

Operation and Maintenance

MODEL D 3

MOBILE SHOCKPROOF X-RAY UNIT

8

Directions No. 11039

**GENERAL  ELECTRIC
X-RAY CORPORATION**

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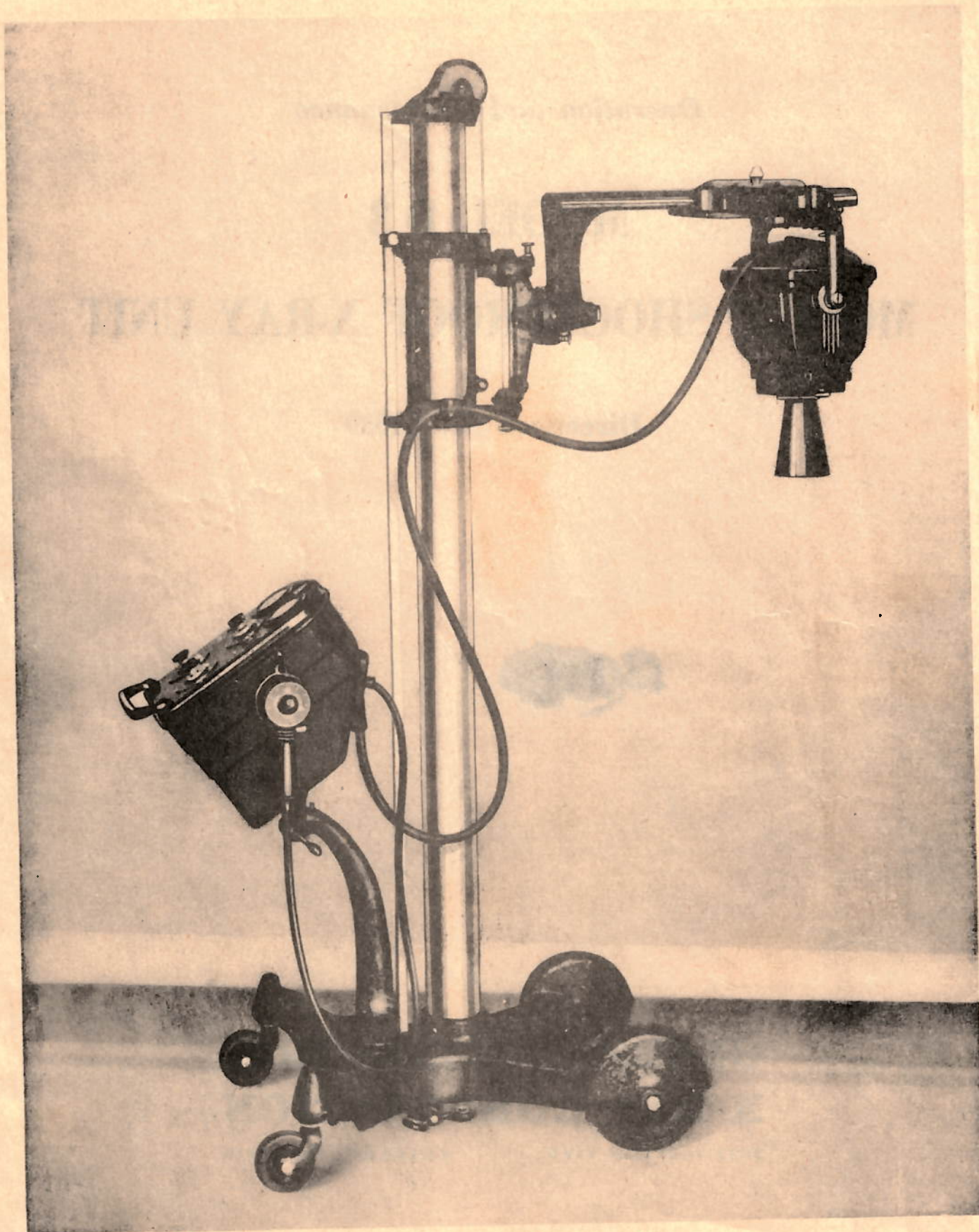
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**GENERAL  ELECTRIC
X-RAY CORPORATION**

2012 JACKSON BLVD.

CHICAGO, ILLINOIS



IMPORTANT ••• X-RAY PROTECTION

X-RAY EQUIPMENT, IF NOT PROPERLY USED, MAY CAUSE INJURY. ACCORDINGLY THE INSTRUCTIONS HEREIN CONTAINED SHOULD BE THOROUGHLY READ AND UNDERSTOOD BEFORE YOU ATTEMPT TO PLACE THIS EQUIPMENT IN OPERATION. THE GENERAL ELECTRIC X-RAY CORPORATION WILL BE GLAD TO ASSIST AND COOPERATE IN PLACING THIS EQUIPMENT IN USE.

Although this apparatus incorporates a high degree of protection against x-radiation other than the useful beam, no practical design of equipment can provide complete protection. Nor can any practical design compel the operator or his assistant to take adequate precautions, or prevent the possibility of authorized or unauthorized persons carelessly, unwisely, or unknowingly exposing themselves or others to direct or secondary radiation.

It is important that everyone having anything to do with x-ray work be fully acquainted with the recommendations of the National Bureau of Standards, and of the International Roentgen Ray Committee on x-ray protection, and take adequate steps to insure protection against injury.

It is assumed that all persons authorized to use the equipment are cognizant of the danger of excessive exposure to x-radiation, and the equipment is sold with the understanding that the General Electric X-Ray Corporation, its agents, and representatives have no responsibility for injury or damage which may result from exposure to x-radiation.

Various protective materials and devices are available. It is urged that such materials or devices be used.

FOREWORD

Your Model D3 Mobile Shockproof X-Ray Unit represents one of the most outstanding developments in the design of equipment for fluoroscopy and radiography. It is the latest development in oil-immersed shockproof x-ray apparatus, the basic principles of which have been incorporated in thousands of General Electric X-Ray equipments now in use by physicians and dentists the world over. These users attest to the amazing efficiency and reliability, characteristic of General Electric shockproof x-ray apparatus.

Since the introduction of the D series by this organization, additional features have been added from time to time to further increase its already wide field of usefulness. We sincerely believe that the D3, with its many additional features, represents the finest equipment of its type available today.

As with all General Electric equipment, the mechanical and electrical design of the Model D3 is based, primarily, upon one major consideration, namely, the consistent production of the highest quality end result. In order that the user may realize this, the following information regarding operating procedure is submitted as a guide.

Obviously, no x-ray apparatus, regardless of its design, is capable of operating itself. In order that the highest quality results be obtained consistently, the operator must understand the basic principles in operative technique, the proper manipulation of which is es-

sential if such results are to be obtained and maintained.

THE FOUR PRIME FACTORS

There are four so-called prime factors necessary in the production of any radiograph. Milliamperage and penetration, or kv.p., are considered the electrical factors, because they are controlled by the x-ray unit itself. The other two factors - distance and time of exposure - are commonly referred to as the personal factors, because their control and manipulation are independent of the x-ray generating equipment.

THE FACTOR OF PENETRATION

The term penetration refers to the high voltage supplied to the x-ray tube by means of the high voltage transformer and regulated by use of the control Fig. 3, (Illustration 1).

