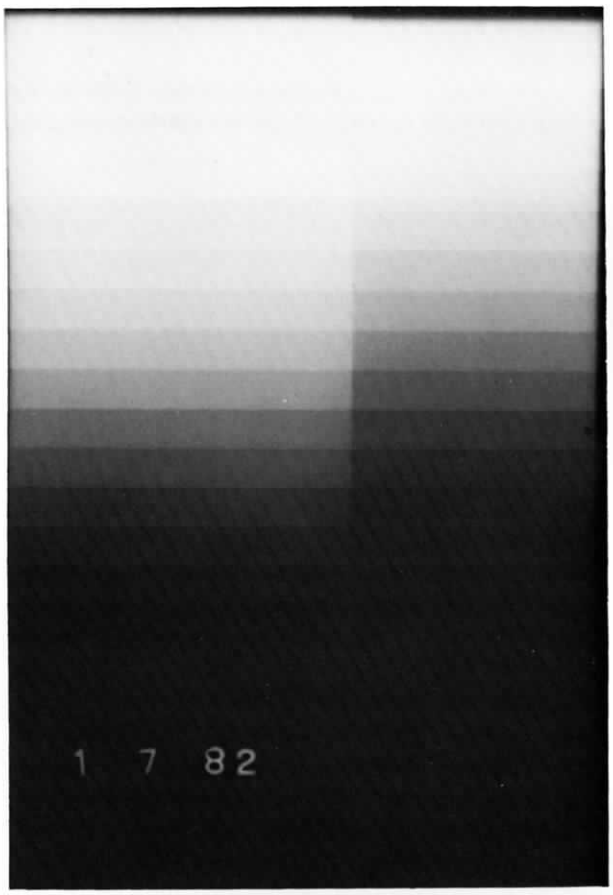


Figure 5.1. Effect of fog on radiographic film. One half of the step wedge image (screen-film exposure) was exposed to safelights for 4 minutes. It is apparent that the fog is not perceptible in the unexposed portion of the image nor is it apparent in the dense portions of the film. Fog tests carried out with unexposed film will not indicate the true effect of fog in the mid-densities, the region of primary importance in radiology. Also, in visually judging if the fog is excessive it is necessary to cover the line between the fogged and unfogged areas with a pencil. Eliminating the sharp border significantly changes your perception of the density difference between the two sides.

There is a problem in judging the amount of fog that is acceptable unless a densitometer is used. A density difference of 0.05, as measured with a densitometer, between the exposed and unexposed portion is the most fog that is acceptable, and this amount of fog should not be apparent for safelight exposure times of 2 minutes or less. If the films must be judged visually, you must obscure the border between the fogged and unfogged portion of the film with a thin opaque object, since over edges that are not obscured, the eye can discriminate density differences on the order of 0.005 to 0.01. With the boundary between the two areas obscured, a visible density difference is about 0.05, or the level at which one must judge the safelighting unacceptable. (To demonstrate this to yourself, cover the boundary between the exposed and fogged and unfogged portions of Figure 5.1.)

What "fog time" is acceptable? We feel that, unless the darkroom can pass the fog test (a density increase of 0.05 or less) for a safelight exposure time of 2 minutes, it is unacceptable. Film is exposed to safelight and other light in the darkroom for considerable periods of time if one considers that each time the film bin is opened all of the film in the bin is exposed. The film is exposed as it is transported into the processor and it is exposed while it is lying on the counter while unloading and loading cassettes.

We have one final precaution concerning the measurement of fog. First of all you should test every type of film you use in the darkroom. Second, all film tested must be preexposed to light (e.g., from an intensifying screen) as it would be in use. If you are testing x-ray film expose it in a cassette with screens to a density of approximately 1.0. Direct x-ray exposed film does not have the same sensitivity as film exposed with light from screens.

## ESTABLISHING A DAILY PHOTOGRAPHIC PROCESSOR QUALITY CONTROL PROGRAM

The major problem we face in establishing a photographic processor QC program is that there are no

preset standards that tell us what our operating levels should be. You should follow the manufacturers' recommendations concerning the proper chemistry to be used with a specific film, the appropriate temperature for the chemistry and wash water, the proper processing time, and the correct temperature for drying the film. However, this does not tell you what density to expect for a specific step on the step wedge.

When we discuss step wedges in regard to a photographic processor QC program, we are referring to a step wedge exposed with a sensitometer (Figures 5.2 and 5.3). Processor QC *cannot* be carried out with a step wedge exposed with an x-ray machine. In order to control the quality of photographic processing we would like to eliminate as many other variables as possible, and if the wedge is exposed with an x-ray generator we will not know whether the generator or the processor is causing the changes in the density of the film.

Likewise, when we discuss sensi-strips we are referring to sensitometric exposures made with your sensitometer on the film normally processed in the machine you are evaluating and processed not less than ½ nor more than 4 hours after exposure. By waiting ½ hour, some of the inherent variability you would see from strip to strip is reduced. However, if you wait more than 4 hours, the effects of latent image decay may become apparent. Furthermore, it has been demonstrated that sensi-strips that were aged more than a few hours are less sensitive to changes in chemistry in terms of chemical activity or variations in temperature (Poznansky and Smith, 1968; Gray, 1976, 1977). In addition, it has been demonstrated that films exposed directly to x-rays, as opposed to x-ray exposure with screens, are extremely insensitive to changes in the chemicals of the photographic processor.

Since we would like the processor to be working under optimum conditions before starting our photo-

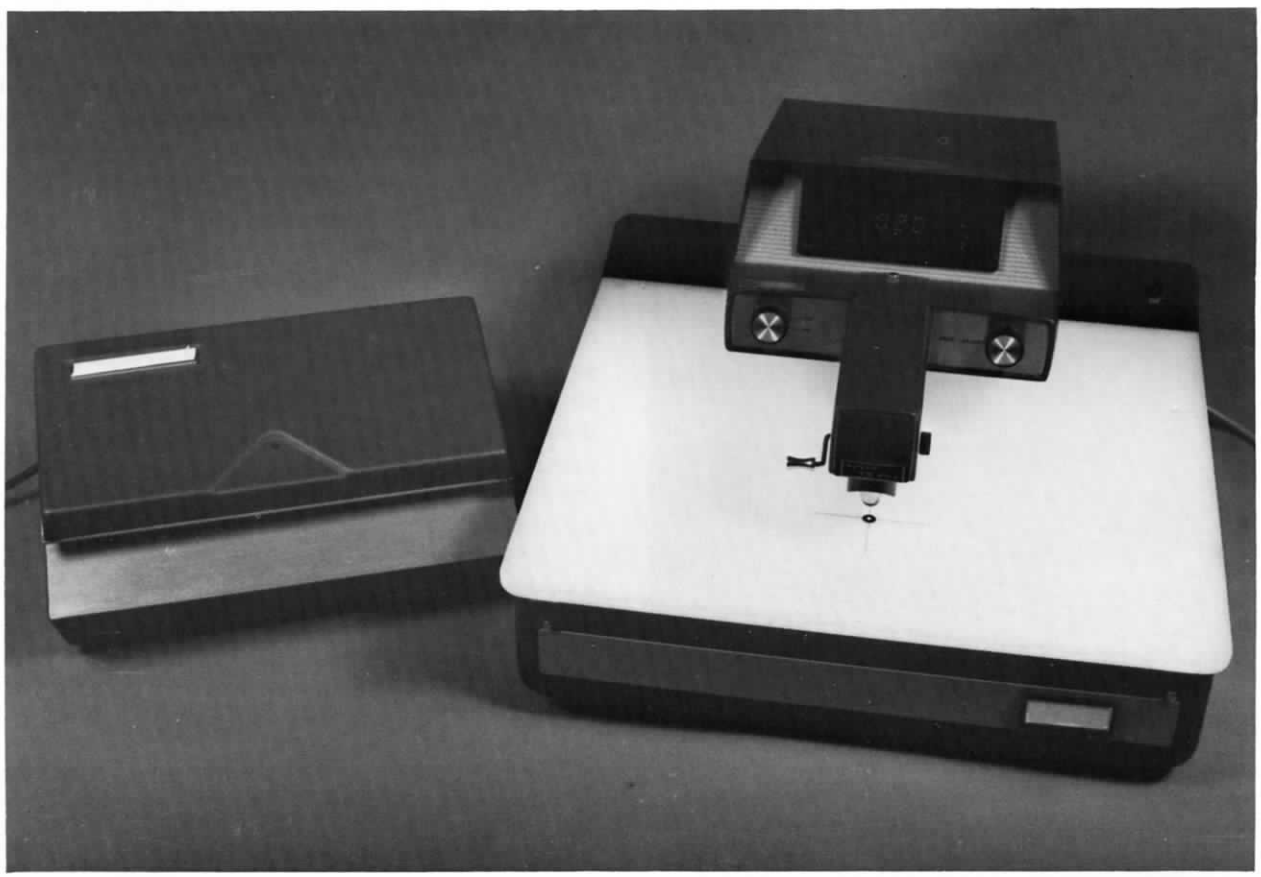

Figure 5.2. A sensitometer *(left)* and densitometer *(right)* are essential for a photographic quality control program. Densitometers with a built-in light source are preferred. The color of the light used for quality control purposes in either the sensitometer or densitometer does not matter. However, sensitometers should *never* be used to compare different radiographic films since such comparisons are only meaningful if the film is exposed with the *exact* type of light with which it is used clinically, i.e., screen light emitted from the appropriate intensifying screens.

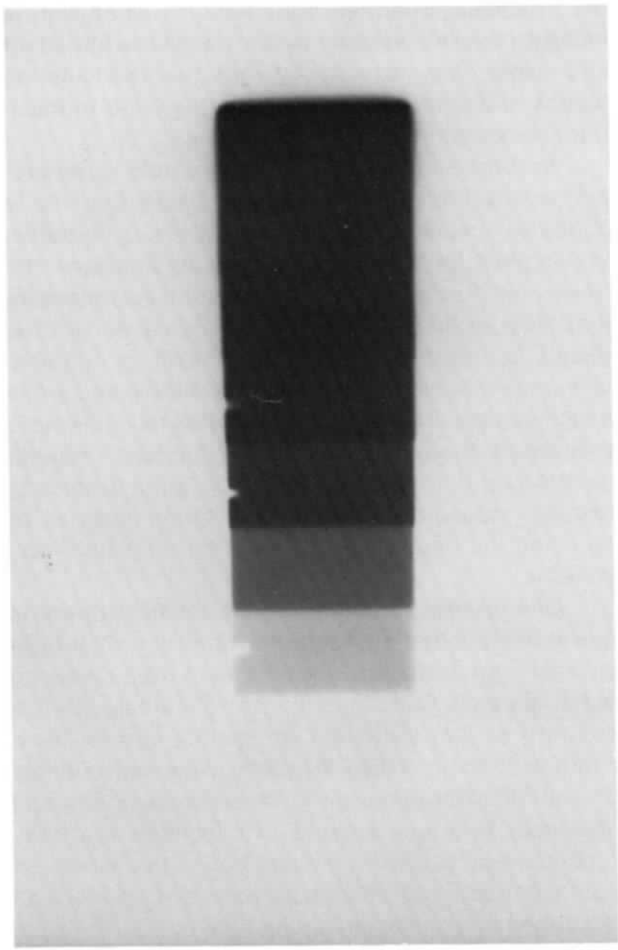

Figure 5.3. Sensitometrically exposed step wedge. The sensitometer provides a known, stepped exposure to film. The step wedge on the sensitometer has been marked to indicate which steps produce densities close to 0.25, 1.0, and 2.0 above the base-plus-fog level of the film so that the appropriate steps are read each time a strip is processed for QC purposes.

graphic processor QC program, it should be cleaned and any necessary repairs made before further work is done on the QC program. **Do not use systems cleaner at this time!** Systems cleaner is a strong acidic solution and if even minute traces of it remain in the processor it will contaminate the chemistry and invalidate your setup procedures. In addition, extreme care should be taken to ensure that not even a few drops of fixer are allowed to contaminate the developer since it takes only a few milliliters of fixer to cause significant changes in the developer (Figure 5.4) (Stears et al., 1979).

Follow the procedure described in the Procedures section of this chapter very carefully. Be sure to set the developer and fixer replenishment at those levels recommended by the manufacturer and verify that you are actually getting the amount of solution indicated by the metering devices.

In photographic QC, as in all QC, one must be extremely cautious to carry out all tests in the same manner each time. It is absolutely essential to run the sensi-strips for both the initial setup procedure and the daily photographic QC with the thin (low-density) end of the strip leading and at the same location on the processor feed tray each time.

The by-products of the development process, primarily bromide ions, diffuse out of the film and can retard development. If processor agitation is less than ideal the by-products will flow over the film and retard the development on trailing portions of the film. The thin end of the strip is fed into the processor first to minimize this effect. (It will be necessary to notch or punch a hole in the sensi-strip at the time of exposure to indicate the thin end of the strip.)

Many processors exhibit differences in agitation and/or temperature from one side of the development tank to the other. Consequently, films processed at

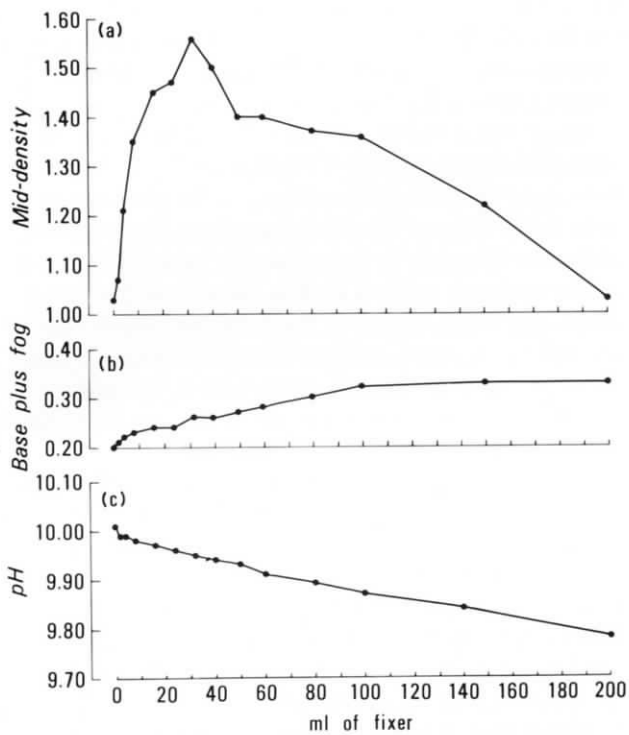


Figure 5.4. Effect of fixer contamination of developer activity and pH. Very small amounts of fixer can cause severe contamination of the developer (only a few milliliters of fixer in a 2.5-gallon developer tank caused the mid-density to exceed control limits). Other measures suggested in the literature, such as the fog level and pH, are not sensitive enough to provide an advance warning of such contamination. (Reproduced with permission from: Stears, J. G., Gray, J. E., and Winkler, N. T., 1979. Evaluation of pH monitoring as a method of processor control. *Radiologic Technology* 50:657-663.)

one location on the feed tray one time and then at another location the next time will produce different sensitometric results. A good rule of thumb is to always process the film at the extreme right of the feed tray each time—and with the thin end of the strip leading.