It will be noted that the kilovolt selector dial incorporates 15 positions, ranging from button 1 to button 15 inclusive. Directly above the autotransformer dial is a selector switch (Fig. 2). This switch incorporates a high low setting by which it is possible to double the number of autotransformer settings without enlarging the kilovolt selector dial itself. Therefore the autotransformer, in combination with the selector switch, has 30 buttons of voltage control. The lowest penetration value is obtained when the selector switch is set on the low side and the autotransformer is positioned on button 1. Such a setting is designated as L-1. From this point

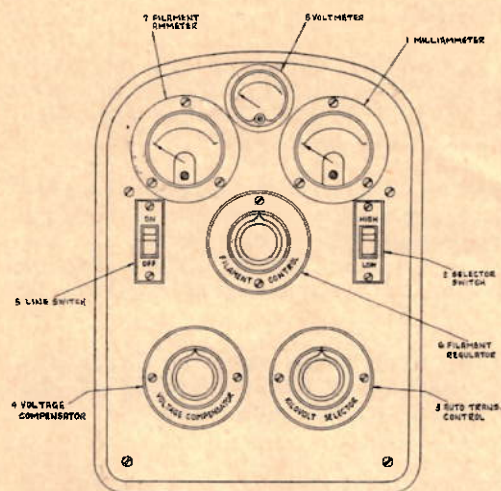


ILLUSTRATION I

the penetration may be gradually increased, through successive steps to L-15. To obtain the next higher setting of the autotransformer it will be necessary to move the autotransformer control (Fig. 3) to button 1 and change the selector switch to the high position. This is designated as H-1 setting and the penetration may be further increased by progressing from H-1 to H-15 depending on the line regulation and the milliamperes at which the tube is being operated. The steps in penetration between each button of the autotransformer, from L-1 to H-15, are the same and represent just enough difference in radiograph density as to be visible on the film, the percentage difference in density between autotransformer buttons being approximately 20 per cent when intensifying screens are used, and 10 per cent without intensifying screens.

The purpose of the voltage compensator, Fig. 4, which has 11 buttons of control brought out of the autotransformer, is to permit the regulation of the voltage from a variable power source in such a manner as to maintain a correct voltage value across the primary of the high voltage transformer since a change in the line voltage to the x-ray equipment would cause a variation in x-ray output. As a certain amount of line voltage variation is quite common, consistent uniformity of results can only be possible, where such variations are corrected by properly adjusting the compensator for the line voltage variations.

To adjust for voltages to the apparatus that are consistently low, or high, variable taps are brought out on the autotransformer at the end opposite to the compensator taps in such a manner as to provide adequate control over a range of voltage between 100 and 135 volts (for the standard A.C. units). These taps are designated L, M, and H for low, medium, and high voltage ranges.

The voltmeter (Fig. 8) is of the type having only a center line showing on its dial face. On the right side of this line is written "voltage high", to the left is written "voltage low". By moving the compensator control (Fig. 4) from button 1 to 11, the voltmeter indicator may be made to move from the "voltage low" side of the line to the "voltage high" side, if the equipment is supplied by proper voltage. However, it is desirable after choosing the proper line tap (L, M, or H) to set the voltmeter directly on the line by means of the voltage compensator control (Fig. 4). Then upon energizing the unit at 15 ma. button H-5, it may be noted that the voltmeter reads low. By shutting off the unit and moving the voltage compensator up 1 button the voltmeter may this time on re-energizing, read directly on the line or very close to it. This therefore, indicates that Chart #1 enclosed is the chart to which all future reference is to be made when the unit is operated on this particular line. If it is necessary to go to the second or third or perhaps even the fourth compensator button (Fig. 4) before the voltmeter will read on the line, it means that the line you are operating on is not as good as the one that would allow you to operate at one or perhaps at two points from the no-load setting. This means, therefore, that for each increase in compensator button from 1 to 4, a chart is supplied that is calibrated for such line regulation (Charts 1 to 4).

The operative technic chart accompanying these directions is based on the proper no load-voltage readings of the compensator voltmeter on an average line. This means, therefore that for your particular installation there has been radiographically calibrated this technic chart, the use of which will give you average radiographs on a male patient weighing 150 pounds or a female patient of 120 pounds. The chart supplied can only represent average radiography, however, and it will be the operator's problem to fill in this chart with a technic value that his experience with the unit will tell him approaches perfection. These technic values can be altered at will, as proficiency in operating the unit develops.

If reference is made to Calibration Chart #1, at which we can assume your unit is to operate, you may note that for a milliamperage setting of 2 and a kilovoltage of 45.4 the autotransformer control should be set on L-1. This is, as you can see from the chart, the lowest kv.p. (kilovolts-peak) that can be expected from the unit at a 2 ma. (milliamperes) setting. Other values have been worked out for 5, 10, 15, 20, and 25 ma. These values illustrate that the penetration or autotransformer setting (kv.p.) varies as the milliamperage is changed. The lower the milliamperage for a given autotransformer setting, the higher the penetration will be and the higher the ma. for a given autotransformer setting, the lower the penetration will be. From this chart it is readily seen that if a radiograph of proper density is obtained with 15 milli-

amperes at 60.7 kv.p. on button L-15 and you desire to increase the visibility of detail by bringing the ma. to 25, but still retain the same density on the film, then you would use button H-4. It will be noted that there is also an upper limit to which the autotransformer control should be set for different values of ma. For example, at 85.3 kv.p., 2 ma. is obtained on H-7 while for the same kv.p., 20 ma. is obtained on setting H-15. No values are given for 25 ma. above 81.5 kv.p.

If a certain density is to be established on the film when changing from one ma. to another on the chart, it is only necessary to follow across a horizontal line to obtain this density. For example, a film obtained at H-10 15 ma. can be duplicated in density at H-14 and 25 ma.

THE FACTOR OF MILLIAMPERAGE

The milliamperage through the tube is controlled by the temperature of the x-ray tube filament. In the head of the D3 is to be found in addition to the tube and high voltage transformer a filament transformer which transforms the primary supply voltage to a value suitable for heating the tube filament to incandescence. The voltage to the filament transformer is controlled by a rheostat or regulator (Fig. 6) which increases or decreases the voltage impressed on the filament of the tube, thereby increasing or decreasing the amount of current flowing in this filament thus regulating its temperature for the particular milliamperage desired.

The filament control (Fig. 6) is therefore the control which will be used to vary this milliamperage. A milliammeter (Fig. 1) connected in the grounded side of the high voltage secondary circuit will indicate the current. The meter reads up to 30 ma. and the scale is divided into 30 increments of one milliamperage each. The filament control (Fig. 6) has an arbitrary 10 point scale which should only be set for approximate values of tube current. This setting is arbitrary because it will vary with adjustment of the voltage compensator (Fig. 4) and the autotransformer control (Fig. 3). As you decrease the setting of the voltage compensator (Fig. 4) (that is, turn it to the left) the filament regulator (Fig. 6) will have to be increased (turned to the right) or if the autotransformer control (Fig. 3) is increased (turned to the right) the filament regulator (Fig. 6) will have to be decreased (turned to the left) for given milliamperage settings.

The above fact takes on added importance in short exposure technic and for this reason as well as for the protection of the tube, a Filament Ammeter (Fig. 7) is incorporated in the filament circuit which will preread the filament current and by setting this meter to established filament current readings, the correct temperature can be set before applying voltage to the tube. This feature eliminates testing for tube currents and saves on tube life. It also greatly facilitates the use of

short exposure technic with the assurance of duplication of results when the same technics are used.

For presetting the Filament Ammeter (Fig. 7) a Filament Current Increment Chart (#6) has been calibrated. The G.E. representative has established at a setting of 80 kv.p., 10 ma. a reading on the filament ammeter of, we shall say, 2.05 amperes. With this as a reference point or base line and a value of 56 kv.p., 15 ma. (as an example) chosen from the technic chart as established values for an A-P pelvis, you will note from increment Chart #6, that a value of 0.07 amperes should be added to the base value of 2.05 to compensate for the increase in technic. Therefore, it will be necessary to set the filament ammeter (Fig. 7) to a value of 2.05 plus 0.07 or 2.12 in order to obtain 15 ma. at 56 kv.p. as called for in the technic chart. Note: The reference filament current should be checked after every 50 exposures.

As previously mentioned, the primary purpose of the filament increment curve is to obviate the necessity of testing prior to each exposure. With the necessity for testing obviated, it can be seen at once that a great saving in tube life should result.

However, it is not necessary to use the filament increment curve for all values. Its use is ordinarily confined to any combination of milliamperage and kv.p. where the rating chart of the tube is three seconds, or less. In other words, if the tube rating chart indicates that it may be operated for 4 or 5 seconds, for example, when it is recommended that the proper milliammeter setting for this value be taken under load or during one test exposure. If, however, the technic demands a fast exposure of say 1 second, it is not advisable to test for this value because the milliammeter will not come to rest after so short an exposure; therefore, the filament increment values should be utilized.

THE FACTOR OF DISTANCE

Distance as referred to in radiography means that distance between the focal spot of the tube and the film. On the sides and front of the tube head has been painted white dots; the focal-film distance is measured from any of these points. It is to be remembered that when varying the distance factor, to maintain the density of the film it will be necessary to increase the time of exposure or the penetration accordingly. The law to follow is: the time of exposure will vary inversely as the square of the distance.

TIME OF EXPOSURE FACTOR

The time factor refers to the time of exposure and for radiography is measured in seconds or fractions thereof.

The time of exposure is controlled through the use of the hand timer. Illustration 11.

The range obtainable varies from 1/8 sec-

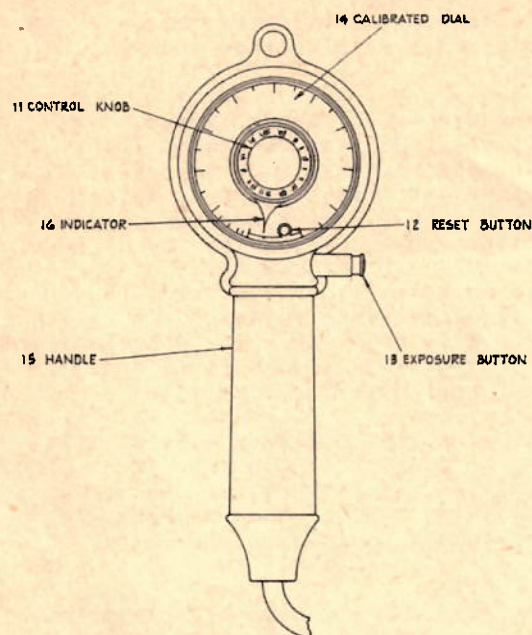


ILLUSTRATION II

ond up to and including 10 seconds. When the technical procedure calls for exposure values in excess of 10 seconds, the time switch is reset to obtain the desired exposure time value.

The time switch employed with the D3 is referred to as a "hand timer". The first indicating line on the dial is $1/8$ of a second. The second indicating line is $1/4$ of a second, and the third is $1/2$ of a second. The fourth indicating line is $3/4$ second and from that point on the dial is calibrated in $1/2$ second values.

As in all radiographic work the more rapid the exposure, the less the latitude, in so far as slight errors in exposure time are concerned. So, if the pointer of the time switch were not set exactly on the 5-second mark, no appreciable difference in radiographic results would be visible. On the other hand, for fractional second work (particularly $1/8$ and $1/4$ second exposures), it is essential that the pointer on the timer be set in exactly the same place for every exposure, if consistent results are to be obtained. It may be found that the most simple means for setting the timer, particularly for the $1/8$ and $1/4$ second exposures, is to utilize the "clicks" which will be heard as the control knob (Fig. 11) is set. For example, one "click" will approximate $1/8$ of a second, and three "clicks" $1/4$ of a second. Some variation in time of exposure may be evident when this method is used, although in the majority of instances the effect upon the radiograph is comparatively small.

If in setting the timer, the indicator (Fig. 16) is turned past the desired position, do not attempt to bring it back by turning the

control knob (Fig. 11) counterclockwise. Instead use the reset button (Fig. 12) which will release the timing mechanism and allow the timer indicator to travel back toward the correct setting without energizing the tube. After a little experience, the operator will find that the desired time setting can be readily obtained through the proper use of this reset button.

The exposure button (Fig. 13) is a "quick make" device, the use of which accurately duplicates timing values. After the indicator has been set, this button can be pushed and the tube will be energized. The contacts that it actuates are made with uniform speed whether the button is pressed slowly or fast, thereby eliminating the difficulty of the operator's failing to press the button all the way in. When this button is actuated it snaps the contacts together and definite pressure is maintained assuring a proper path by which the current will be carried. As the contacts close, a resistance is momentarily connected the primary circuit to the high voltage transformer. This resistance prevents excessive surge voltages in the transformer. As the contacts follow through, this resistance is short-circuited and normal line voltage is applied to the unit.

THE END RESULT

In this instance, the finished radiograph is referred to as the end result. A radiograph may be generally defined as a record of various types of tissue wherein a difference in relative opacity to the x-ray exists. Obviously, if the body did not present such differences in opacity, radiography and fluoroscopy would be impossible.

The radiograph may be said to be made up of four so-called film factors which the operator may control more or less through the manipulation of the aforementioned four prime factors.

The four film factors are referred to as:

1. Detail or definition
2. Contrast
3. Radiographic density
4. Magnification and distortion

The highest quality result can be produced only when the operator thoroughly understands the differentiation between the four film factors and the control of each individually. There is no definite, clean-cut standard as applied to all of the film factors, because varying opinions among leading radiologists virtually preclude the possibility of definitely standardizing radiographic quality. However, the general rule as applied to the above-mentioned film factors, is as follows:

A radiograph of the highest quality has the very maximum in differentiation of tissue. In order that maximum differentiation of tissue be obtained, regardless of the subject or part, the first requi-

site is maximum sharpness of detail or definition. The second is proper contrast and desired radiographic density, depending largely upon individual preference. The third is minimum magnification and distortion.

DETAIL AND DEFINITION

Detail, or definition, refers to the sharpness of various contour lines and the clean-cut, clearly defined lines of cancellous structure of the bones. The sharper and more distinct such contour lines, the better the detail or definition.

The five factors which have most to do in the production of detail sharpness or definition are:

1. The size of the tube focal spot
2. The focal-film distance
3. The distance of the object from the film
4. Motion of the part during the exposure
5. Intensifying screens

The smaller or sharper the tube focal spot, the finer or sharper the resultant detail in the film. The Model D3 introduces an exceptionally fine focal spot which is consistent with the values of voltage and current which it must withstand.

The greater the focal-film distance or the shorter the object-film distance, the sharper the resultant detail in the radiograph. The effect of focal-film distance, as well as object-film distance, upon detail sharpness is minimized as the size of the tube focal spot is decreased.

The small size of the tube focal spot in the Model D3 permits the use of closer film distances without sacrificing detail sharpness in the least.

If the part under examination moves during the exposure, a loss in detail will result. Much of the danger of motion may be overcome by properly immobilizing the part with immobilizing band, sandbags, or a compression cone. For those parts of the body wherein immobilization is difficult, the time of exposure must be reduced sufficiently to preclude the possibility of motion, if maximum sharpness is to result.

The use of intensifying screens detracts somewhat from detail sharpness. That is, sharper detail results when radiographs are taken without intensifying screens. However, the slight loss in detail sharpness caused by intensifying screens is more than compensated for by the very much shorter exposure-time values and finer-focus tubes permitted by their use.

On the other hand, certain parts of the body, such as the thinner extremities, ordin-

arily do not require the use of intensifying screens because of the relatively low energy required; hence, screens are usually dispensed with when doing such work.

Maximum differentiation of tissue is possible only when the utmost sharpness of detail is present.

CONTRAST AND RADIOGRAPHIC DENSITY

These two factors will be considered together, as their purpose is the same. Both contrast and radiographic density make detail or definition more visible. Of the two, contrast probably plays a more important part than radiographic density; each, however, is indispensable to the other.

Both contrast and density are essential to maximum visibility of detail. Obviously, with neither contrast nor density present in the film, nothing would be visible.

Virtually all factors governing sharpness of detail or definition can be considered mechanical, with the exception of motion. Therefore, the factor of detail or definition may be considered a somewhat set factor. The film factors of contrast and density, however, should be considered variable factors, not only because both must be varied over a considerable range, depending upon the part and subject being rayed, but also because of the wide variation in opinion among diagnosticians as to what constitutes the proper combination of contrast and radiographic density for the various parts of the body.