After determining the proper operating levels, record these values on the control charts and indicate the upper and lower control limits as shown in Figure 3.2. Now you can adjust all of the processors in your department to operate at the same levels (adjusting the temperature or replenishment rates as a last resort), assuming that you are using the same film in all of the processors.

## DAILY PHOTOGRAPHIC QUALITY CONTROL OF MECHANIZED FILM PROCESSORS

Now that you have established the operating levels and control limits, you must maintain your checks on your processor on a regular basis. First of all, it is not necessary to monitor any parameters other than the densities of the sensi-strips on a regular basis unless problems arise. You should have already recorded the replenishment rates and temperatures on the control chart for reference. These can quickly be checked on a regular basis using the replenishment flowmeters and the thermometer built into the processor. It is not necessary to check the chemistry and water temperatures every day, nor to record these on a control chart, since any changes in the developer temperature will be immediately evident on the density of the sensi-strips and fluctuations in the fixer and wash water will not normally cause significant problems (in fact, some processors today operate with a "cold water" system, i.e., they use cold tap water so it is not necessary to monitor the temperatures).

It is not necessary to plot an entire characteristic curve each day since this provides no significant information that cannot be obtained by monitoring several density points and the density difference. In fact, it may be possible to monitor only the medium-density level, but the density difference and the base-plus-fog levels do provide useful additional information with little additional effort.

Daily photographic quality control should, as the name implies, be carried out on a daily basis. It is usually not necessary to make processing QC checks more often than this if the processor is stable and it is not being run for long periods of time without films being processed (such as overnight). (You should consider attaching a standby kit to every processor because this reduces the water and electrical consumption while helping to conserve chemistry, since the processor operates normally only when film is being processed. At other times the drive is turned off and water flow is reduced, but the recirculation pumps and dryer fan are operating enough to maintain the machine in a "ready" status.)

In some situations it may be possible to monitor the processor on a less frequent basis, but this is quite risky unless several other controls are initiated. In this situation it would be necessary to pretest the freshly mixed chemicals (perform a dip test) to assure that their activity meets the standards set by the quality control program (Winkler, 1975). In addition, only machines that are known to be stable and are in a high-volume area where a consistent mix of films is processed should be considered for less frequent monitoring. For the small amount of time it takes to expose, process, and read sensi-strips the risk of reducing the frequency of testing far outweighs any benefits.

One problem in photographic quality control is due to the fact that photographic films vary slightly in characteristics (speed, contrast, etc.) from emulsion batch to batch. Consequently, one should maintain a quantity of film sufficient for quality control for a 6-month period in a cool, dry place away from sources of radiation (refrigeration is ideal for such storage) and away from any sources of chemicals that may produce vapors. Before the last box of this emulsion batch is used you should perform a cross-over as described on page 46 and adjust the operating levels and control limits on the control charts if the new emulsion characteristics are different from the previous batch. (The range of the control limits, e.g., ±0.10, should not change.)

In some areas of the country (the south and southwest) water as cold as that required for the processor may not be available during the summer months. Most processors require that the wash water temperature be 5–10 °F below the developer temperature since this cooler water acts as part of the temperature control system. In many of the warmer climates the tap water temperature can approach 90–95 °F, resulting in a loss of control of the processor. If you attempt to use chilled or refrigerated water to bring the normal 120–140 °F hospital hot water down to the required 85 °F a considerable amount of refrigeration will be required. Only a relatively small amount of chilled water will be required to drop the tap water (at 95 °F) to 85 °F. Figure 5.5 shows a plumbing arrangement that allows for adding refrigerated water to tap water in the summertime while still using the conventional temperature control valve (Gray, 1977). You should be sure, at any rate, that the water chiller used has sufficient capac-

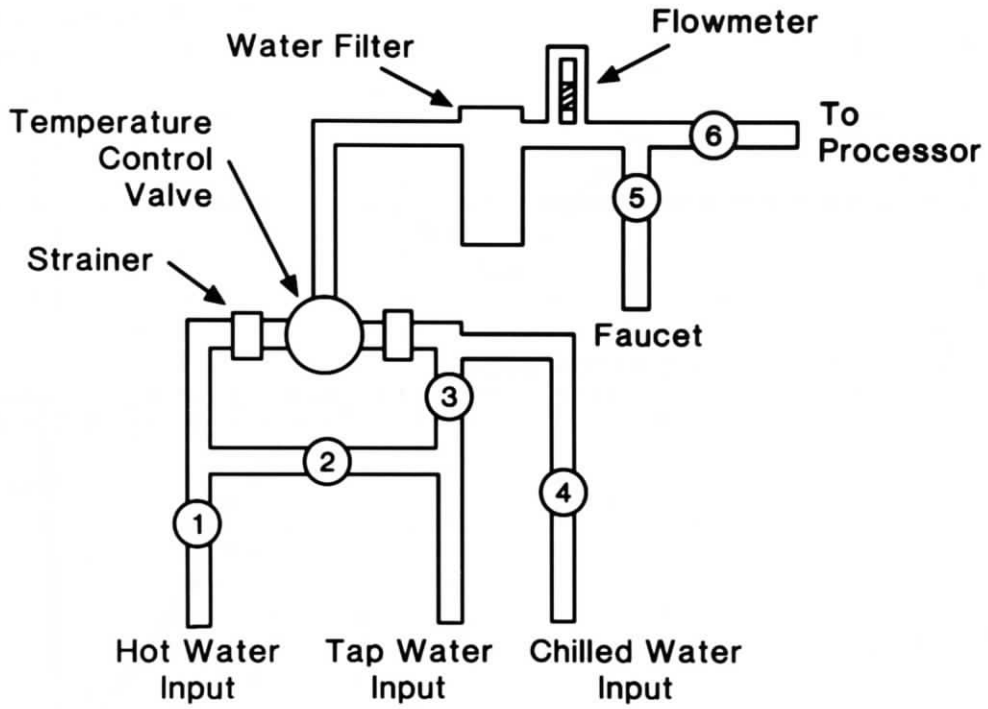


Figure 5.5. Temperature control, filtration, and flow monitoring system. A water filter should be installed before the point where the wash water enters the processor, along with a flowmeter, not a pressure gauge. In areas where the tap water temperature may approach the temperature required for the wash water, it is difficult to control and maintain the appropriate temperature without using refrigerated water. If refrigerated water is mixed with hot tap water [usually around 120–140 °F (49–60 °C)] a large quantity will be needed, requiring a large refrigeration plant. With the plumbing arrangement shown here it is possible to cool the normal cold tap water [around 90 °F (32 °C)] with refrigerated water, but only a small quantity of refrigerated water is needed. For normal operation valves 1 and 3 are open with valves 2 and 4 being closed. If the cold tap water approaches the desired wash water temperature then valves 1 and 3 are closed and valves 2 and 4 are opened.

ity to handle the volume requirements of the photographic processors (some require as much as 2.5 to 3 gallons of water per minute).

## PROCESSOR CLEANING AND MAINTENANCE

Processor cleaning and maintenance is a major part of the photographic quality control program. Unless the processor is maintained in a clean and mechanically sound condition you cannot expect the best photographic processing results. You should follow the manufacturer's cleaning and maintenance schedule very closely.

With a good QC program, including cleaning and maintenance of the processor, it will not be necessary to change chemistry except as recommended by the manufacturer of the processor or when your control charts indicate that a change is required. In many instances the chemistry only need to be changed every 3 or 6 months. A good QC processor cleaning and maintenance program will actually reduce your workload while providing optimum processing.

A processor maintenance log is essential so that the QC technologist knows when maintenance has been performed on the processor, chemistry has been changed, or more replenisher added to the replenishment tanks—all changes that could affect the quality of the films produced.

Systems cleaner is a rather caustic (pun intended) topic. Although it is necessary at times to utilize systems cleaner, if it is not used properly it can cause havoc with your quality control efforts. Follow the instructions on pages 47–48 carefully and be sure to season the tanks and racks after using systems cleaner. Seasoning consists of placing developer and fixer in the appropriate tanks and then, with the racks in place, operating the processor for 10 to 15 minutes without processing film. These chemicals should then be discarded and fresh chemicals added, starting the processor operation in a normal manner at this time. The seasoning with the developer and fixer allows for the neutralization of the chemicals in the systems cleaner, which would normally leach into the chemistry during processor operation and change

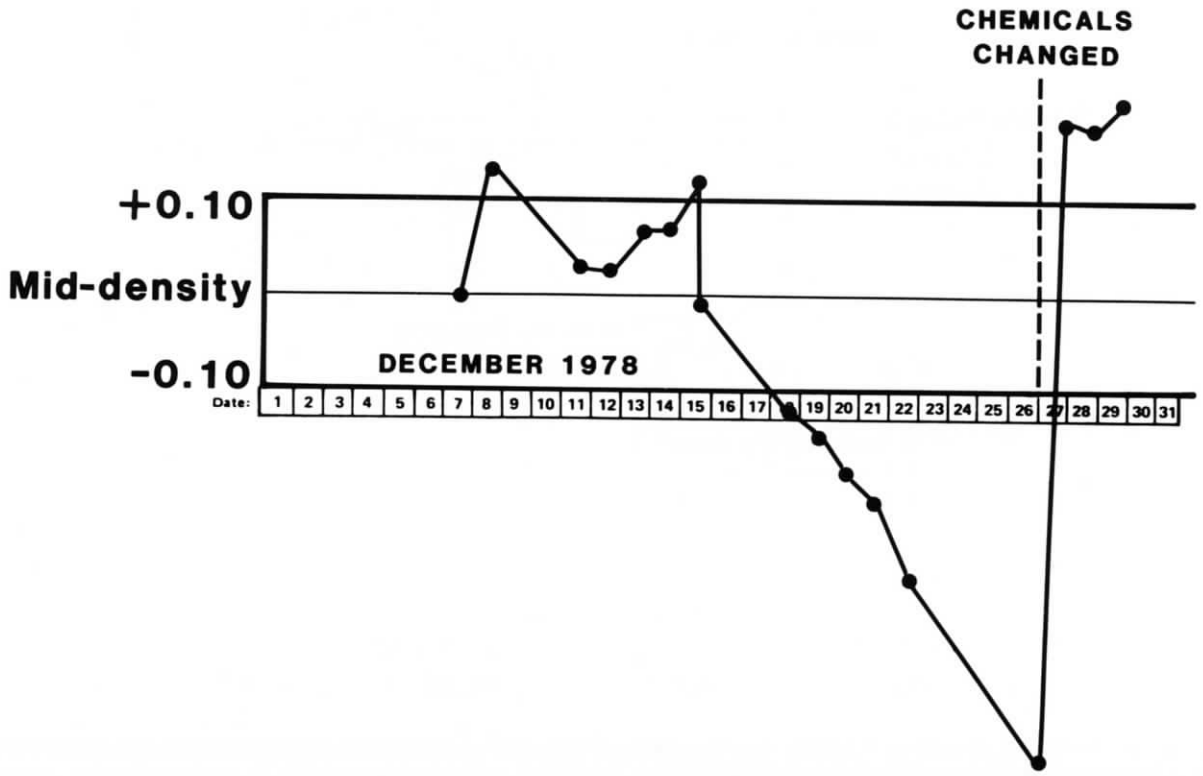


Figure 5.6a. Effect of flood replenishment on photographic processors. Rapid deterioration of developer activity is apparent in this control chart from a low-volume processor. (Reprinted with permission from: Frank, E. D., Gray, J. E., and Wilken, D. A. 1980. Flood replenishment: A new method of processor control. *Radiologic Technology* 52:271–275.)

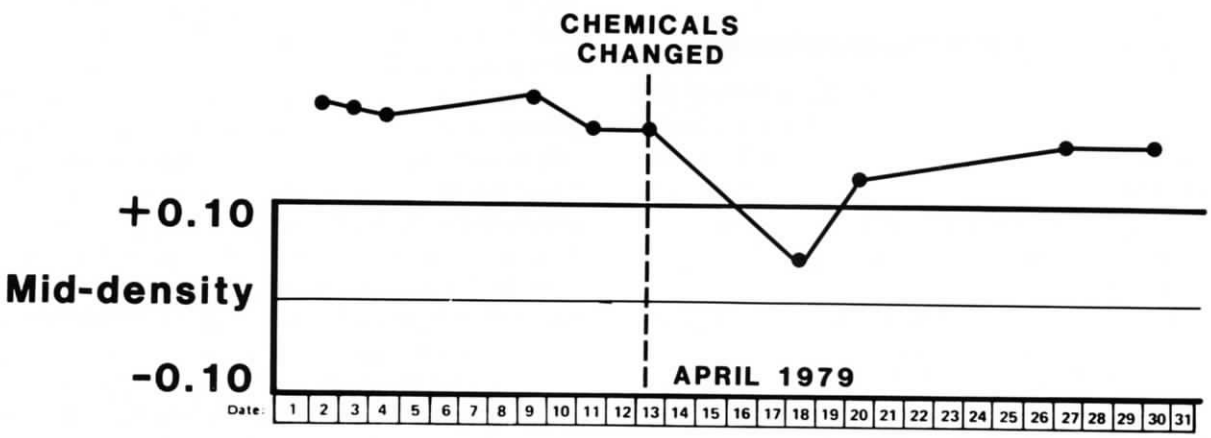


Figure 5.6b. After initiating a program to adjust replenishment rates and temperatures, along with changing the chemicals every month, the processor was a bit more stable but operated at levels outside the control limits and required constant attention (pampering).

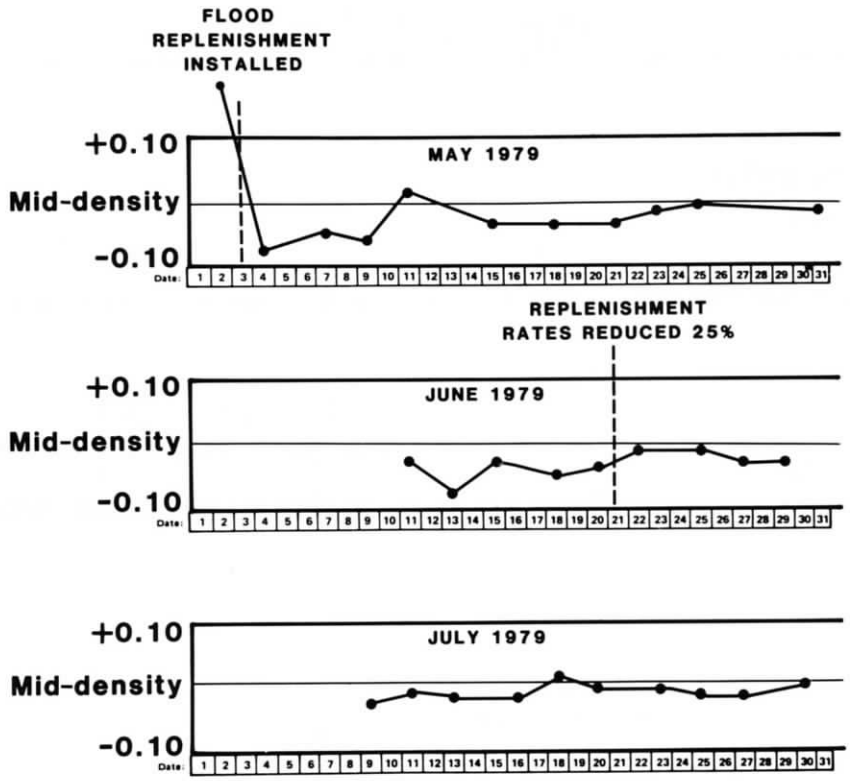


Figure 5.6c. After installation of a flood replenishment system it is apparent that the excessive variability of this processor has been eliminated and, in fact, it has become one of the most stable processors in our institution.

change their activity, causing the processor to go out of control.