Contrast is defined as representing the difference between the extreme blacks and whites on the radiograph. As contrast is decreased, the percentage of difference between these various densities on the film is reduced, and vice versa.

In contra-distinction to contrast, is radiographic density which refers to general appearance of the film. As radiographic density is decreased, the various shades of gray on the film - from light into near black or black - are made darker in the same proportion, unless the radiograph is that of a definitely opaque area, such as the barium-filled stomach. For example, if 20 per cent additional radiographic density is added, all of the various shades of gray on the film become darker by 20 per cent. As radiographic density is decreased, the result is reversed - the exception, of course, being areas which are actually opaque.

As previously mentioned, every radiograph should show, without exception, the maximum in sharpness of detail or definition. On the other hand, maximum differentiation of tissue means neither maximum contrast nor maximum density, but rather a proper balance of contrast and density in order to obtain maximum visibility of detail.

A radiograph can be so made that it rep-

resents only a study in black and white. Suppose that a radiograph of the skull were taken under conditions which should produce the very sharpest detail, but with a technical procedure which produces the proper radiographic density only in the much less opaque region of the sinuses, and leaves the skull itself perfectly white. Such a radiograph may be said to possess maximum contrast, but because of insufficient radiographic density, it would be of little value from a diagnostic standpoint. A radiograph of such quality precludes the possibility of visualizing the sharpness of detail throughout the bony structure of the head.

By the same token, a technical procedure may be used on the same part as would result in so much radiographic density that the entire film would be one color: black. In this case, maximum visibility of detail is not possible, because too much radiographic density obscures contrast.

The greatest single detriment to contrast in the radiograph is secondary fog, produced by secondary or stray radiation emanating from the patient's body. If radiographic contrast is to be controlled, the mechanical and technical factors which affect secondary fog must be recognized. Opinions differ somewhat as to the relative importance of the various factors which have to do with the control of secondary fog, but only in respect to their relative importance - not whether a particular factor does or does not affect secondary fog.

The so-called mechanical means in general use for the control of secondary fog are:

1. The Potter-Bucky diaphragm
2. The use of cones cylinders, or some other means for limiting the area of x-ray exposure to the body - that is, port of entry.

Both the Potter-Bucky Diaphragm, with its moving grid, and the "all metal" grid which is stationary, have the same function in respect to secondary fog. In each instance, the device is placed between the patient and the film, and due to the principle of construction absorbs a high percentage of the secondary radiation, which emanates from the patient, before it reaches the film. The amount of secondary fog thus removed depends upon the design of the Bucky grid and, more important, the voltage or penetration used.

Secondary fog to the film is directly proportional to the amount of primary radiation which enters the body or the part being rayed. Therefore, any means which limits the port of entry will reduce proportionately the quantity of secondary radiation which could affect the film. Of the various methods used for this purpose, the one most generally adopted is the use of cones or cylinders attached to the tube stand. In some instances, a piece of lead with an aperture is used instead of a cone. In other instances, pieces of lead rubber, with various sizes of apertures, are placed directly over the area to be rayed.

Cones and diaphragms are obtainable in many sizes and, regardless of the size of the cone used, additional contrast is obtained. It is advisable to use a cone for any radiograph in which additional contrast is desired. The very best combination for obtaining contrast, particularly in radiography of the heavier parts of the body, is the use of both the Potter-Bucky diaphragm and cones.

The types of cones furnished with the D3 are: an extension cone and a type "K" cone. The first has a diameter of 4 inches. Its height when contracted is 7½", and when extended is 13 inches. It is used for sinus work. A larger compression cone (Type K) is furnished for general radiography. It has a 4½-inch port and is 6 inches high.

The more opaque the part being radiographed, the greater the total amount of secondary fog emanating from the patient. The reason for this is the greatly increased energy, either in the form of penetration or milliamperes-seconds. Therefore, the more opaque the part being rayed, the more necessary it becomes to use every available means for reduction of secondary fog.

Many operators are under the impression that inability to obtain the same contrast in the heavier parts of the body as in the thinner parts, or with the same part of the body on individuals of different opacities, is because of the difference in secondary radiation produced. This is partially true, but the main reason for less radiographic differentiation between tissues of a heavier individual, is that there is less difference in opacity between the thickest and thinnest tissues of the part being rayed. Tissues of the heavier patient obviously have a greater filtering effect, which is opposed to maximum differentiation in the resulting radiograph.

Take for example, the spine, which in itself is no more opaque in 125-pound subjects than in 200-pound subjects. Yet the intervening tissues are considerably more opaque on the heavier subjects. On the contrary, kidney radiography, in so far as visibility of kidney outline is concerned, is more successful on fat or heavy patients, because the tissues immediately surrounding the kidney are relatively less opaque.

The use of intensifying screens may have a marked effect upon contrast because of the very important role of penetration in the production of contrast. The lower the penetration, the greater the contrast - the higher the penetration the less the contrast. Because intensifying screens permit the use of greatly decreased penetration values over those necessary for radiographs taken without screens, the reason for the influence of intensifying screens upon contrast is apparent.

The part which penetration plays in the production of contrast should be considered from two angles - first, its effect in producing secondary radiation emanating from the

patient's body, which in turn affects the film. It must be remembered that, if two radiographs of the same part are taken, each having the same radiographic density but produced with different penetration values, the one with the lower penetration will show more contrast. If the radiographic density of these two films is the same, the actual amount of scattered or secondary radiation set up within the tissues is approximately the same, but the character of such stray or secondary radiation is such that, at the higher penetration values, a far greater proportion emanates from the patient's body. Consequently, only the secondary radiation emanating from the patient's body can affect the film. That which is set up and absorbed within the tissues need not be considered.

Therefore, secondary fog on the film is increased as the penetration is increased; decreased as the penetration is reduced. If it were possible to eliminate all secondary fog from the film, penetration would still have a material effect upon contrast.

With increased penetration, the x-ray absorption for different densities tends to equalize. That is to say, were it feasible to use a voltage sufficiently high, absorption would become constant for all densities. As the penetration is decreased, the relative absorption between various opacities will increase; hence, if maximum contrast is desired, it is obtainable only through the use of a relatively low penetration.

For further illustration, we may compare the body composed of tissues varying in opacity or ability to absorb x-rays - with the penetrometer. The penetrometer is a so-called aluminum ladder, made up of different thicknesses of aluminum. Let us assume for example, that this particular ladder is made up to ten steps; the first step 3 mm. thick and each succeeding step increasing 3 mm. in thickness, with the tenth, or last step, 30 mm. thick.

If this aluminum ladder were radiographed with a sufficiently low penetration value, it would be possible to virtually blacken out the lower or thinner steps, while the thicker and more dense steps would be apparently opaque. On the other hand, if the voltage were increased and the total number of milliampereseconds were reduced to the point that the density in the thinnest step of the ladder is the same as for the low-voltage radiograph, the result could be a complete visualization of all the steps of the ladder, including the most opaque.

The percentage of difference in density between each step of the ladder would be materially less with the high penetration result than for the low penetration result. This effect would be approximately the same, even though it were possible to remove all secondary fog from the film.

Accordingly, penetration within itself, and entirely aside from its effect upon sec-

ondary radiation, may alter the contrast in the radiograph.

The product of milliamperage and exposure time is referred to as milliampereseconds. Milliampereseconds has no effect upon radiographic contrast except in those areas of the body wherein a portion of the radiograph is actually opaque. In other words, a change in milliampereseconds alone does not affect the difference between the various opacities in a given area.

On the contrary, penetration, in addition to its material effect upon contrast, likewise affects radiographic density. When the factor of penetration is utilized to change radiographic density, the resultant contrast on the film decreases with each increase in penetration, and vice versa. When milliampereseconds are used to change radiographic density, the actual contrast in the film does not change unless secondary fog to the film is changed. Consequently, with a given penetration and with the same subject, secondary fog to the film is directly proportional to the milliampereseconds employed. The greater the number of milliampereseconds, the greater the quantity of secondary fog to the film, and vice versa.