## FLOOD REPLENISHMENT

In many situations, it is necessary to operate a mechanized processor even though the daily workload is less than the minimum 25 to 50 14 × 17-inch (35 × 43-cm) films per day or the equivalent area of film in smaller sizes. Normally the developer is rapidly oxidized, resulting in a continual decline of chemical activity with subsequent drops in the mid-density levels, as well as changes in contrast (Figure 5.6). It is easy to increase the technique to compensate for this decline, but this results in less than satisfactory films and an increased patient exposure.

Flood replenishment was first introduced for both industrial and medical x-ray film processors by Titus (1979a, 1979b, 1979c). A discussion of the technique is available in the papers by Titus, and a thorough discussion of clinical applications along with control charts before and after flood replenishment can be found in a paper by Frank et al. (1980).

The basic idea of flood replenishment is quite simple. Since sufficient replenishment is not being introduced into the processor by the films being processed, and other chemical components are also being introduced at less than an ideal rate (e.g., bromide, a by-product of the development process), it is necessary to artificially add these to the processor at a rate that will assure constant chemical activity. This is done by disconnecting the replenishment pumps from the automatic replenishment control system and connecting them to a timer that adds a predetermined amount of developer replenisher (with starter) and fixer replenisher at set intervals. The amount of solution added through the flood replenishment should replace the entire volume of the solution tanks in the processor every 16 working hours. This usually results in an increase in the consumption of chemistry but produces a stable processing environment. It also helps to prevent excessive chemical buildup on the rollers and, in general, keeps the processor much cleaner.

A word of caution is necessary concerning flood replenishment: **starter solution must be added to the developer replenisher in the replenisher tank each time fresh replenisher is mixed.** The amount of starter should be that specified by the manufacturer of your developer for mixing fresh developer solutions.

# PROCEDURES

## 5.1. DARKROOM FOG CHECK

### Purpose

To assure that the safelights and other potential sources of "unsafe" light will not fog the film being handled in the darkroom.

### Equipment Needed

1. Unopened box of x-ray film (must be the type normally processed in the darkroom to be tested)
2. Screen-film cassette
3. Two pieces of black, opaque paper each as long as the film to be used and one-half of the film width
4. Densitometer
5. Clock with second hand or stopwatch

### Procedure

1. Turn off all of the safelights and other lights in the darkroom.
2. After your eyes have had time to adapt to the darkness (about 5–15 minutes) look for any source of light you can find. Pay particular attention to the seals around processors, passboxes, darkroom doors, etc., and to ceilings (suspended ceilings can leak light from surrounding rooms). If you can see any light in the darkroom these sources should be eliminated.
3. After you have made sure there are no apparent light leaks, turn off all safelights, cover indicator or pilot lights on equipment with opaque material, and remove any luminous dial clocks from the darkroom.
4. Open a new box of film. [***Note:*** This box of film must be the same type that is normally used in the darkroom. If more than one type of film is used the following tests should be carried out with each type of film.]
5. Load the film into the cassette in total darkness.
6. Expose the film.
   a. To evaluate x-ray film, make a uniform radiographic exposure with the film in a cassette (with intensifying screens) so that the density on the film is approximately 1.0.
   b. To evaluate other types of film, make a uniform exposure with the imaging device normally used so that the density is approximately 1.0.
7. Place the film on the counter in the darkroom with all of the lights off.
8. Cover the left half of the film with the one opaque sheet of paper. Keep this half covered throughout the next two steps.
9. Turn on the safelights and indicator lights.
10. Cover all but the upper quarter of the remaining portion of the film with the second piece of opaque paper and expose that portion for 2 minutes. Shift the opaque paper so that one-half of the film is uncovered and expose for 1 minute. Shift the paper again so that three-quarters of the film is uncovered and expose for another minute. (This film now has a total exposure of 4, 2, and 1 minutes in the three exposed areas and should look similar to Figure 5.7.)
11. Determine the density difference between the exposed areas and the *corresponding* unexposed area and record these values. If a densitometer is not available, cover the border between the adjacent areas with a thin strip [about $^1/_8$ inch (3 mm)] of opaque material and compare the visual appearance of the areas.

### Problems and Pitfalls

1. It is essential to use the same film as is handled in the darkroom.
2. The densities of the films must be read on adjacent areas to avoid processor and exposure variations.

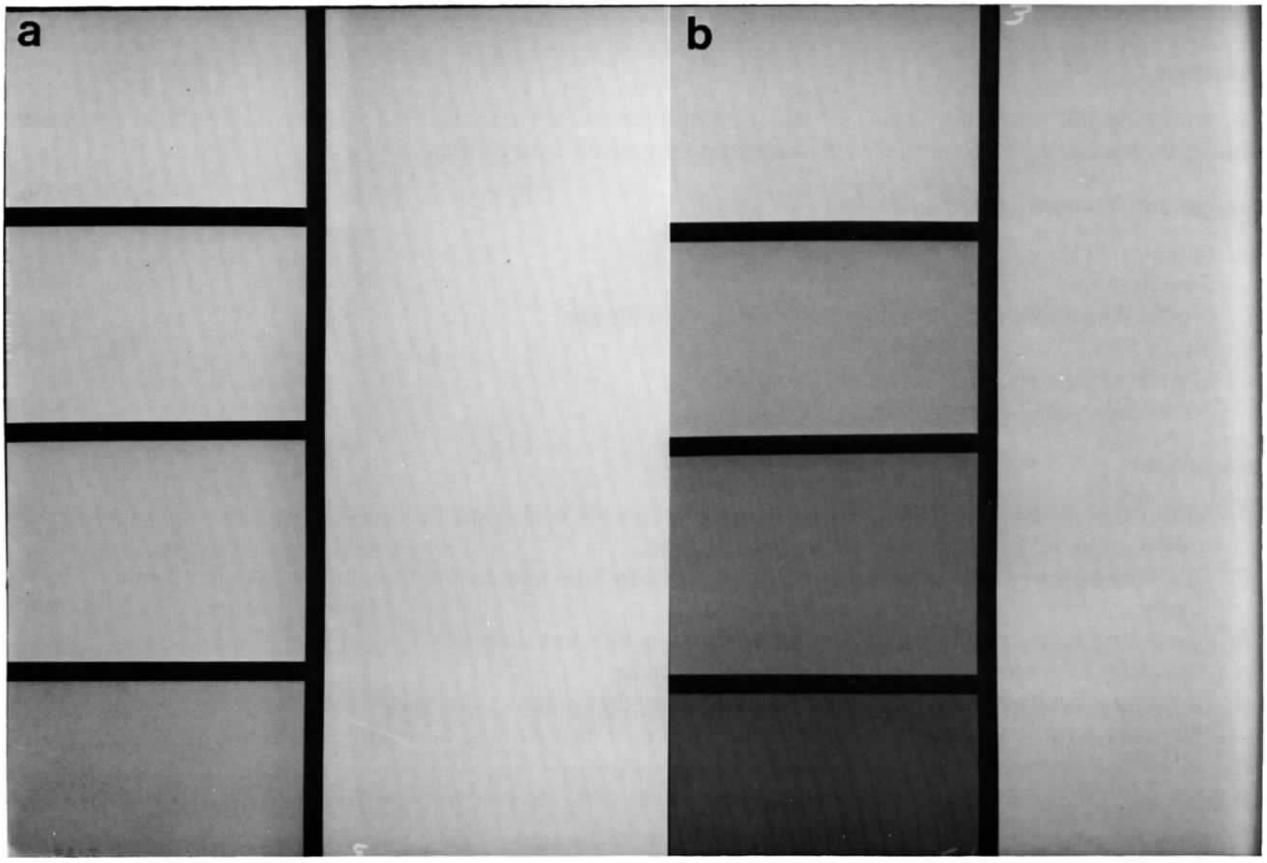


Figure 5.7. Darkroom fog check results. Any comparison of fog tests should be made with a densitometer. However, visual comparisons can be made if the borders between the various areas on each film are covered with a pencil or strip of opaque material. (**a.**) Virtually no density difference is visually apparent between the 1- and 2-minute fog times (center two areas on left) and the large, unfogged area, but a visual difference is apparent between the 4-minute fog time and unfogged area. This result would indicate an acceptable amount of fog in the darkroom. (**b.**) Even at 1 minute a visual difference is apparent when compared to the unfogged portion of the film. The safe lighting in this darkroom is in need of improvement.

### Acceptance Limits

The density difference between the fogged and unfogged portions of the film should not exceed 0.05 for the 2-minute exposure area and *must not* exceed 0.05 for the 1-minute exposure area. For visual comparison, you should see no density difference between fogged and unfogged sides of the film for the 2-minute exposure area and must not see a difference in density for the 1-minute exposure area.

### Corrective Action

If the density difference exceeds the limits noted above:

1. Check to assure that the proper safelight filter is in the safelight.
2. Check the safelight filter for signs of fading, aging, or cracking and replace it if indicated.
3. Assure that the proper wattage bulb is being used in the safelight. (Check the film manufacturer's recommendations for the recommended type of safelight, wattage of the bulb, and distance of the safelight from the working surface.)
4. If after these checks fog still exists, cover all indicator lights and repeat the tests with just the darkroom safelights on. [***Note:*** It would be ideal to carry out this test in every darkroom every 6 months or whenever you suspect that fog may be creating problems.] A darkroom can be quite bright and not fog film if it is properly designed and lighted. There is no need for black walls or countertops—walls can be white and countertops either white or stainless steel. If the safelights are really safe and there is no source of "unsafe" light in the darkroom you will be better able to see and work in a darkroom with light-colored surroundings.

## 5.2. ESTABLISHING A DAILY PHOTOGRAPHIC PROCESSOR QUALITY CONTROL PROGRAM

### Purpose

To determine the operating levels for all photographic processors in the department. (The operating levels should be the same for all processors processing the same type of film.)

### Equipment Needed

1. Sensitometer
2. Densitometer
3. Digital thermometer or metal-stemmed dial thermometer
4. Stopwatch
5. Control emulsion
6. Fresh chemicals

### Procedure

1. Drain the developer and fixer tanks in the processor and flush the tanks and racks with fresh water. [***Note:*** **Do not** use systems cleaner at this time.]
2. Replace the developer recirculation filter with a new filter and assure that the processor is functioning normally.
3. Drain and flush the replenisher tanks and hoses with fresh water.
4. *Carefully* mix fresh developer-replenisher and fixer.
5. Refill the replenisher tanks, operating the replenisher pumps temporarily to assure that all fresh water is flushed out of the replenisher lines and to assure that the replenisher pumps are functioning properly.
6. Flush the processor fixer tank again with fresh water.
7. Fill the fixer tank in the processor with fresh fixer and replace the fixer rack.
8. Again flush the developer tank.
9. Fill the developer tank with fresh developer-replenisher and add the correct amount of starter as noted in the manufacturer's instructions.
10. Carefully replace the developer rack, crossover racks, etc.
11. Allow the processor to operate for 30 minutes.
12. Check the developer temperature, fixer temperature, and wash water temperature. The chemistry temperatures should be within 0.5° of those recommended.
13. Check the replenishment rates and the time it takes a film to pass through the processor (the time it takes from when the leading edge enters the processor until the leading edge exits the dryer).
14. Allow the processor to be used until 50 14 × 17-inch (35 × 43-cm) films, or the equivalent, *per gallon of developer* have been processed.
15. Expose six sensi-strips. If you are using a double emulsion film and a sensitometer that exposes only one side you should expose strips on both sides of the film, i.e., three sheets of film with two exposures each.
16. Wait at least 30 minutes before processing the strips.
17. Process the sensi-strips—**thin end leading, same side of the feed tray.**
18. Zero and calibrate the densitometer.
19. Read the densities on the six strips. Be sure to read the densities in the center of each strip, not near the edges. (Check the zero and calibration of the densitometer after reading each strip.)
20. Determine the average of the densities of the six strips for each step.
21. Select and mark the steps producing the densities nearest to 0.25, 1.0, and 2.0 above the base-plus-fog level of the film (Figure 5.3).
22. Determine the appropriate values and record these values and the control limits on the control chart (Figure 3.2). Three values should be recorded:

    DD (Density Difference) = high − low (± 0.10)
    MD (Medium Density) = mid (± 0.10)
    B + F (Base-Plus-Fog) = B + F (± 0.05)

23. Adjust *all* processors using the same film and chemistry to produce the same values.

### Problems and Pitfalls

1. It is assumed that running 50 14 × 17-inch (35 × 43-cm) films per gallon is a "normal" mix of films and that the volume is at least 25 to 50 14 × 17-inch (35 × 43-cm) films per day.
2. See the "Problems and Pitfalls" discussion under "Daily Photographic Quality Control of Mechanized Film Processors," below.

### Acceptance Limits

The control or acceptance limits for daily processor control should be ±0.10 for both the medium density and density difference. Until you are familiar with the procedures and have your processors in good control you may wish to use wider limits of ±0.15 for the MD and DD but you should maintain the limit of +0.05 for the base-plus-fog. If you use the wider limits initially you should be able to shift to the tighter limits within not more than 1 month after you start your quality control program.

### Corrective Action

If you have difficulties with any of the above procedures, contact the technical service representative from the firm that manufactures your film and chemistry.

## 5.3. DAILY PHOTOGRAPHIC QUALITY CONTROL OF MECHANIZED FILM PROCESSORS

### Purpose

To assure on a day-to-day basis that all photographic processors are operating at the same levels and producing consistent, high-quality films.

### Equipment Needed

1. Sensitometer
2. Densitometer
3. Digital thermometer or metal-stem dial thermometer
4. Control emulsion

### Procedure

1. Follow the manufacturer's start-up procedures every day.
2. Allow sufficient time for the processor temperature to stabilize—about one-half hour. Assure that the wash water temperature is adjusted properly, where appropriate.
3. Check the following:
   a. Solution temperatures
   b. Replenishment rates
   c. Water flow rates
   d. Dryer temperature
4. Run several clean-up sheets and check them for roller marks and scratches. (Use exposed but unprocessed film for cleanup sheets.)
5. Expose enough sensi-strips for a single day's use. If the film is a dual emulsion film expose a strip on both sides if you are using a sensitometer that only exposes one side.
6. Wait at least ½ hour but not more than 4 hours before running all of the sensi-strips in the processors.
7. Process the strips—two per machine, thin end leading, in the same location.
8. Zero and calibrate the densitometer.
9. Read the three density patches and the base-plus-fog level from the two strips (for sensitometers requiring two exposures) from each processor and average the pairs of readings.
10. Plot the DD, MD, and B + F on the control charts.
11. Analyze the control charts carefully.
    a. Are all three points within the control limits?
    b. Are there any apparent trends?

12. If any single point (or points) falls outside of the control limits, run two more strips and verify that your first readings were correct.

**Problems and Pitfalls**

Photographic processor quality control is probably the most difficult program to establish and operate properly. The photographic process is full of its own quirks, idiosyncracies, and pitfalls. Extreme care must be taken to follow the steps described exactly and to keep in mind all of the problems and pitfalls listed below. For further information and a more detailed discussion of photographic processor quality control and the associated problems, you should refer to the two-volume Bureau of Radiological Health publication on the topic (Gray, 1976, 1977).

1. Mercury or other liquid thermometers should never be used around photographic processors since the contents may contaminate the processor if the thermometers are broken. Digital thermometers or metal-stem dial thermometers are preferred.
2. The temperature in the developer tank should be taken in the same place each time. In addition, do not trust any thermometer that may be permanently installed in your processor since it may be more variable than your good quality control thermometer and it may not be accurately calibrated. (You can check the calibration of your thermometer against the standard thermometers used in the clinical laboratories.)
3. Many processors do not have adequate agitation of the solutions on the film's surface. This results in a directional effect caused by bromide drag. Bromide, a by-product of the development process, suppresses development and, if the dense end of a sensi-strip goes into the processor first, the larger quantities of bromide liberated will suppress the processing and the densities of the following strips.
4. Only a sensitometer should be used to expose your control strips. An x-ray generator is not repeatable enough to use for this purpose.
5. Sensi-strips aged more than a few hours may lose their ability to detect changes in the processor that may be apparent on freshly exposed radiographic or sensi-strips. However, it usually helps to age the strips for at least one-half hour after exposing them since this tends to decrease the amount of variability from strip to strip.
6. Film emulsion varies from batch to batch, and such variations may be considerable. Consequently, you should select enough film from the same emulsion batch to last at least 3 to 6 months. All of this film except the box that you are using should be stored, sealed in its original packaging, in a refrigerator or, preferably, a freezer in an area where you are sure it will not be exposed to scattered radiation, chemical fumes, or radioisotopes. [***Note:*** Be sure to remove a box of film from the freezer or refrigerator at least 48 hours before you wish to use it. This allows the box sufficient time to come to room temperature.]
7. When it is necessary to change to a new emulsion batch, you must "cross-over" the old and new emulsions and adjust the control limits appropriately. This is done by exposing at least six sensi-strips on the old emulsion and six on the new emulsion. These strips are processed in a processor that is known to be in good control, their densities read, and the averages of the old and new emulsion values for the MD, DD, and B + F determined. If there is any difference in the old and new emulsions then the operating levels are adjusted appropriately.
8. In addition to a reduction in the sensitivity to changes in the process condition of an exposed sensi-strip, all photographic emulsions exhibit a certain amount of latent image failure. This means that the film appears to be less sensitive if it is processed a period of time after it is exposed, or it appears less dense overall. This can create problems not only in quality control, but on the clinical level if you use equipment with a film receiver and do not process the films frequently.
9. Low-volume processors, those machines processing less than 25 to 50 14 × 17-inch (35 × 43-cm) radiographs or their equivalent in an 8-hour period, are probably the most difficult of all processors to control properly. See the Procedure section on "Flood Replenishment" below.
10. Replenishment rates are provided by the manufacturer for a specific film-developer combination processed at a specific temperature and usually in a specific processor. In addition, the rates are provided for a specific mixture of film sizes for a set number of film sizes and for a set number of films processed in an 8-hour working day. If your conditions deviate from the ones specified by the manufacturer in any way, it will be necessary to adjust your replenishment rates—but only if your control charts indicate that the replenishment rates are either too high or too low. Watch your control charts closely for trends and only

make small corrections (15–20%) in your replenishment rates at any one time. After a correction has been made in the replenishment rates, monitor the processor for at least 1 week before making further changes.

11. In most areas, water filters are essential to assure optimum photographic processing. However, the filters become clogged, reducing the flow of wash water and the amount of water available to the temperature control system of the processor. A flowmeter located in the water line immediately before it enters the processor is essential. This should be monitored on a daily basis to assure that the water flow rate is that specified by the manufacturer of the processor.

**Acceptance Limits**

The acceptance limits on the DD and MD should be ±0.10 in density while the limit on the B + F should be +0.05. You may wish to use a slightly wider acceptance limit (±0.15 on the MD and DD) initially (for the first month) until you have all of your processors working in a stable condition.

**Corrective Action**

Corrective action is *required* if one or more data points falls outside of the control limits and *remains* outside of the control limits for a second set of test strips.

1. Be sure to verify the out-of-control condition with another set of sensi-strips *before* taking any corrective action.
2. Make the adjustments that you believe will bring the processor back into control.
   If control limits are exceeded check the following:
   a. Developer temperature
   b. Replenishment rates
   c. Water flow rates
   d. Water temperature (when appropriate)
   e. Recirculation
   f. Filters
   g. Batch mix dates
   h. Recent maintenance
   i. Film fog
   j. Transport time
   k. Control emulsion

   If trends are noted in the control charts check the following:
   a. Developer temperature
   b. Replenishment rates
   c. Change in the mix, types, and number of films being processed
   d. Proper mixing of replenisher
   e. Control emulsion age or fog (base-plus-fog tends to rise gradually as the film ages)
   f. Leaks or overflow from the fixer tank getting into the developer tank
   g. Gremlins
3. Make only one adjustment to the processor at a time.
4. After each change run another set of sensi-strips.
5. For future reference keep a log of the types of changes made (the amount the temperature was changed, for example), and the resultant change in the three control parameters.
6. When the processor is back in control, plot the new data points, circle all three of the points from the out-of-control strips, and record the adjustment made directly on the control chart in the space provided.

## 5.4. PROCESSOR CLEANING AND MAINTENANCE

**Purpose**

Processor maintenance is an essential part of the departmental QC program. In fact, it is virtually impossible to maintain an adequate processor QC program without processor maintenance. The purpose of processor

maintenance is to assure that the processor is maintained in a clean, functional condition as intended by the manufacturer.

**Equipment Needed**

Discuss the needed equipment with the representative of the manufacturer of your processor.

**Procedure**

1. Establish and maintain processor maintenance logs. These must include information concerning the type of maintenance carried out (both preventive and repair maintenance) and cleaning, including the dates the work was done and who did the maintenance.
2. Clean cross-over racks every day immediately after the processor has been shut down. In addition, wipe all exposed surfaces with a damp cloth and assure that chemicals are not allowed to dry on any surface.
3. Processor racks should be cleaned and checked weekly. Flushing with fresh water and cleaning with a nonabrasive cleaning pad is sufficient. **Do not** use systems cleaner at this time.
4. Verify the condition of the processor after any maintenance and weekly cleanings using a set of sensi-strips.
5. If the processor goes out of control, suspect that some maintenance has been carried out and check to assure that everything was set back to the normal operating conditions.
6. LISTEN! Each processor has its own unique sound. Any change in sounds may indicate changes in the processor that may affect the quality of the radiographs produced.
7. Systems cleaner—*only as recommended by the manufacturer.* [***Note:*** Always wear safety goggles when working with systems cleaner.]
   a. Never submerge the racks in the systems cleaner.
   b. Never mix the developer and fixer systems cleaner or use in the wrong tanks or on the wrong racks.
   c. Flush the tanks three times with fresh water after cleaning, running the recirculation pumps.
   d. Season the tanks and racks after using systems cleaner. This is done by filling the processing tanks with developer and fixer and allowing the processor to operate for approximately 10 to 15 minutes without processing any film. This chemistry is then drained from the tanks and the tanks refilled with fresh chemistry. This seasoning process helps eliminate any residual systems cleaner, which may adversely affect the chemistry over the next few days.
   e. Make a note indicating that systems cleaner was used on both the processor maintenance log and the control charts.

## 5.5. FLOOD REPLENISHMENT

**Purpose**

This modified method of processor replenishment may be required for low-volume processors (less than 25 to 50 sheets of conventional 14 × 17-inch (35 × 43-cm) radiographic film per 8 operating hours) in order to maintain stable processing levels. In addition, this method is usually needed in processors dedicated to processing of single emulsion nuclear medicine films, ultrasound imaging films, mammographic films, or 100-mm roll films, or the equivalent.

**Equipment Needed**

1. One 5-minute, 120-volt interval timer (about $35)
2. A 6-foot (180-cm) length of 4-conductor electrical cable
3. Strain-relief wire cable connectors
4. Electrician or qualified service engineer

**Procedure**

1. The timer must be installed by a qualified service engineer or electrician so that the replenisher pumps operate for 20 seconds out of every 5 minutes. (The replenisher pumps are no longer operated by the

microswitches connected to the entrance cross-over rollers.) This assures that approximately 780 ml of developer and fixer solution are added to the processor for each hour of operation.

2. After the timer has been installed, drain the chemicals from the processor and replenisher tanks and flush the tanks with fresh water, running the replenishment and recirculation pumps to assure that all old chemicals are purged from the system. (Be sure to remove the old developer recirculation filter, replacing it with a new one after you have flushed the system.)
3. Mix fresh developer replenisher and fill the replenisher tank.
4. Add 95 ml of developer starter (or the amount recommended by the manufacturer) to each gallon of developer replenisher in the replenisher tank and stir thoroughly.
5. Mix fresh fixer and fill the replenisher tank.
6. Operate the replenishment pumps until the developer (not the water that may be in the pumps and lines) starts to flow into the processor tanks.
7. Again drain and flush the processor tanks and then fill with the solutions from the replenisher tanks. [***Note:*** *Do not* add more starter to the developer tank.]
8. Adjust the developer and fixer pumps to deliver 65 ml of developer for each 20 seconds the replenisher pumps are operating.

**Problems and Pitfalls**

1. This method will provide for a stable processor by replacing the total volume of chemistry in the processor every 16 operating hours (approximately). Consequently, your consumption of replenisher (both fixer and developer) will increase but the pay-back will be in higher quality, consistent films.
2. Every time you mix developer replenisher and add it to the replenisher tank, **it is essential that you add the developer starter as noted in procedure step 4 above.** This means that you are operating with the equivalent of fresh (not seasoned) chemicals at all times but, again, you will also have a stable processor since the developer will be replaced before it has a chance to become oxidized or deteriorate in any other way.
3. If the type of timer is different than the one mentioned above, set the replenisher flow rates so that you deliver approximately 780 ml of replenisher to the processing tanks every hour.
4. For specific instructions on the type of timer, how to modify the processor, and so forth, contact the technical representative from the company who manufactured your processor.
5. Be sure not to mix any more developer or fixer than you can use in 2 weeks since these chemicals will deteriorate in the replenisher tanks.

**Acceptance Limits**

The acceptance limits for films processed in a processor using flood replenishment should be the same as for any other processor ($\pm 0.10$ in density for MD and DD and $+0.05$ for the B + F).

**Corrective Action**

The corrective action required when the control limits are exceeded is the same as those for a processor operating with a normal replenishment system.

# 6 BASIC TESTS

In this first chapter on equipment tests we discuss some very basic tests that can be carried out with simple and inexpensive test tools. These tests are practical for a small office with only one piece of x-ray equipment or for larger facilities. These tests have one thing in common—they are easy to do, but they do provide basic information about the condition of your equipment. They are not, in most cases, as definitive as tests described later in this book, but they are a starting point.

## VISUAL AND MANUAL QUALITY CONTROL CHECKS

These tests should be carried out in all x-ray facilities since they are just as applicable to a small facility as to a large facility. A check list is necessary (see the forms in Appendix A) to assure that all of the checks are made on a regular basis. Although many of the tests may seem very basic they all serve a purpose. For example, the High Tension Cable Check is required to assure that cables are not becoming cracked or frayed, which would present a potential hazard in terms of fire and possible injury to patients and technologists.

All of these tests are "pass-fail" tests, which means that either the equipment meets the standards or repair must be made by a qualified service engineer, or in some cases the QC technologist. These checks should be carried out before any other QC checks are made in each room every time QC tests are made.

## IMAGE RECEPTOR SPEED

When you begin a quality control program, and even after a QC program has been in effect for some time, it is not uncommon to find cassettes of varying types, i.e., different fronts and different manufacture, containing screens of different manufacture, speed, and age. These may be in general use in the department without compensation in exposure factors being made by the staff technologists, who may be unaware of the difference. This increases the variability in the quality of the radiographs produced and increases the number of repeat films, resulting in unnecessary radiation exposure to the patients while increasing the department's operating costs.

It may be necessary to segregate cassettes and screens of one type in a particular room in the department and color code those cassettes so that they are not inadvertently used in another area. If at all possible, a common type of cassette and screen should be used throughout the department since this decreases the potential for using the wrong cassette for the wrong exam.

If you decide to maintain two or more types of screens, then it is a good idea to use a different type of cassette for each screen type so that each is readily identifiable. This also helps in the darkroom if more than one film type is used since the darkroom or x-ray technologist loading the cassettes can easily identify the differences. (Ideally, you should strive to use the same screen-film-cassette combination throughout the department to reduce such potentials for error.)

## SCREEN-FILM CONTACT

Whether your cassettes are old or new, they must be checked for screen-film contact on a regular basis. If any cassette appears to be damaged between regular checks, it should be checked immediately. Only if the

screens are held in intimate contact with the film will you be able to obtain maximum definition in patient radiographs.

When you purchase new screens the screen-film contact tests should be carried out *prior* to acceptance of the new cassettes. As with any acceptance test, you should make the vendor aware that such tests are going to be carried out before complete payment will be authorized.

### X-RAY FIELD-LIGHT FIELD CONGRUENCE

This test, also known as the nine-penny test, was first suggested by the personnel at the University of Wisconsin at Madison and requires the cheapest quality control test tool available—nine pennies. The purpose is to assure that the light field and x-ray field are properly aligned. It is simple but important in that many times the technologist thinks the appropriate area is being radiographed, as indicated by the light field, only to find out that the x-ray field is actually shifted an inch or two, resulting in a radiograph that does not include the area of interest to the radiologist. This often leads the technologist to use a larger than necessary x-ray field to compensate for the lack of congruence, resulting in an increased exposure to the patient.

### BASIC HOMOGENEOUS PHANTOM TEST

For this test you may use either the patient equivalent phantom (PEP) described earlier or a 5-gallon cubitainer filled to the appropriate depth with water. In either case the purpose is to assure that the films produced are at the proper density and the entire radiograph is uniformly exposed. This test can also be used to compare different rooms in your department to assure that for the same patient a film of the same density will be produced for the posted technique in each room.

### BASIC TOMOGRAPHY TEST

Tomographic test tools may cost hundreds of dollars but this test allows you to test the resolution, thickness of cut, and cut location of tomographic units with a tool that you can put together in your own department. Most tomographic units of the attachable type (not an integral part of the table) suffer much abuse and are seldom properly inspected by service personnel in routine checks. This simple test will allow you to assure that your tomographic unit is functioning properly.

### STEP WEDGE TEST FOR GENERATOR LINEARITY

Now the test tools are becoming more expensive—an aluminum step wedge costs about $50. A wedge with 2- or 3-mm steps is required for this test, but with it you will be able to evaluate generator linearity. Linearity is important since it means that for the same mAs, regardless of the mA and the time stations selected, you will produce a radiograph with the same density. Many generators that have not been recently calibrated will produce results that are so variable that patient radiographs will range from acceptable to being too light or too dark for a diagnosis to be made.