On the other hand, the factor of penetration should be used whenever possible to change radiographic density, in preference to the milliamperage factor, which is undesirable primarily because of its effect upon the x-ray tube, and also because of the change in penetration as the milliamperage is varied. The time of exposure factor should not be considered the variable of choice, because of the possibility of motion.

When it is not practical to vary penetration, the second choice is time of exposure. As already mentioned, if only milliampereseconds can be changed, the operator has little or no control over the factor of contrast, except through the use of mechanical appliances; that is, the Bucky diaphragm and cones.

Maximum differentiation of tissue is utterly impossible unless the factor of penetration can be varied. There are, of course, other factors which may have a material effect upon both contrast density, but such factors are well within the control of the operator if a sufficient amount of care is exercised. The age, temperature, and condition of the developing solution; length of developing time, etc., have a material effect upon both contrast and density. Additional information about the above mentioned factors may be found elsewhere in this booklet.

MAGNIFICATION AND DISTORTION

The other factors to consider in the analysis of the basic principles underlying the production of maximum differentiation of tissue, are magnification and distortion. Many operators erroneously consider these factors to be synonymous, but the distinction is

easily understood when they are considered separately.

The factor of magnification plays a relatively small part in the diagnostic value of a radiograph, unless it reaches such a proportion that certain objects are entirely obscured by the increased size of other parts of the body farther away from the film.

The closer the object is to the film, the less is the magnification, and vice versa. Likewise, the greater the focal-film distance, the less the magnification, and vice versa.

Naturally, focal-film distance and object-film distance must be used reciprocally. The closer the object to the film, the less the focal-film distance may be; and the greater the distance between the object and film, the greater the focal-film distance should be.

It is not practical to eliminate magnification entirely, although the careful operator may reduce it to the minimum.

As previously mentioned, the object-film distance, as well as the focal-film distance affects not only magnification but detail sharpness as well. The use of sharper-focus tubes minimizes the effect of magnification in its relation to the diagnostic value of the film.

The factor of distortion may, of course, be classified with magnification, although it is not the same. In the first place, it is possible to have magnification with little or no distortion. On the other hand, it is very difficult to have distortion without magnification.

In this instance, distortion is referred to as actually distorting or changing the true shape of the part under examination. Distortion is caused by the improper relation of the tube to the object. The operator should be sufficiently familiar with anatomical structure so as to avoid true distortion whenever possible.

If the object itself is actually round, certainly little if any advantage is gained by so centering the tube that such object on the film appears to be elliptical. This, in a sense, is what is meant by true distortion.

DARKROOM

In the making of an exposure, the film passes through seven processes in the darkroom, as follows: (1) loading, (2) unloading, (3) developing, (4) rinsing, (5) fixing, (6) washing, and (7) drying.

Care must be exercised in handling the films in order to avoid abrasions, static marks, and desensitized areas. Abrasions are fine, black hair-lines ordinarily caused by friction on the emulsion. They are produced by rubbing on the emulsion surface. Static

marks are fine, black branch-like lines appearing on the clear portion of the film, caused by the exposure of the emulsion to some form of static discharge. They may be produced during a part of the manufacturing process, or at any later handling of the film before developing. Transparent spots on the film may be caused by: kinking the film during the loading or unloading process, which results in desensitized areas; by spots on the intensifying screens; foreign matter of any kind of the film; air bubbles in development; bubbles in the emulsion itself; storing films in a wet place; or by careless handling of the film while wet.

THE DEVELOPING SOLUTION

The developing solution oxidizes the silver bromide that has been affected by exposure. In other words, it changes the latent image of an exposed film to a visible image.

There are several different chemicals in the x-ray developing solution, the names of which may be obtained from the manufacturer. However, it is advisable to use the standard package developer, as prepared for the type of films used, which insures proper quantity and quality of the chemicals. Any variation of the quantity or quality of the chemicals may upset the balance, thereby bringing about a proportional change in the end result. The developing solution should be mixed according to the directions on the package.

The life of a developing solution depends upon the amount of film surface developed, temperature at which the solution is kept, amount of exposure to the air, freedom from contamination, etc. Ordinarily the developer may be used until it becomes necessary to change the operating procedure to make up for the loss of density caused by the weakened developer. Maximum radiographic quality can be obtained only with a clean, fresh developing solution.

An under-exposed film cannot be corrected by prolonged development. Prolonged development will only give a chemical fog and will obliterate part of the radiographic detail already obtained. An over-energized film may be partly corrected by shortening the time of development. However, the best results can be obtained only through utilization of the proper electrical energy that permits the film to receive the correct developing time, depending upon temperature.

Immediately following the developing process, the film should be carefully rinsed in running water, by rapidly raising and lowering the film for about five seconds. This process should be short, because the developing process continues during the rinsing time or until stopped by the fixing solution. However, improper rinsing may produce stained films, and it is a much more common practice to rinse insufficiently than too much.

THE FIXING SOLUTION

The hypo, or fixing solution, dissolves out the unexposed and undeveloped silver bromide, leaving a permanent silver oxide image. The fixing solution, as in the case of the developing solution, should be obtained in package form for the most consistent results. As in the case of the developer, full directions are given for mixing.

When fixation is completed, the film should be washed from 15 to 30 minutes in running water. The temperature should be as near that of the other solutions as is practicable. If possible, the wash water should cover the hanger as well as the film.

Following the washing process, the film should be hung up to dry in a warm place - preferably where the air is circulating. The temperature of the air may be from 35 degrees to 90 degrees. Clean, dry air, at a temperature of about 80 degrees Fahrenheit, is quite satisfactory. The time of drying will depend entirely upon atmospheric conditions - especially circulation, humidity, and temperature.

TECHNIC CHART

The technic chart accompanying this manual has been developed for average radiography utilizing calibration chart #3. If, however, the line regulation is such that either chart 1, 2, or 4 is to be used, then it will be necessary to maintain only milliamperes seconds at the same kilovoltage in order to obtain the correct density in the film. For example, to radiograph an A-P ankle the technic chart specifies 62 kv.p., 15 ma. at 5 seconds as the values necessary for average radiography. If you find that the unit tests for a line condition which necessitates the use of chart 4, then it will be necessary to increase the kilovolt selector from H 2 (chart 3) to H3 (chart 4), but still maintain the same ma. seconds (15 x 5) to obtain the correct density. Should you find that chart 1 can be used, then it will be possible to increase the milliamperes and decrease the time; in other words, if it is desired to maintain 75 ma. sec., which is (15 x 5) ma. seconds, then 25 ma. on button H 5 for 3 seconds (equals 75 ma. sec.) will produce the same density as the technics given above.

It must be remembered that when line regulation permits changing to other calibration charts than that for which the technic chart was worked out (chart 3), the kilovolt selector will of necessity have to be changed in order to obtain the same penetration.

Any variation in size of the person to be radiographed suggests that alterations should be made on technic chart values. The technics as given can be used as a starting point to find what values are necessary to obtain a finished result. Experience will be the best teacher in becoming proficient in using this chart.

Description of the Technic Chart:

The chart selected is divided into several groups, in order to facilitate finding the technic for any part of the body.

The first column is designated as "Region". The abbreviation "P.A." means posterior-anterior or from back to front. If a "P.A." view of the hand is desired it will mean that the hand will be placed on the cassette with the palm toward the film and the tube focal spot directed at the back of the hand.

The abbreviation "lat." designates a lateral view. For example, a lateral view of the ankle would be taken with one side of the ankle toward the film. The lateral view could be taken with either the inside, or the outside of the ankle toward the film. However, it is common practice, when such a view is to be taken, to place the patient in the most comfortable position - which is with the outside of the ankle or part toward the film, and the inside toward the tube.

For many other parts of the body it makes little difference which side of the part is nearest the film in the lateral view provided the diagnostician is familiar with the position used. It is common practice to standardize positioning and not deviate in routine work.