# PROCEDURES

## 6.1. VISUAL AND MANUAL QUALITY CONTROL CHECK

### Purpose

To assure that the components in an x-ray room not normally evaluated as part of the QC tests, but that are visually apparent, are appropriately checked on a regular basis. This includes all x-ray equipment as well as equipment related to patient comfort and safety.

### Equipment Needed

1. Check list
2. Tape measure
3. Carpenter's level

### Procedure

Using the check list, visually and manually, check the following items, noting a pass by a check and a fail with an "F":

1. *SID indicator or marks*—Check the accuracy of the SID indicator using a steel measuring tape. Measure from the focal spot mark on the x-ray tube housing to the Bucky tray. If a mark is not present indicating the location of the focal spot, measure from a point 1 inch (2.54 cm) above the bottom of the tube housing. Also, check the accuracy of any measuring tape that may be built into the collimator. Assure that other distance indicator marks on the tube crane railings are in place and are accurate, e.g., the center mark for a wall-mounted film holder.
2. *Perpendicularity*—With the x-ray tube positioned in the standard position used for Bucky radiography, stand at the end of the table and then on one side, visually verifying that the collimator, x-ray tube, and crane appear to be perpendicular. If not, adjust or have this repaired before attempting alignment tests.
3. *Angulation indicator*—Use a level to make sure the tube and collimator are level when the angulation indicator reads 0°. Angle the tube in both directions and assure that the indicator is moving properly and not sticking in any position.
4. *Locks*—Check the function of all tube crane locks, assuring that they lock securely and unlock properly. Also, check the lock switch itself to assure that it is not broken.
5. *Field light*—Determine if the light works and is bright enough to be seen under normal operating conditions. Check for discoloration, dirt, and any other foreign matter on the underside of the collimator.
6. *Bucky center light*—Center the tube to the center of the cassette tray using the Bucky center light. Pull the overhead tube crane toward you and determine if its center corresponds to the position indicated by the Bucky center light, using the field light.
7. *High-tension and other cables*—Check all cables for frayed coverings, tight bends, and unsupported areas, and assure that none of the cables are pinched when the x-ray tube, crane, and table are moved to extreme positions. The stress relief fittings at the x-ray tube insert area should be intact and not kinked. Assure that any cables associated with foot switches are in good condition and that ground lines are intact.
8. *Overhead crane movement*—Move the tube crane system around the room and assure that it moves easily and quietly and does not encounter obstructions. Again, verify that cables do not bind or are not pinched during movement.
9. *Bucky lock*—Assure that the Bucky lock is functioning properly. (If the lock is not holding tightly, oscillation of the Bucky grid could cause the entire assembly to shift during the exposure, blurring radiographic detail.)
10. *Cassette lock*—Verify that the cassette lock holds the cassette firmly.
11. *Float and power top switches*—Check the function of the locks and smoothness of motion of the tops. Also, check that the switches are not loose or damaged.
12. *Measuring caliper*—Physically check the caliper and measure an object of known thickness.

13. *Step stool*—Inspect and then stand on the stool to assure that a solid step is provided and that the stool does not slide on the floor.
14. *Angulation indicator and center stop*—For tilting tables, place a level on the tabletop and assure the table is level in the center stop position when the indicator reads 0°. Check other stop positions if applicable.
15. *Foot board and shoulder rests*—Check the patient's foot and shoulder rests to ensure that they attach and remove easily. Also, pay particular attention to all locks to ensure that they will not come loose under the weight of a patient.
16. *Hand switch placement*—For the safety of the operator, the exposure hand switch should be mounted in a manner such that an exposure cannot be made if the operator is outside the control booth. (This is required by law in many states.)
17. *Window*—The operator's view from the control booth should not be obstructed in any way. [Windows should be a minimum of 24 × 18 inches (60 × 45 cm) with the long dimension in the vertical direction, and mounted on a 62-inch (158-cm) center.]
18. *Panel switches, lights, and meters*—Check the function of all the control panel switches, lights, and meters.
19. *Technique charts*—Assure that technique charts are present in the room and that they are the appropriate charts for the x-ray tube and the procedures normally done in the room.
20. *Overload protection*—Verify the function of the overload protection circuit for the specific x-ray tube(s) in the room (see pages 78–79).
21. *Locks*—Check the function of all the fluoroscopic tower locks, assuring that they lock securely and unlock easily.
22. *Power assists*—Assure that the power assist will move the fluoroscopic tower easily in all possible directions and that the motion stops when pressure is released from the switch or pressure-sensitive handle. These checks should be carried out with the table in both the horizontal and vertical positions.
23. *Motion smoothness*—Does the fluoroscopic tower move easily and quietly and not encounter interruptions?
24. *Switches, lights, and meters*—Check the function of all the lights, switches, and meters.
25. *Compression device or spoon*—Assure that the compression device moves in and out easily and quietly and is not damaged or splattered with contrast media. If a compression spoon is used, assure that it is located near the position of the radiologist during fluoroscopy and is not damaged or splattered with contrast.
26. *Fluoroscopic monitor*—Check the overall condition of the monitor, and verify that all electrical cords are intact and do not restrict the movement of the monitor. Assure that the switches on the monitor are functioning and intact and that the monitor face is clean.
27. *Fluoroscopic grid*—Check the function of the grid, making sure it moves in and out easily and that there is no grid cutoff or grid damage.
28. *Fluoroscopic timer*—Assure that the fluoroscopic timer is functioning and that an audible alarm sounds when the preset time (a maximum of 5 minutes) is reached.
29. *Fluoroscopic drapes*—Check the physical condition of the drapes, making sure they are not torn or damaged. Assure that the drapes move to their different positions with ease.
30. *Park position interrupt*—When the tower is in the park position, the x-ray generator should not be capable of producing radiation. Assure that the park position switch is working smoothly.
31. *Bucky slot cover*—Assure that the Bucky slot cover is present, is working smoothly, and covers the Bucky slot completely.
32. *Fluoroscopic shutters visible (high/low)*—Check the fluoroscopic shutters to assure that they are just visible inside the edges of the fluoroscopic image with the tower in the low and high positions.
33. *Gonad shields, aprons, and gloves*—Assure that these items are present and fluoroscopically inspect them for holes or cracks.

**Problems and Pitfalls**

1. On some older types of collimators, a special plastic sheet on the front of the collimator acts as a filter to reduce the amount of soft radiation reaching the patient. Therefore, it is important to assure that this material is present and that it is replaced with the same material (not Plexiglas).
2. Plexiglas and other plastic sheets in collimators may darken with age and exposure to radiation. These should be replaced with similar material.

### Acceptance Limits

These are left to the technologist. Discuss problems with the service engineer. Many problems may not need immediate repair, but any item dealing with patient or staff safety should receive immediate attention.

### Corrective Action

After all checks have been made, request service for the problem areas, and verify that corrections have been made in a reasonable time.

## 6.2. IMAGE RECEPTOR SPEED

### Purpose

To assure that the image receptors (cassette-screen combination) used in a department may be used without altering exposure factors (i.e., are all the same speed).

### Equipment Needed

Densitometer (visual comparison of film density may be used if a densitometer is not available)

### Procedure

1. Inventory and sort all cassettes by cassette and screen type. Inspect mechanical integrity of cassette, i.e., latches, hinges, frames, and light seals. Inspect screens for dirt, scratches, worn spots, and yellowing due to age. Repair, clean, or discard any faulty cassettes before continuing this test.
2. Select one of the most common cassette and screen types for a standard.
3. Load the standard cassette and up to three other cassettes with film from the same box (cut to size if needed).
4. Place the cassettes on the x-ray table top with edges touching (Figure 6.1).
5. Identify the cassettes with lead numerals or markers.
6. Center the x-ray beam between the cassettes at the corner where all are touching.
7. Make an x-ray exposure that will produce a density in the range of 1.0 on the "standard" cassette-screen-film combination (approximately 70 kVp, 100 mA, $^1/_{60}$ sec at 100-cm SID).
8. Measure the density near the x-ray beam center on all films or view each film side-by-side with the "standard" on an evenly lit illuminator.

### Problems and Pitfalls

1. X-ray film can vary in speed by ± 10% between emulsion batches and sometimes more between boxes depending on age, storage, etc. For this reason, it is necessary to use film from the same box.
2. X-ray beam intensity varies because of the heel effect parallel to the anode-cathode axis of the x-ray tube, so it is essential to make the density comparison at the corner of the films that were closest to the center of the x-ray beam.
3. This test provides cassette-screen speed information at one kVp only. You should test cassettes at the kVp commonly used if it is low (e.g., for extremity work) or high (e.g., for GI studies).

### Acceptance Limits

Density measurements should be within ± 0.05 of the "standard" or should not appear "significantly" different to the eye.

### Corrective Action

Cassette and screen combinations that fall outside of the acceptance limits should be removed from general service or segregated and labelled in some readily identifiable way for special use.

## 6.3. SCREEN-FILM CONTACT

### Purpose

To locate those cassettes that have poor screen-film contact.

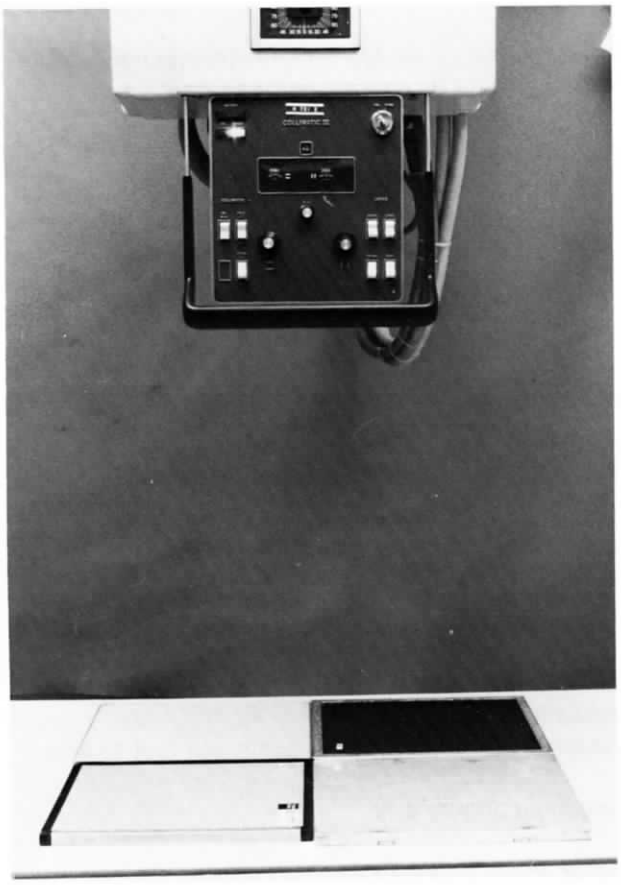

Figure 6.1. Image receptor speed test setup. Three cassettes are compared to a "standard" by exposing all four simultaneously, using the same type of film from the same box in each cassette. Note the lead identification numbers on each cassette. The densities should be compared only in the corner of the films that is closest to the central ray.

### Equipment Needed

1. Wire mesh test object [15 × 18 inches (38 × 46 cm)]. Copper wire mesh with 1/8-inch (3-mm) spacing of the wires is preferred for use with ordinary cassettes and screens. For high-resolution imaging systems, such as are used for mammography, #60 copper mesh [60 wires per inch (25 wires per cm)] is preferred.
2. Densitometer

### Procedure

1. Place the wire mesh test object and the screen-film cassette on the x-ray table top (Figure 6.2).
2. Collimate the x-ray beam to the cassette size.
3. Identify the cassette with lead numerals.
4. Radiograph the wire mesh phantom at factors of about 2 mAs at 70 kVp with a 100-cm SID.
5. Check to assure that a density of 1.5 to 2.0 is obtained on the film.
6. View the wire mesh radiographs in a dimly lit room on an x-ray viewbox at a distance of about 6 feet (2 meters). Areas of poor contact will appear darker than areas of good contact (Figure 6.3).

### Problems and Pitfalls

1. Grossly over- or underexposed radiographs cannot be readily interpreted.
2. Artifacts from improper film handling during cassette loading are frequently seen. These may be ignored in interpretation of the contact radiographs but indicate a need to improve film loading techniques.
3. Freshly loaded cassettes may exhibit poor contact because of entrapped air. Wait a minimum of 10–15 minutes after cassette loading before making screen contact tests.

### Acceptance Limits

1. Large central areas of poor contact indicate the need for corrective action.

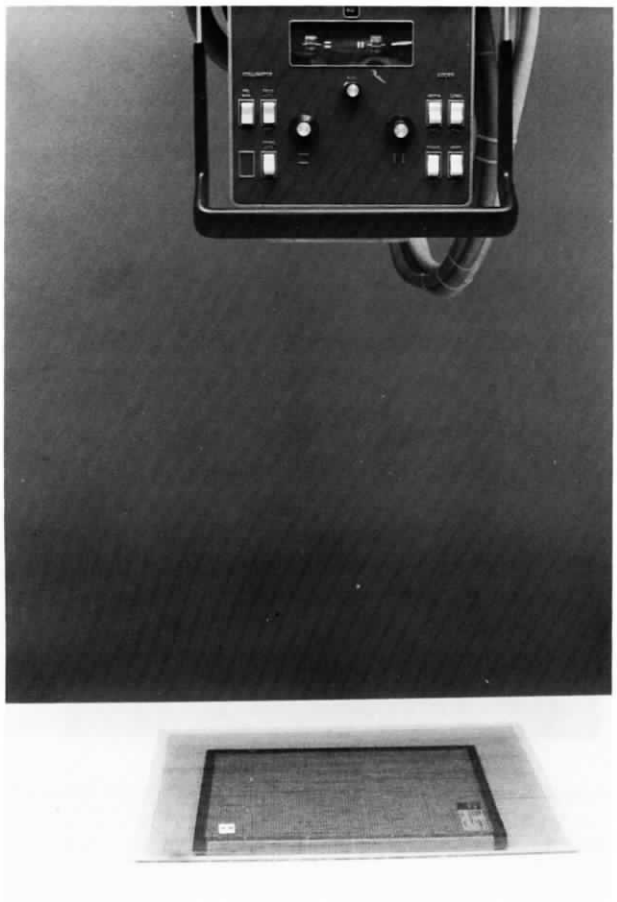

Figure 6.2. Screen-film contact test setup. An exposure is made with the test mesh on top of the cassette, with an identification number. The exposure should be such that a density of at least 1.5 is produced on the film.