The abbreviation "A.P." refers to the anterior-posterior view. In this instance the posterior part is placed toward the film and the anterior part nearest the tube.

The abbreviation "Semi-Lat." refers to a semi-lateral or oblique position. In this instance the part is turned approximately halfway between lateral and either "A.P." or "P.A."

The abbreviation "A.D." refers to above-the-diaphragm. The only part of the body where reference to this position is made is the ribs.

The heading of the third column is "kilovolt selector". The terms "Low" and "High" may be placed in this column and will have reference to the setting of the selector switch (Fig. 2, Illustration 1) in either the "low" or the "high" position in order to obtain the correct voltage values as present on Chart 1.

The fourth column represents the kv.p. obtained from a certain autotransformer setting. It is to be noted that this column has been filled in with figures which may be taken as so-called "ideal" settings, for they are based on average sized individuals. For varying the penetration (kv.p.) for individuals other than average size see Tables A and B.

The blank column is provided to enable the operator to record such changes in penetration as are deemed necessary, either because

of individual preference, as regards radiographic density, or because of a variation in either speed of films or intensifying screens.

The kv.p. settings as given on the chart must be considered as approximate. Each value in penetration, as given, should be used as a guide, and the blank space provided should be filled in by the operator to suit individual preferences.

It is suggested that a radiograph be taken using the penetration values as given on the chart. The result will indicate whether the value, as given, must be increased or decreased. If exposures are made (both with and without intensifying screens) and proper compensation made on the test films, the necessary penetration change should be made correspondingly for all other parts of the body. Some variation will be present, but it will be found that the desired result can be obtained much more quickly from such a chart than if all factors were left a matter of individual choice.

For example, if a radiograph in the extremity group (such as a wrist) is taken according to the non-screen procedure outlined in the technic chart, it may be found that two autotransformer buttons higher are required to produce the desired density. In view of the above change, it will be found that all other parts of the body, wherein the non-screen technic is recommended, will probably require two additional autotransformer buttons.

When the desired value has been found, the blank space should then be filled in by the operator.

The fifth column is "Milliamperage". The milliamperage should be set according to the instructions given previously in this manual and should be maintained during the length of exposure. Line conditions may sometimes necessitate changing the filament regulator setting, even during a 5-second exposure, if the proper milliamperage is to be maintained; however, this should not happen if the proper power is supplied the unit. Because of the effect of milliamperage variation upon penetration and the combined effect upon density, the milliamperage values must not be permitted to vary if consistent results are to be obtained.

Radiographic density varies directly as both milliamperage and time of exposure (sixth column). Multiplying the milliamperage by the time of exposure equals milliampere-seconds. Therefore, the common rule is that radiographic density varies directly as milliampere-seconds.

That is, if 20 per cent additional milliamperage or time of exposure is given, all other factors remaining the same, the radiographic density will be increased 20 per cent.

For exposure values of one second or

longer, slight inaccuracies in the setting of the time switch may not noticeably reflect in the film. Obviously, the shorter the exposure value, the greater the necessary accuracy in setting the timer if consistent densities are to be obtained.

The seventh column is "Distance". As previously stated, this refers to the distance from the focal spot of the tube to the film. Because radiographic density varies as the square of the distance, this factor must be carefully set. A difference of even 3 inches in 25 will cause a variation of 25 per cent in radiographic density.

The eighth column is for "Filament Amperes", which is to be established on installation.

The ninth column indicates if the Bucky diaphragm is used. If Bucky work is contemplated, it will be necessary to add 15 kv.p. to the values given or to increase the time by 4. Care should be exercised to see that the rating of the tube is not exceeded in making increases of this sort.

The tenth column designates whether or not intensifying screens are recommended.

For all parts of the body wherein intensifying screens are utilized, Patterson Hi-Speed Screens and General Electric Rayspeed Cassettes are recommended. Any deviation from this will necessitate a change in the chart - either as regards autotransformer setting or time of exposure.

To change the radiographic density for any area, the best results will be obtained if only one factor at a time is changed. The two factors which may be considered variable are penetration and exposure time. Of the two, penetration is preferable.

Immobilization of the part should always be provided when possible, sandbags for such parts as extremities; immobilizing bands for the skull, pelvis, spine, etc.; compression cones or extension cylinders for sinuses.

For children from five to twelve years of age, either a reduction in penetration of approximately 10 kv.p. should be made, or the exposure time as given on the chart for the average adult should be reduced 50 per cent.

If it is desired to select a procedure which differs from that given on the chart, any number of combinations are practical. If the exposure value given on the chart is reduced to one-half, 10 kv.p. must be added to maintain radiographic density. To double any exposure value given on the chart, deduct five autotransformer buttons. For example, the P.A. chest procedure given in the Technic Chart is as follows:

Autotransformer button H-4, or 66 kv.p.
15 milliamperes

48 inch distance
1/4 second exposure time

If it is desired or necessary to use twice the time at the distance given, the kv.p. value would be 56, instead of 66.

The only consideration in making such variation is not to exceed the penetration limit in kv.p. for each milliamperage value. If the necessary increase in penetration is such as to exceed the limit, then either the time of exposure must be increased, or the distance decreased.

However, the time values as given are well within most of the limitations established by common practice, and the charts have been prepared only after careful consideration of the various exposure-time values in general use.

Other necessary information concerning the use of the technic chart will be found on the chart itself and should be carefully studied.

It is only through careful observation and attention to details that the greatest value can be obtained from even the highest-powered x-ray equipment. The design of the Model D3 is such that the time values for the great majority of areas are either the same or very little longer than those recommended for the most powerful equipment. With its extremely small focus tube, it is capable of producing a sharpness of detail or definition not possible in any other equipment, regardless of size. Therefore, careful consideration of the factors as given for the various parts of the body specified will produce results of amazing diagnostic quality.

RADIOGRAPHY OF SUBJECTS OVER OR UNDER AVERAGE SIZE

The radiographic technic, as given in the chart, is based upon male and female subjects of average size. As there is variation of opinion as to what constitutes a so-called "average" sized adult, an explanation may be of assistance.

The average man is approximately five feet nine inches tall, and weighs approximately 150 pounds. The average woman for the same approximate thickness will be considered five feet two inches in height, and weighs 115 to 120 pounds. It is upon these averages that the technic is based. The term "average weight" refers also to the individual whose weight is more or less evenly distributed over the entire body. This is something the operator must always take into consideration if more uniform results are to be obtained.

There are other factors besides thickness of part which affect the end result, such as the patient's age - whether the patient is more or less soft, or hard and muscular - etc.

Some individuals, because of such conditions, are easier to radiograph than others, so there is no definite rule that can be followed with absolute accuracy. However, as the operator increases his or her experience, errors in judgement - due to the patient factor, will be reduced to the minimum.

A variation in thickness of extremities should not cause a great deal of difficulty, as such work is easier to compensate for than work with heavier parts, because so many comparative regions are listed in the technic chart. If the object being radiographed is an ankle swollen to the size of the average knee, then the knee technic should be used; or, if the individual is of such size that the normal ankle is the size of the average knee, the same holds true. The operator with limited experience should spend considerable time in studying the thickness of the part which is being radiographed; with added experience, the errors due to poor judgment of the thickness of the subject will, of course, be reduced.

Variation in thickness and size of the trunk - that is, pelvis, kidney, lumbar spine, etc. - is much more difficult to judge, even for the experienced operator. It is due probably to this reason more than any other that, wherever a lack of uniformity exists in the routine results produced in the laboratory, it is usually with the heavier parts of the body. When the subject to be radiographed is unusually large, there is a tendency on the part of the operator to use too much penetration; that is, the idea seems to prevail that the best results will be obtained if the penetration is materially increased, and if the operator's judgment is poor, that the film can be saved in the darkroom by removing it from the developer before fully developed. Such procedure is almost fatal in so far as contrast is concerned; yet this is common practice.

In most instances it is more difficult to radiograph thick parts than thin ones, and in all probability this will always be the case; but, at the same time, every effort should be made to produce the finest possible result regardless of the thickness of the patient. A film which is too light in radiographic density, but which has received full development - or a film which is too dark in radiographic density and has also received full development - at once tells the operator that the energy used has either been insufficient or too much. In either case it is a relatively simple matter to go back and either increase or decrease the energy for the next radiograph. The experience gained from such a procedure will be far more valuable when the next heavy patient is to be radiographed than the experience gained from considerably too much energy and too little developing time.

As a guide for variation of technic, according to the thickness of the trunk and the body especially, the following tables may be of assistance. Table "A" includes all the regions of the trunk except the lateral lumbar

spine. A separate table for this part is necessary because this region does not increase in thickness as rapidly as the weight of the patients might indicate. The operator must, necessarily, learn from experience to judge patients who do not come under so-called "average" classification, such as, for in-

stance, a female patient 5 feet 2 inches tall who weighs 200 pounds, or a male patient 6 feet 2 inches tall weighing 140 pounds. In any case it is, after all, a question of thickness, not of weight, which the operator must consider.

TABLE "A"

Variations from the average technic given on the technic chart, for all parts of the trunk of the body, except the lateral lumbar spine.

Male Weight-Height	Female Weight-Height	
100 lbs. 5'2"	75 lbs. 4'7"	Deduct 12 kv.p. from that shown on the chart, or multiply exposure time by 6/10. For best average routine results, a change in kilovoltage is preferred to a change in exposure time.
125 lbs. 5'5"	100 lbs. 4'10"	Deduct 6 kv.p. from that shown on the chart, or multiply the exposure time by 8/10.
150 lbs. 5'9"	120 lbs. 5'2"	See the technic chart.
175 lbs. 5'10"	145 lbs. 5'3"	Add 9 kv.p. to that shown on the chart or multiply exposure time by 1-3/10.
200 lbs. 6'0"	170 lbs. 5'5"	Add 18 kv.p. to that shown on the chart or multiply the exposure time by 2-1/2.
225 lbs. 6'0"	190 lbs. 5'8"	Add 24 kv.p. to that shown on the chart, or multiply exposure time by 3-1/3.
250 lbs. 6'1"	210 lbs. 5'9"	Add 30 kv.p. to that shown on the chart, or multiply exposure time by 5-1/2.

LUMBAR SPINE, LATERAL

In radiography of the lumbar spine in the lateral position, the operator may find it necessary to change exposure time as well as penetration, to compensate for a variation in the thickness. This holds true particularly if Hi-Speed screens are not available. When possible, however, the penetration should be used as a variable factor - not only to change

density upon the same subject, but to compensate for a variation in thickness of part.

Because of the relatively slight difference in opacity between the lumbar vertebrae and surrounding tissues, it is advisable to set the time factor as long as practical, in order that the lowest possible penetration be employed.

TABLE "B"

Variation from standard technic on the lateral lumbar spine, for patients above or below average weight and thickness.

Male	Female	
100 lbs.	75 lbs.	Multiply the exposure time shown on the chart by 3/5, or deduct 12 kv.p.
125 lbs.	100 lbs.	Multiply the exposure time shown on the chart by 4/5, or deduct 6 kv.p.
150 lbs.	120 lbs.	Use the technic as shown on the chart.
175 lbs.	145 lbs.	Multiply the exposure time shown on the chart by 5/4, or add 6 kv.p.
200 lbs.	170 lbs.	Multiply the exposure time shown on the chart by 6/4, or add 9 kv.p.

Male	Female	
225 lbs.	190 lbs.	Multiply the exposure time shown on the chart by $7/4$, or add 12 kv.p.
250 lbs.	210 lbs.	Multiply the exposure time shown on the chart by $8/4$, or add 18 kv.p.

The penetration limitation, with the Model D3 operating at various milliamperages, has been previously given. This penetration limit should not be exceeded, as damage to the tube may result. Before making any questionable exposure, consult chart #7. This precaution will prevent over-rating the tube.

INFANTS AND CHILDREN

It is realized that the following is rather scanty in its information, but the latitude which will be found - particularly in rapid exposure technics - is such that the recommendations made on the chart will serve as an excellent starting point. Naturally, variations will have to be made - depending upon the circumstances and the actual size of the subject. The following is the variation in penetration or time of exposure from the technic shown, and based upon an individual of average size.

INFANTS

Deduct 21 kv.p. from that shown on the chart, or use $1/4$ the exposure time. When immobilization is a factor, the shorter exposure time should always be employed.

CHILDREN

Deduct 10 kv.p. from that given in the chart, or use $1/2$ the exposure time. When immobilization is a factor, the shorter exposure time should always be used.

It will be found that exposures of $1/8$ of a second are more practical for this type of work in most cases.

HEAT DISSIPATION

The cooling curves shown on Chart #8 give the load limits of the D3 head. The

curves based on temperature and bellows compression are actually equivalent cooling curves plotted in terms of the maximum heat dissipated from the head during any one-half hour interval.

An exposure given in the rating charts may be made whenever the heat still in the head from previous exposures, together with the heat involved in the one to be made, does not exceed 450,000 units which is calculated as the product of kv.p. x ma. x seconds. This value is an arbitrary unit of heat that has been adopted for convenience in the discussion of this cooling chart.

The heat stored in the tube from an exposure of 80 kv.p., 25 ma., 5 seconds, would be 10,000 kv.p. ma. sec. and forty-five such exposures could be made without rest intervals other than a thirty-five second interval between exposures.

If a series of 50 exposures is desired at the above technic it will produce 500,000 heat units (kv.p. ma. sec.). This it is seen is too high; therefore a series of 45 are given, which gives 450,000 heat units, and before the next 5 exposures are made the tube must be allowed to cool until the heat produced by the first 45 is sufficiently low to allow the additional 50,000 to be added without exceeding a total of 450,000 units. The tube must therefore cool down to 400,000 heat units remaining before the 50,000 can be added. This requires a cooling interval of 18 minutes.

These rating charts indicate maximum energies that must not be exceeded. Operation at these ratings makes possible the best radiographic results that are consistent with reasonable tube life. A longer tube life can be obtained, however, by the use of lower energies - well within the values given on this chart.