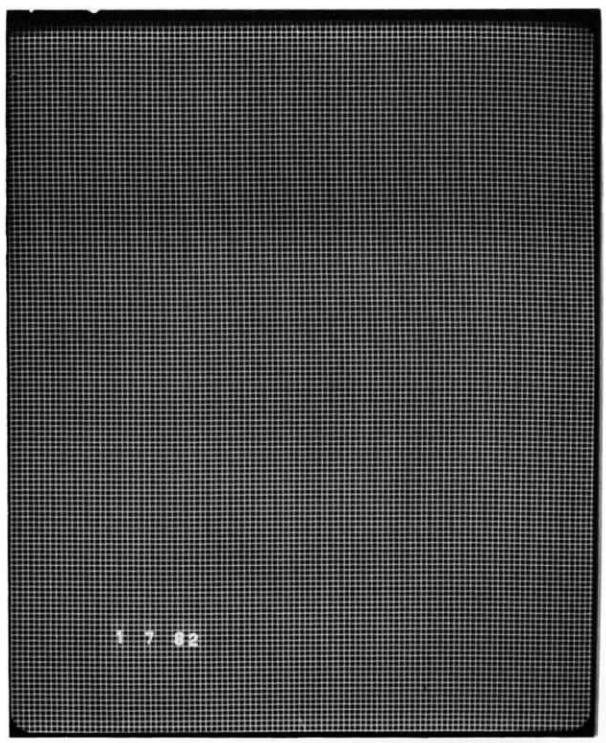

Figure 6.3a. Radiograph of screen-film contact test showing acceptable results. In viewing the resultant films you should stand at least 6 feet (2 meters) from the viewbox. You are not interested in looking at the details of the mesh and in comparing the sharpness of the individual wires. Rather, you should look for areas of apparent increased density, indicating poor contact and also unsharpness. It is easier on your eyes to stand back and look for the dark areas than to view the film from a close distance and look for unsharp areas, and it is a lot faster.

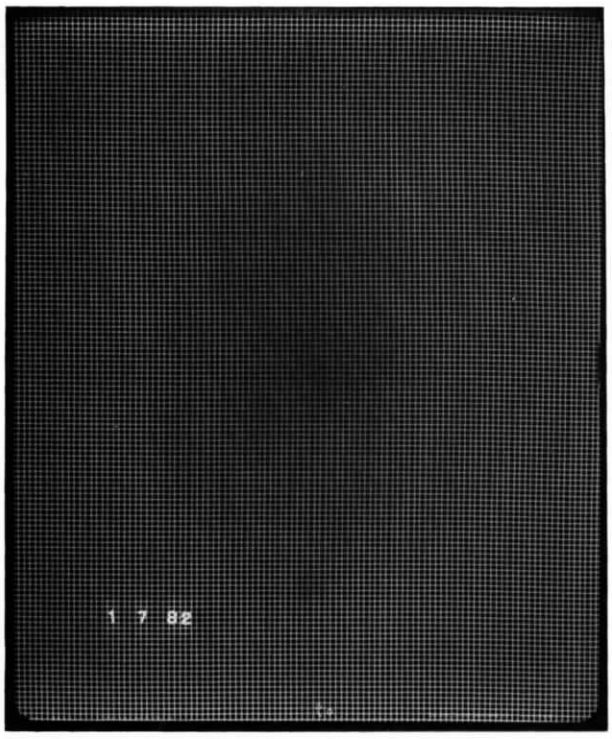

Figure 6.3b. Unacceptable contact is exhibited in this screen as a large dark area in the center of the radiograph of the mesh. This cassette should be repaired or replaced.

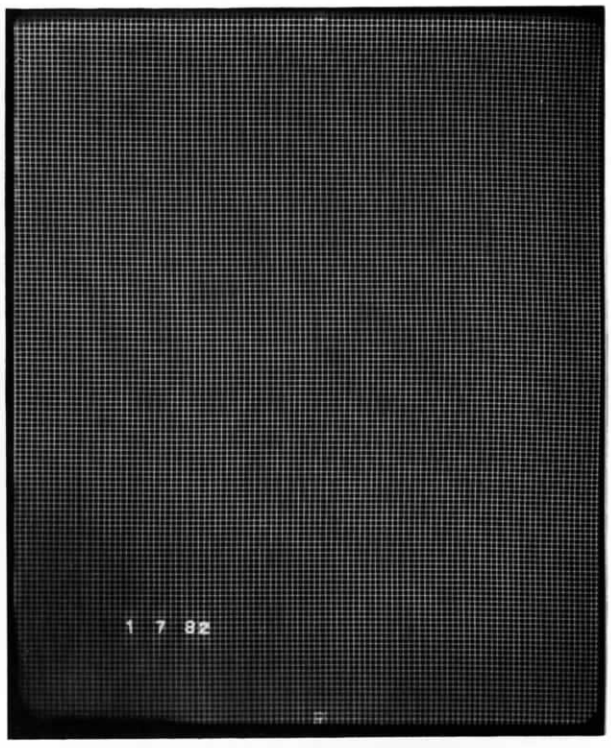

Figure 6.3c. Increased density is apparent in the lower left corner of this radiograph of the mesh. Although this indicates unsharpness it may be necessary to accept this since it occurs on the edge of the image, which it is hoped is outside of the major area of interest.

2. Small areas of poor contact along the edges or corners may have to be accepted.

**Corrective Action**

1. Cassettes occasionally can be repaired by re-arching (bending) the cover or springs.
2. Check the latches on those cassettes with corner or edge contact problems.
3. Rescreening with new pads may be a possible solution.
4. Replacement of cassettes that do not provide good screen-film contact is generally the best solution.

## 6.4. X-RAY FIELD-LIGHT FIELD CONGRUENCE

**Purpose**

To assure that the x-ray field and the light field are congruent.

**Equipment Needed**

1. One 10 × 12-inch (24 × 30-cm) cassette
2. Nine pennies
3. Lead letters, A and F (may be used rather than the ninth penny)

**Procedure**

1. Place a 10 × 12-inch (24 × 30-cm) cassette on the x-ray table top with its long dimension parallel to the long dimension of the table.
2. Center the light field to the center of the cassette at a 40-inch (100-cm) SID.
3. Manually collimate the x-ray beam to an approximate 6 × 8-inch (15 × 20-cm) field size.

4. Position two pennies in the center of each margin of the light field such that one entire penny is inside the light field and one penny is outside the light field. Place the ninth penny in the quadrant of the light field toward you and to your right as an orientation marker or place the lead "A" at the anode end of the x-ray tube and the "F" to mark the front of the x-ray table (Figure 6.4).
5. Place lead markers well inside the light field on the cassette to identify the room number and date.
6. Make a radiographic exposure using technical factors appropriate for a hand.
7. Process the radiograph and determine if the x-ray field is properly positioned (Figure 6.5).
8. Record the results in the QC room log.

**Problems and Pitfalls**

1. This test does not assure central x-ray beam perpendicularity.
2. This test does not assure that positive beam limitation (PBL) systems adjust to the proper cassette size.

**Acceptance Limits**

Federal guidelines for certified equipment allow ±2% of the SID for light field–x-ray field alignment. For a 100-cm SID, ±2 cm (1 penny) is acceptable. Light field–x-ray field alignment can and should be well within this amount. Alignment to ±1 cm (±0.5 penny) can reasonably be achieved.

**Corrective Action**

A service engineer should be called to align the light field to the x-ray field if acceptance limits are exceeded.

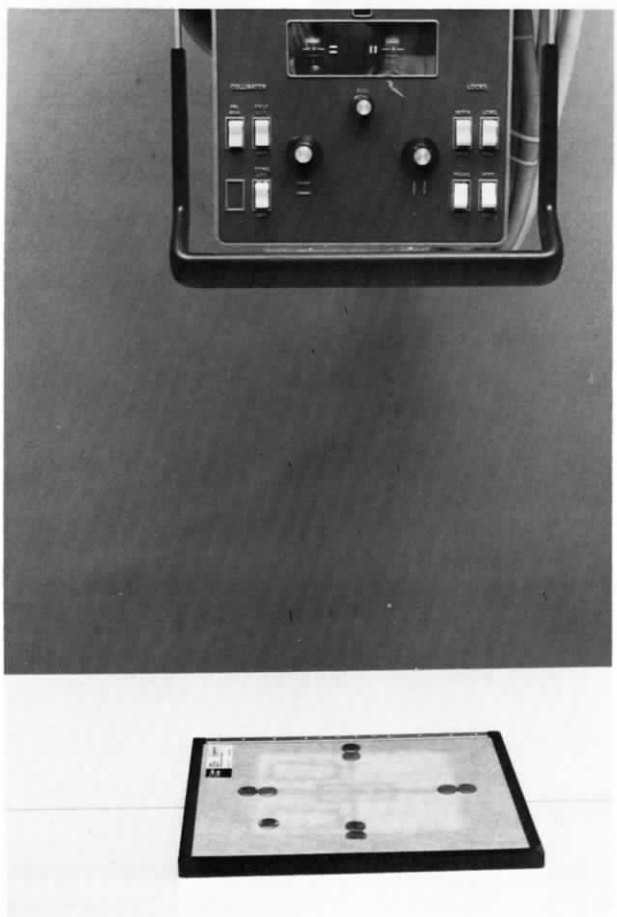

Figure 6.4a. X-ray field–light field congruence test setup. The nine-penny test uses the ninth penny to indicate the orientation of the cassette relative to the x-ray–light field.

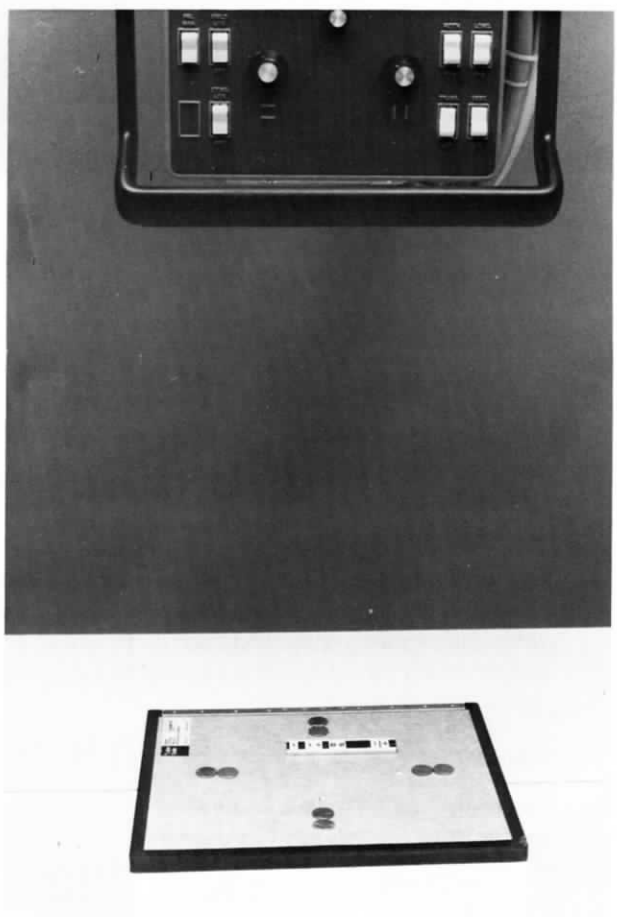

Figure 6.4b. The eight-penny x-ray field–light field congruence test uses lead letters to indicate the orientation of the film.

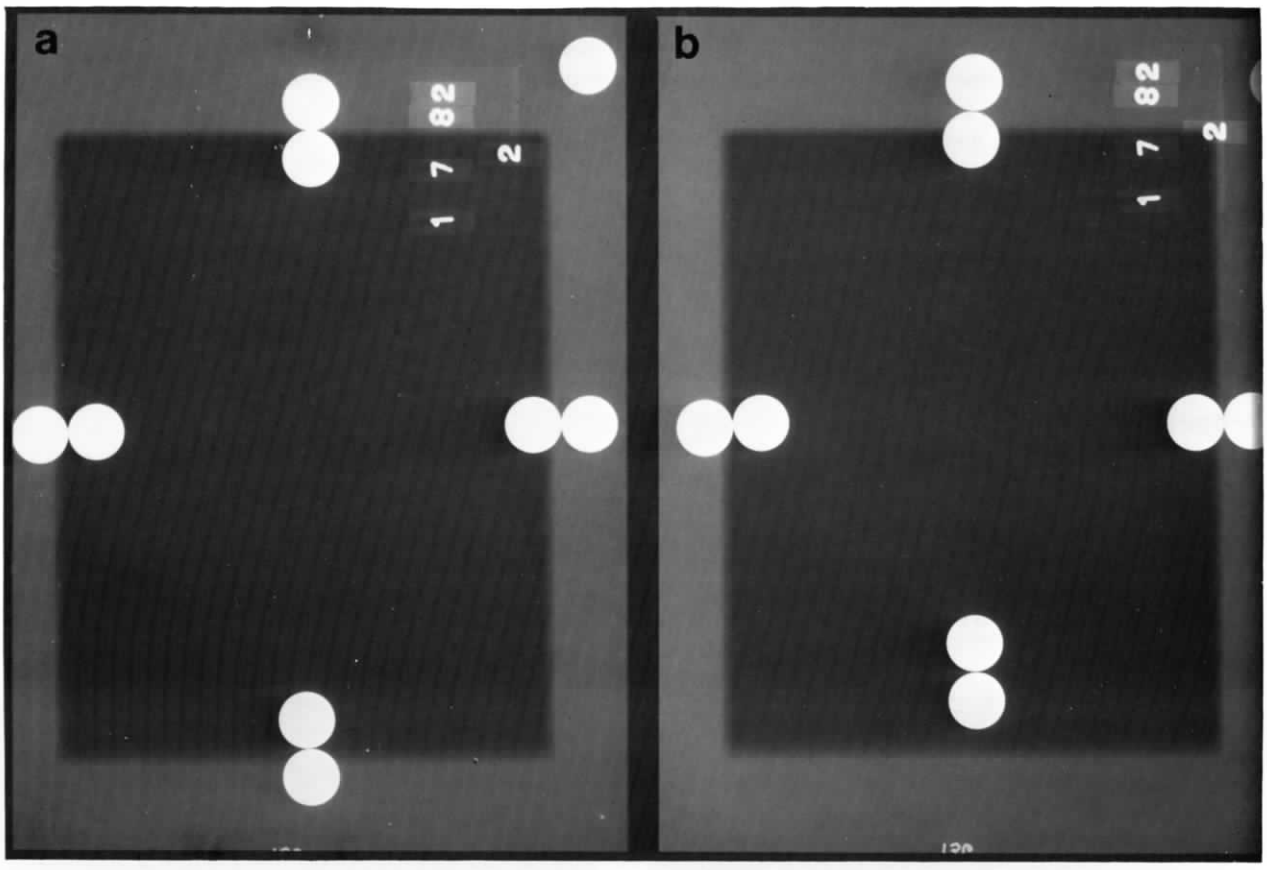


Figure 6.5. X-ray field–light field congruence test results. These radiographs should show the date, room number, and pennies. (**a**) Results where the x-ray field falls within half of a penny's distance from the center line are ideal. (**b**) If any side of the x-ray field exceeds the proper location by more than one penny (e.g., at the bottom of this image) a service engineer should adjust the collimator.

## 6.5. BASIC HOMOGENEOUS PHANTOM TEST

### Purpose

To assure that the routine Bucky radiographs will be satisfactory at posted technical factors.

### Equipment Needed

1. Patient equivalent phantom (PEP) [***Note:*** A water phantom made from a 5-gallon (20-liter) cubitainer may be used instead of the uniform density phantom; however, it is more difficult to work with. Fifteen cm of water will produce results similar to 15 cm of lucite.]
2. Densitometer (Visual comparison of film density may be used if densitometer is not available.)
3. Lead letters A and C

### Procedure

1. Center the uniform density phantom on the x-ray table top.
2. Center the x-ray tube to the phantom.
3. Insert a 14 × 17-inch (35 × 43-cm) cassette transversely in the Bucky tray, center it to the phantom and central x-ray beam, and collimate the beam to the phantom (Figure 6.6). Identify, with lead letters, the anode and cathode ends of the phantom, as well as the room number and date.
4. Expose a radiograph using your posted technical factors for an anteroposterior view of a 21-cm lumbar spine and process the film. For example, with a three-phase generator, Kodak XL film and X-Omatic regular screens, a 16:1 ratio grid, and a 48-inch (120-cm) SID, use about 68 kVp and 65 mAs.

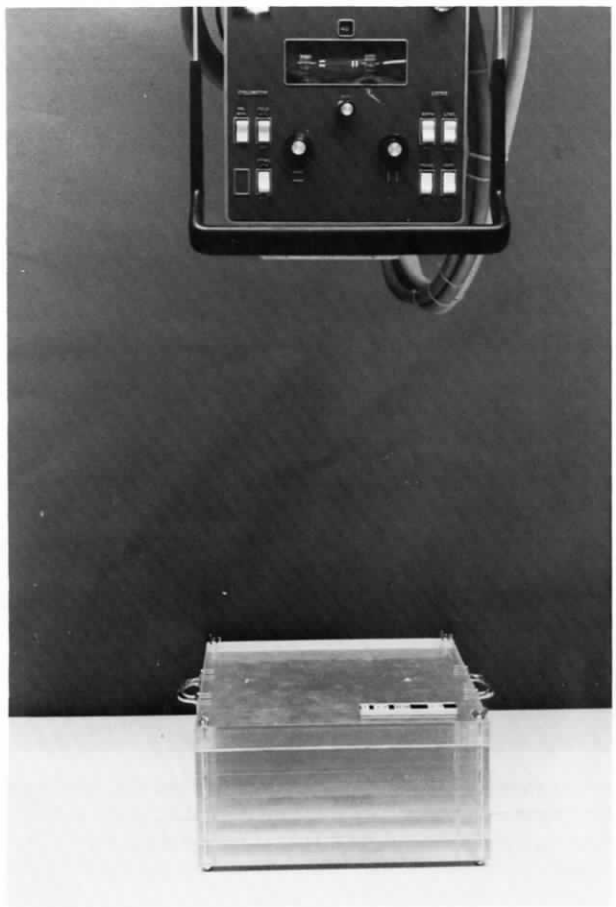

Figure 6.6. Basic homogeneous phantom test setup. The x-ray field should be centered and collimated to the edges of the phantom. A marker indicating the date and room number should be included.

5. Measure the film density in the center of the phantom. Visually compare the film density near the edges of the phantom image in a direction perpendicular to the anode-cathode axis (Figure 6.7).
6. If a densitometer is not available, visual acceptance limits can be established using two films, one exposed at +3 kVp and the other exposed at −3 kVp. These films should be made after the generator has been calibrated and after the processor has been optimized. On return visits, these films can be used to compare the density of the phantom film visually. The comparison should be done by placing the current phantom film on a viewbox between the two films originally exposed at +3 kVp and −3 kVp. If the density of the current film falls between the densities of the acceptance limit films, you may assume that radiographs of reasonable quality, in terms of density, will be obtained.

**Problems and Pitfalls**

1. Since this test evaluates the total system, it does not identify the exact cause of the problem. For example, if the density is too light or too dark, among other reasons the problem could be due to processing, generator calibration, or improper posted technical factors.
2. Expect to see density variations along the anode-cathode axis of the phantom because of the heel effect.
3. Problems caused by cassette and tray interference with motion of the Bucky grid are frequently not demonstrated unless a 14 × 17-inch (35 × 43-cm) cassette is used transversely, as for a routine pelvic examination.

**Acceptance Limits**

1. Ultimately, you will have to determine what the density, as measured in the center of this phantom radiograph, should be based upon technical factors that produce satisfactory images on patients with your screen-film combination. (The density measured in the center of the film should be about 1.2 ± 0.15.)
2. The film density in a direction perpendicular to the anode-cathode axis should not appear significantly different to the eye when viewed on an illuminator. If it does, Bucky grid cutoff due to nonperpendicularity of the x-ray beam, lateral decentering, or nonuniformity in the Bucky motion may be suspected.

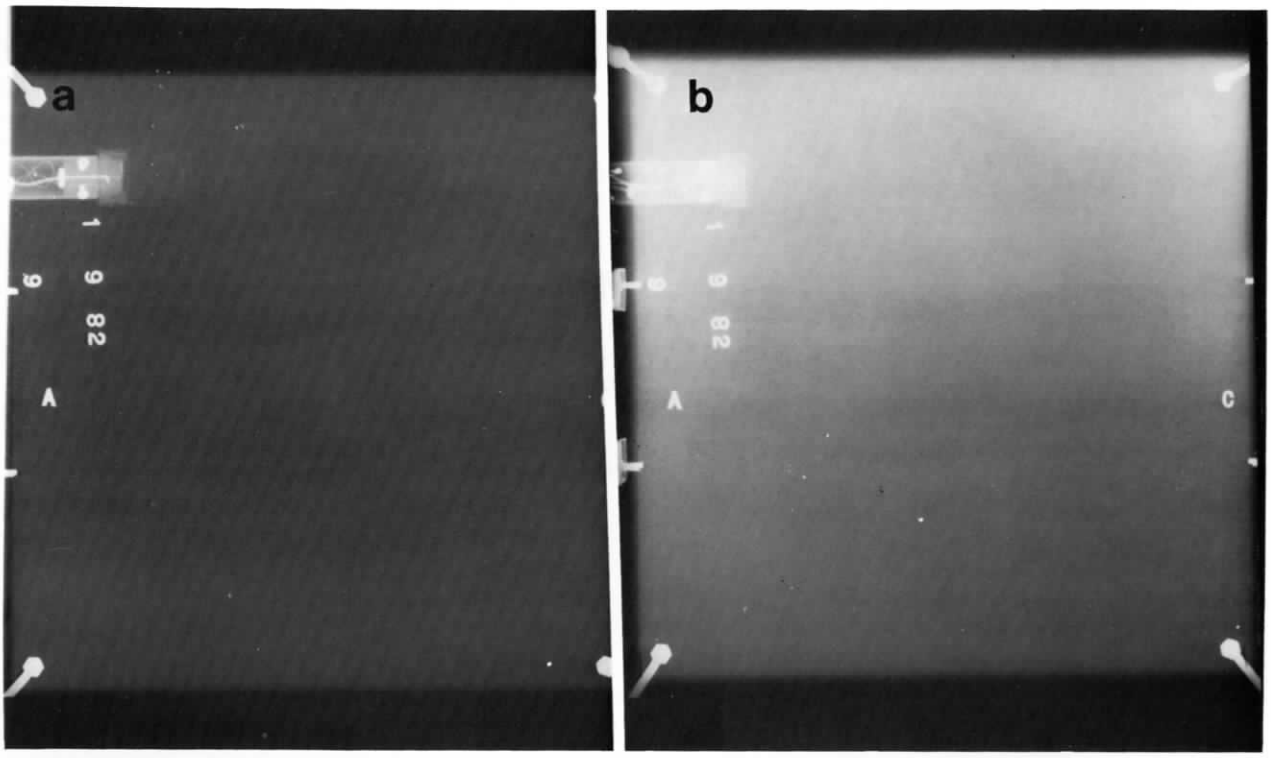


Figure 6.7. Basic homogeneous phantom test results. (**a**) A good film should appear relatively uniform in density, although you may anticipate some density differences parallel to the anode-cathode axis, especially at the anode end of the x-ray field. With the PEP the technique for a 21-cm lumbar spine film should produce a density of about 1.2 near the center of the film. (An ionization chamber shows in this radiograph and can be added to record the patient entrance exposure for this technique.) (**b**) The density variation perpendicular to the anode-cathode axis (indicated by the lead letters "A" and "C") that is apparent in this radiograph is not acceptable. This was caused by a grid–x-ray beam alignment problem.

### Corrective Action

Appropriate adjustments should be made by a qualified service engineer.

## 6.6. BASIC TOMOGRAPHY TEST

### Purpose

To assure that the tomographic cut level and thickness are correct and that the image sharpness is optimal.

### Equipment Needed

Simple tomographic test phantom (Figure 6.8):

1. Cut a 30°–60°–90° triangular-shaped piece from a 2 × 4-inch (5 × 10-cm) piece of wood.
2. Attach a copper window screen of #40 mesh to the angled surface of the wood block.
3. Attach a small piece of copper wire or a straightened paper clip to the screen halfway up the block.
4. Attach a lead number to indicate the cut level.
5. Attach a thin lead sheet such as found in an old cassette or cardboard film holder to the base of the wood block.

### Procedure

1. Place the simple tomographic test phantom on the tomographic table top (at a 45° angle to the tube-film motion if a linear tomographic system is being evaluated) and center it to the x-ray beam (Figure 6.8b).
2. Set the tomographic section level adjustment to correspond with the level of the wire marker.
3. Select the amplitude setting most commonly used for tomography.

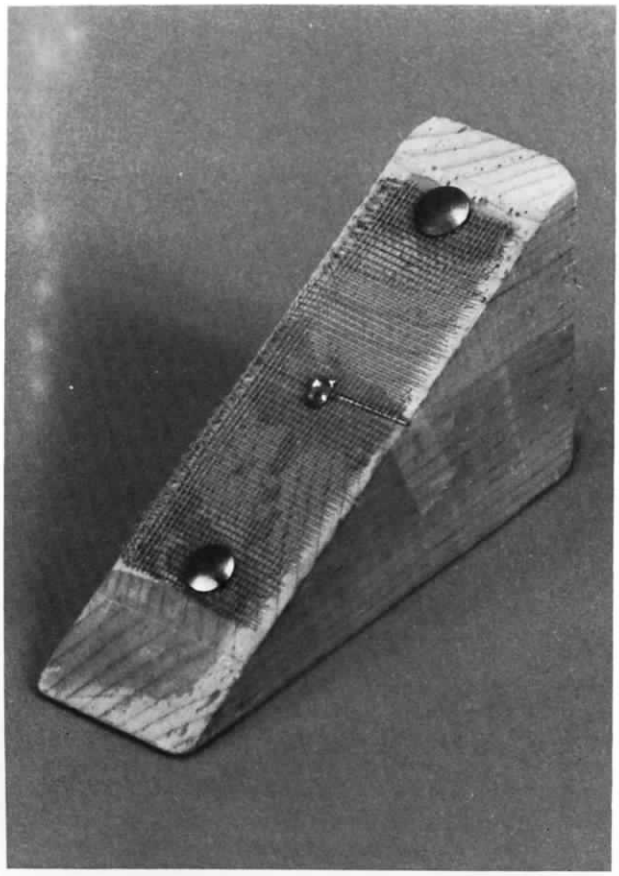

Figure 6.8a. This basic tomography test tool can be simply constructed as described in the text.

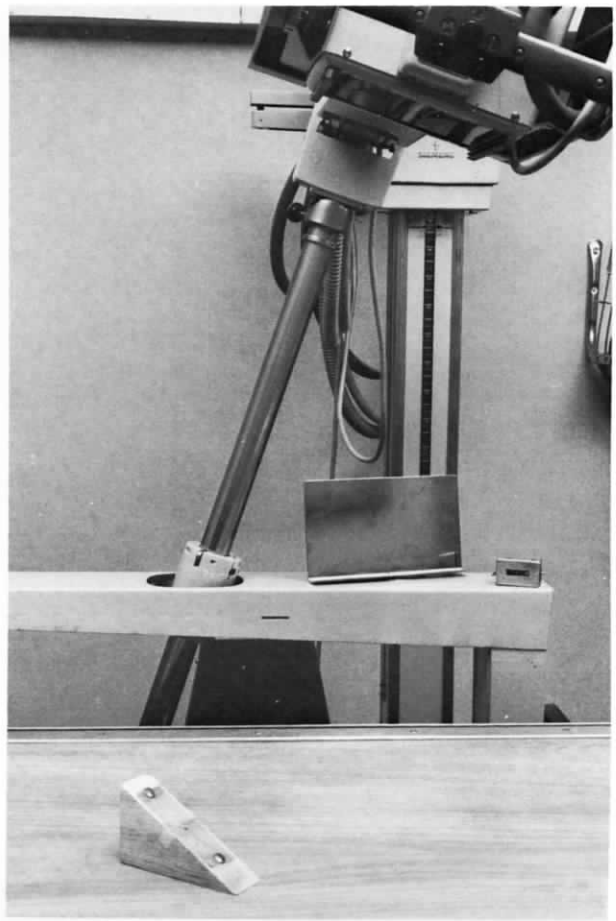

Figure 6.8b. Basic tomography test setup. Whenever this test tool is used to evaluate a tomographic system with linear motion the tool should be placed at 45° to the direction of motion.

4. Select the lowest mA available, 50 kVp, and the exposure time appropriate for the amplitude setting.
5. Make a tomographic exposure of the phantom.
6. Process and view the radiograph (Figure 6.9).

**Problems and Pitfalls**

1. Failure to position the test phantom at a 45° angle to tube-film motion on linear systems will result in incomplete blurring of the screen wires in the direction of tube-film travel.
2. Since the phantom is relatively radiolucent it may be difficult to select exposure factors that will not "burn out" the images of the test object. The addition of another thickness or thicknesses of cassette lead to the bottom of the phantom may be required.
3. Aluminum window screen should not be used because it offers insufficient attenuation of the x-ray beam to produce a useful image.

**Acceptance Limits**

Except for the tomographic section level, which should be within ±0.5 cm of the setting, this is not a highly quantitative test. If the in-focus image of the wire mesh does not coincide with the image of the wire indicator, measure the distance between the centers of these images and divide by 2 to determine the adjustment that must be made to the tomographic section level indicator. In-focus images of the wire mesh on the tomogram should appear sharp to the eye and there should be only one area that appears in focus. If there is more than one area in focus, the tomographic motion may not be smooth. On linear systems, there should be a zone of sharp

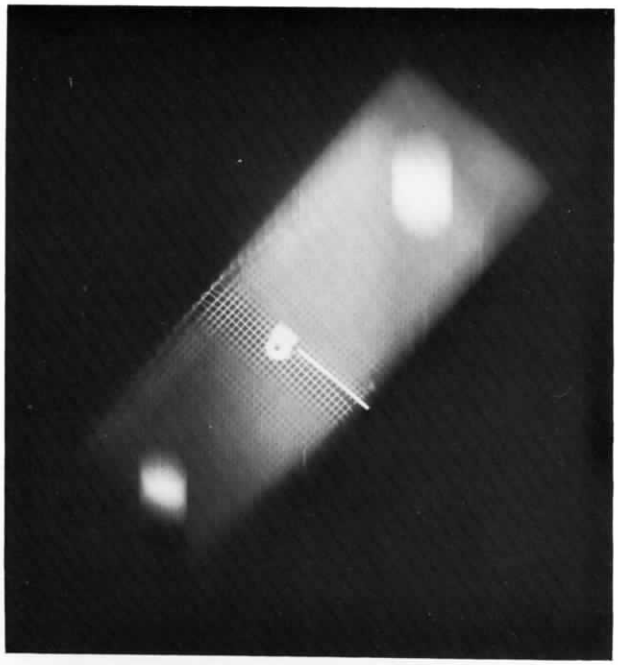

Figure 6.9a. Basic tomography test results. A properly functioning tomographic unit will produce one sharp area located near the indicated plane of cut with an increase in blurring as you move away from the plane of cut.

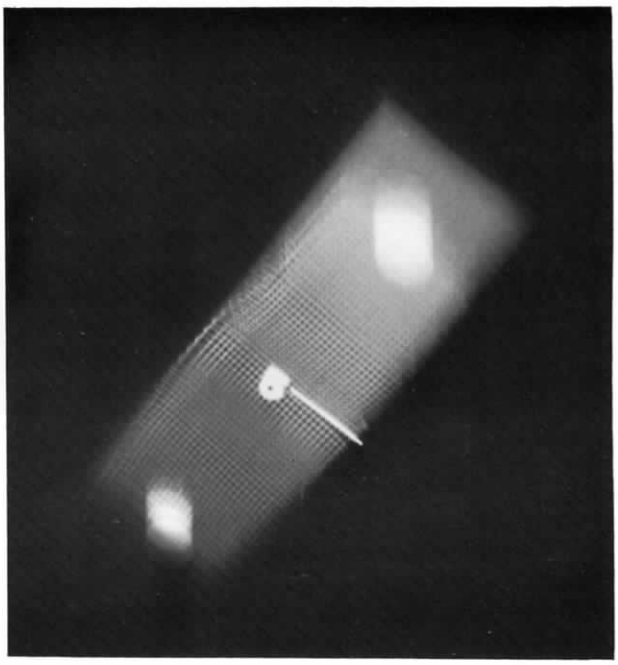

Figure 6.9b. Erratic motion of the tomographic unit will produce several areas that appear to be sharp at different levels with blurred areas in between. In addition, you can easily see multiple images of the tacks holding the screen, indicating that the x-ray tube was not moving smoothly.

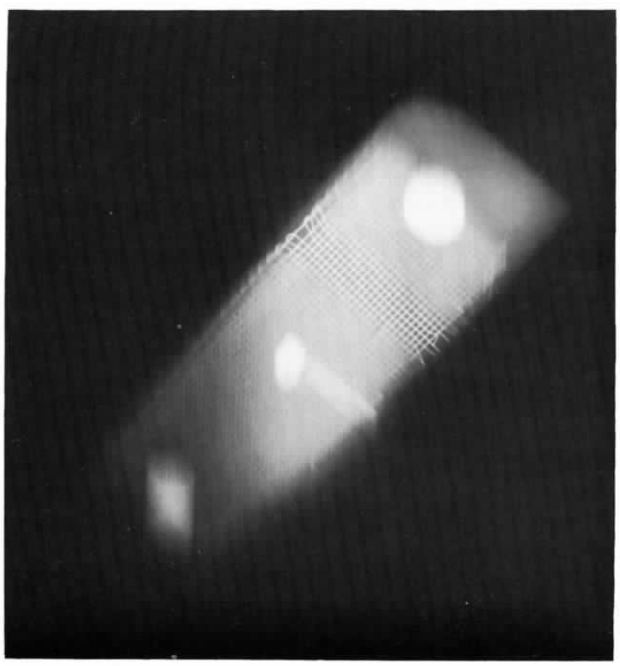

Figure 6.9c. In addition to good image quality you should assure that the tomographic unit is cutting at the indicated level. In this case the cut was quite a bit higher than indicated.

focus with a visible, although blurred, region on both sides. The thickness of the region in focus may be approximated by measuring the width of the mesh that is in focus and dividing by 2.

**Corrective Action**

Appropriate adjustments should be made by a qualified service engineer.

## 6.7. STEP WEDGE TEST FOR GENERATOR LINEARITY

**Purpose**

To simply check the mA station linearity of an x-ray generator.

**Equipment Needed**

1. Aluminum step wedge (one with 2- or 3-mm steps is preferred over a wedge with thicker steps)
2. Screen-film cassette, 10 × 12 inch (24 × 30-cm)
3. Fresh box of film
4. Lead sheet to block off one half of the cassette
5. Densitometer (visual comparison of film density may be used if a densitometer is not available)

**Procedure—Step Wedge Calibration**

1. Raise the x-ray tube to its maximum height.
2. Place a freshly loaded 10 × 12-inch (24 × 30-cm) cassette on the tabletop with the long axis of the cassette parallel to the length of the x-ray tube (Figure 6.10).
3. Mask off one-half of the cassette across its length with lead.
4. Place the step wedge on the cassette so it is in the central beam and perpendicular to the anode-cathode axis of the x-ray tube, thus avoiding problems introduced by the heel effect.
5. Collimate the beam to the step wedge.
6. Expose the step wedge at 80 kVp using the 100 mA station or the mA station on the generator closest to 100 mA at approximately 0.1 sec.
7. Move the step wedge to the other half of the cassette and mask the previously exposed area with the lead sheet.
8. Using the same factors make *two* individual exposures of the step wedge (i.e., a double exposure).
9. Develop and check the film (Figure 6.11a). The ideal exposure should exhibit each step of the wedge without the use of a bright light on the single-exposed wedge. If the film is under- or overexposed, repeat the exposures and change the exposure factors until an image is produced in which all steps on the wedge are seen on the single-exposed side.
10. Using a densitometer, select a step on the single-exposed wedge that has a density close to or slightly higher than 1.0 and mark it with a marking pen. On the double-exposed wedge, read the densities until the step that has the density closest to the 1.0 density on the single-exposed wedge is located. Once the match is found, mark it and count the number of steps between marks on the single- and double-exposed wedges to determine how many steps represent a 100% change in exposure. For example, if four steps separate the single- and double-exposure match, which represents a 100% change in exposure, then each step will represent about a 25% change.
    If you do not have a densitometer, cut the film so that the step wedge images can be placed side-by-side on a viewbox. On the single-exposed wedge select and mark a step that has a medium-gray density such as would be found in the soft tissue on an AP lumbar spine film. By sliding the double-exposed wedge past the single-exposed wedge, compare the densities with the selected step until the closest match is found, then count the number of steps to determine the number that yields a 100% change in exposure.

**Procedure—Generator Linearity Test**

1. Using the same cassette and film type used to calibrate the step wedge, make exposures at all the mA stations normally used on the generator. Keep the kVp constant and vary the exposure time to keep the mAs constant, e.g., at 80 kVp use 50 mA at 0.2 sec, 100 mA at 0.1 sec, 200 mA at 0.05 sec, and 400 mA at 0.025 sec.

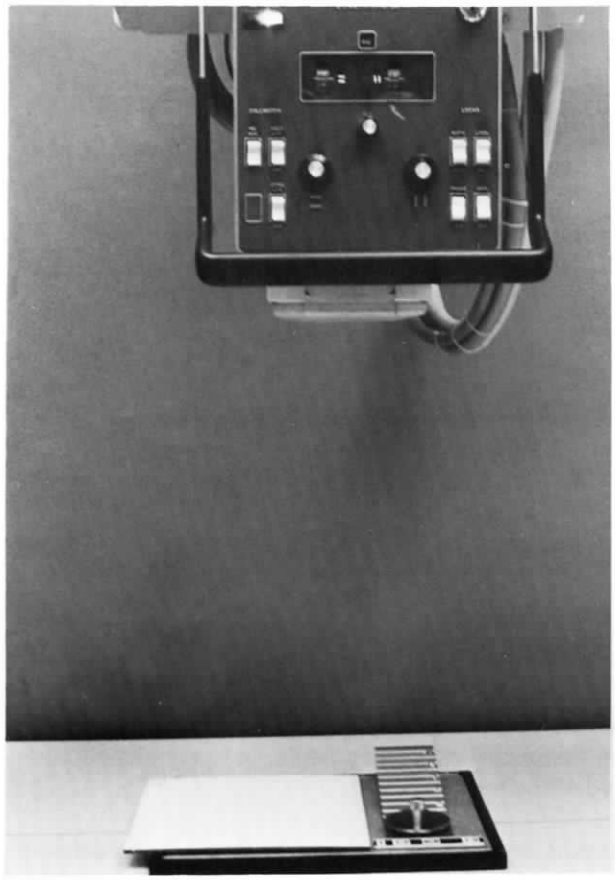

Figure 6.10. Generator linearity test setup. The step wedge should be placed directly under the central beam, and the remainder of the cassette covered with at least 1/8 inch (3 mm) of lead. Note that this step wedge also contains a spinning top for checking the timing of single-phase generators. Room identification and date information must be included on the radiograph.

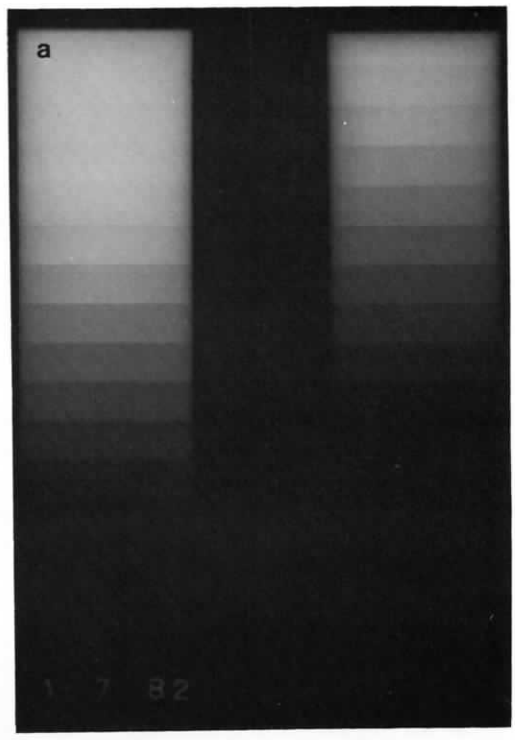


Figure 6.11a. Generator linearity test results. These two step wedges were produced as part of the calibration procedure with the wedge on the right receiving twice the exposure of the one on the left.

2. Use the method described in Procedure Step 10 above to compare the film density and determine how well the mA stations of your generator are calibrated (Figure 6.11b and c).

**Problems and Pitfalls**

1. Variation from this procedure can create problems that will falsely influence the results of this test.
2. Depending on the step wedge, variations in calibration of less than ±25% may not be detected with this test.
3. If a problem is found, you have no way of knowing the cause of the problem, i.e., exposure time, mA, or kVp.
4. This procedure must be done in a short period of time to prevent variation in film processing from influencing the test results.
5. Each time the test is performed, the single- and double-exposure initial film *must* be repeated because any drift in kVp will alter the densities and density differences from one step to another.

**Acceptance Limits**

The density of a step wedge image should match on the same step for all mA stations. A match on any other step will mean a variation of greater than ±25% (if there are four steps between the single- and double-exposure film matches), which is unacceptable.

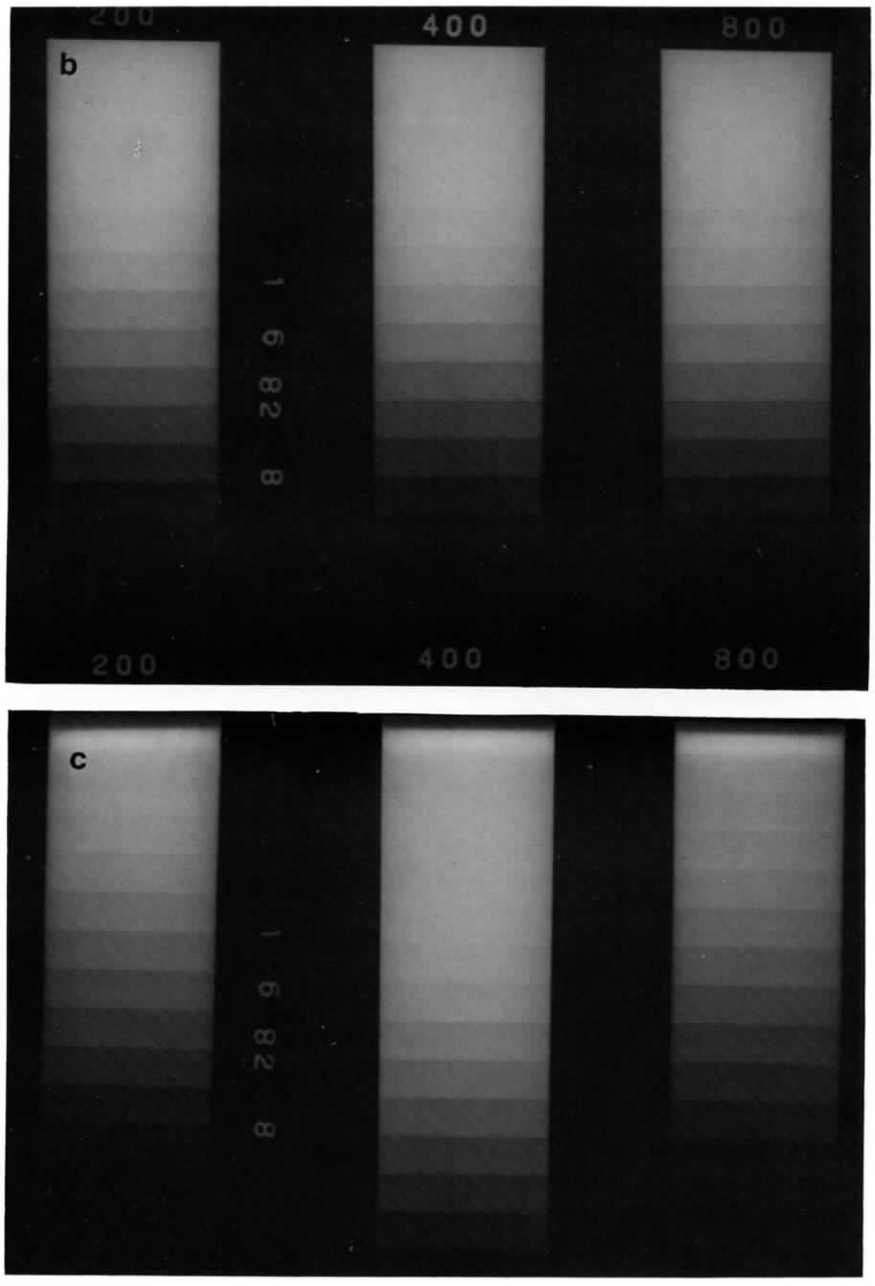


Figure 6.11b. Test results for one room before calibration, in which the wedge was exposed at 80 kVp and the same mAs but at 200, 400, and 800 mA as noted. There is a considerable difference in the density of the film produced at the 400 mA station. In comparing just these three images it is difficult to determine whether the 400 mA station is producing insufficient output or if the 200 mA and 800 mA stations are operating at a higher than normal output. (**c**) Test results produced in the same room with the same settings but after calibration. In this case, little variation in density is noted between the three mA station films.

### Corrective Action

Have a qualified service engineer check the exposure time, mA, and kVp calibration.