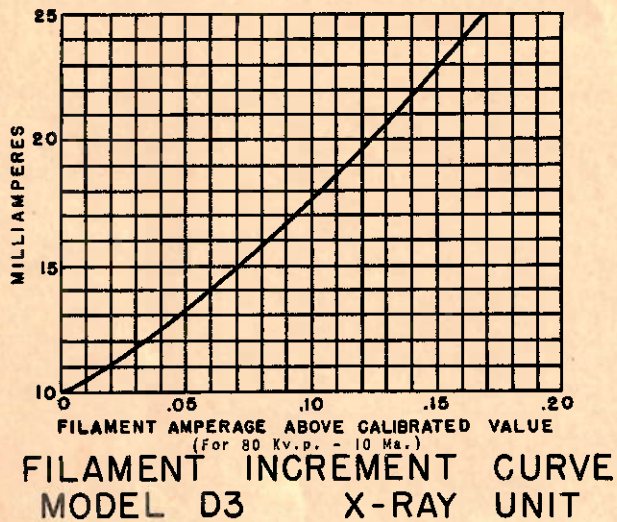


CHART NO. 6

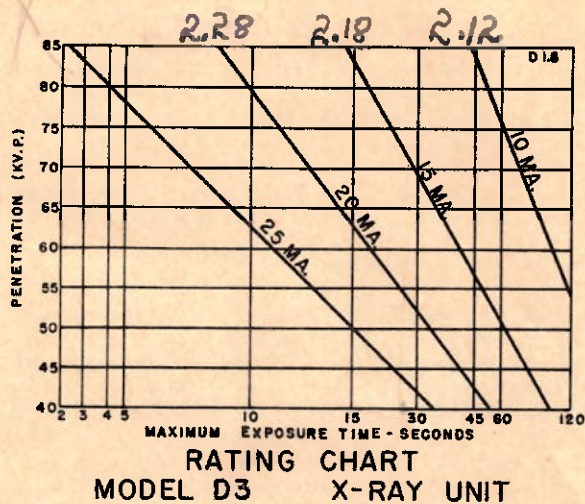


CHART NO. 7

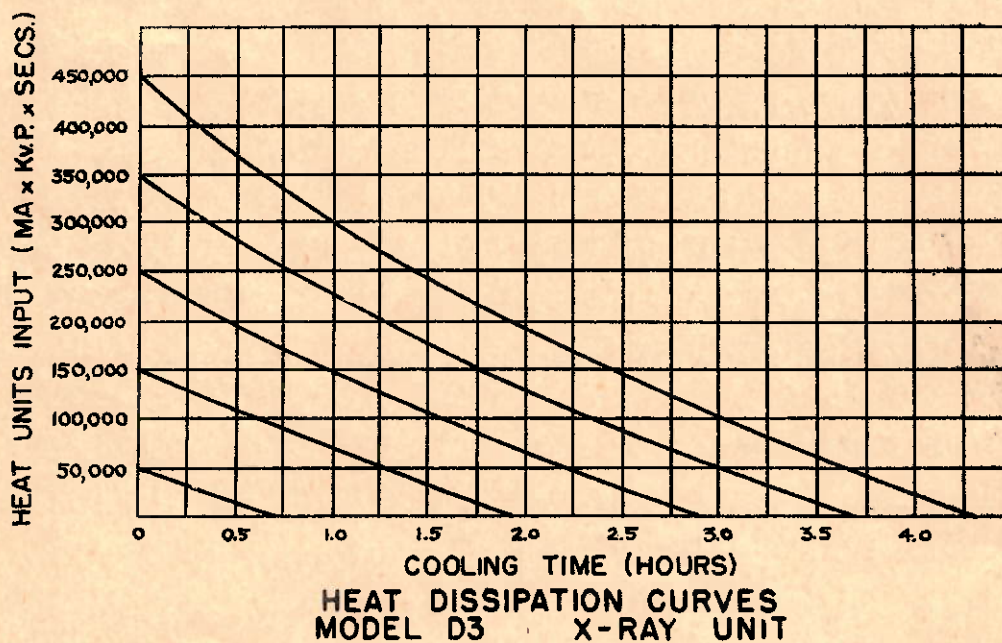


CHART NO. 8

PERTAINING TO EXPOSURE VALUES WITHIN SAFETY LIMITS

It is imperative that the user of this x-ray equipment should know how much x-ray exposure may be given to a particular area without exceeding safe limits.

The maximum permissible exposure values given in these tables are intended as a guide, and to be used until the user can replace them with data based on the actual measured output and his own estimate of the value of the threshold erythema. For assured safety these values shall not be exceeded until they are replaced by the users own values.

The tables of maximum permissible exposure values are based on: (1) The average output of a typical installation. (2) The average figure of 275 roentgens for a "threshold erythema." (3) A factor of 50 per cent to cover unpredictable variations in either of the first two factors.

The tables cover two conditions, namely, radiography and fluoroscopy. This is necessary because in fluoroscopy the fluoroscopic

shutter control introduces 1.5 millimeters of aluminum added filter which is not present in doing radiography.

The exposure limits as given in the tables are in milliamperere seconds. Thus, 150 milliamperere seconds would be given in 10 seconds at 15 milliamperes, or in 30 seconds with 5 milliamperes, or in 50 seconds at 3 milliamperes; the exposure in each case, expressed in milliamperere seconds being merely the product of milliamperes and time of exposure.

The tables given for radiography show two values of exposure limits, one for all parts of the body except the head, and a second value for the head which is approximately 25 per cent less than the first.

In referring to the tables the first column indicates the focal-skin distance as measured from the focal spot of the tube to the skin surface nearest the tube. The second column gives the number of milliamperere seconds that may be employed safely.

RADIOGRAPHY

In using the Model D-3 Shockproof X-Ray Unit for radiography in any of its combinations, the inherent filtration is less than when doing fluoroscopy with the shutter control in place. The difference in total filtration is 1.5 mm. aluminum less when the shutter control unit is not in place which results in a lower exposure limit as can be seen on comparing the tables.

MAXIMUM PERMISSIBLE: EXPOSURE VALUES IN
MILLIAMPERERE SECONDS FOR
RADIOGRAPHY

For All Parts of the Body
Excepting the Head

Focal-Skin Distance (Inches)	Milliam- pere Seconds	Focal-Skin Distance (Inches)	Milliam- pere Seconds
10	265	10	200

For the Head

Focal-Skin Distance (Inches)	Milliam- pere Seconds	Focal-Skin Distance (Inches)	Milliam- pere Seconds
12	380	12	290
14	520	14	390
16	680	16	510
18	870	18	650
20	1060	20	800
22	1280	22	960
24	1530	24	1150
26	1790	26	1350
28	2070	28	1570
30	2380	30	1800

NOTE: After any part has received the full exposure limit in milliamperere-seconds, a minimum of twenty-eight days should elapse before further exposure is given. The limit as given in the table may be repeated after twenty-eight days have elapsed.

FLUOROSCOPY

The following fluoroscopic precautions and procedures shall be observed.

The operator shall allow his eyes to become fully accommodated to the darkness before starting a fluoroscopic examination. This may be done by remaining in a dark room or wearing fluoroscopic goggles provided with special dark lenses. AT LEAST FIVE TO TEN MINUTES ARE NECESSARY FOR PROPER ACCOMMODATION OF THE EYES.

Failure to observe this rule will result

in unsatisfactory fluoroscopic vision and will tempt the operator to increase the milliamperage, kilovoltage, and time, beyond the recommended minimum value and thus expose the patient, and under certain conditions, himself, to dangerous amounts of radiation. This rule applies with particular emphasis to the use of head type fluoroscopes.

X-Ray protective devices, such as lead rubber gloves, lead rubber aprons, lead protected fluoroscopic chair, etc., shall always be used. The operator's bare hands shall

never be exposed to the x-ray beam.

THE DISTANCE BETWEEN THE TARGET OF THE X-RAY AND THE PATIENT'S SKIN SHALL BE AT LEAST TEN INCHES. Greater distances are preferable since they reduce the likelihood of over-exposure and improve the fluoroscopic image. The intensity of the x-radiation reaching the patient's skin varies inversely with the square of the distance from the target of the x-ray tube; for example, the intensity at 10 inches distance is 4 times that at 20 inches distance, all other factors remaining the same.

The best practice is to use a minimum of 1 mm. aluminum filter, or more, between the x-ray tube and the patient. (1.5 mm. of aluminum is included in the fluoroscopic shutter that may be included with this Model D-3 unit. When the shutter is not used, the inherent filter is equivalent to approximately 0.5 mm. aluminum.)

The milliamperage setting shall be as low as possible without sacrificing satisfactory fluoroscopic vision. MILLIAMPERAGE SHALL IN NO CASE EXCEED 5 MA.

Kilovoltage is set in accordance with the thickness and density of the body part being examined. For best vision it shall be kept as low as possible, although with unusually heavy patients the full 85 kv.p. may be used. It is common practice to use not more than 3 ma. at not more than 85 kv.p. for abdominal fluoroscopy, 3 ma. at 70 kv.p. for chest, and 3 ma. at 60 kv.p. for extremities. The general rule is to use the lowest energy which will provide the desired fluoroscopic

visualization.

Make short, intermittent exposures rather than long, continued ones. This practice allows the eyes to re-accommodate during the dark intervals and increases the visibility of the image. It reduces the amount of radiation the patient receives and prolongs the life of the x-ray tube.

Restrict the size of the radiation aperture (shutter) to the smallest area necessary to cover the part being examined. This prevents needless exposure of other parts of the patient's body and improves the sharpness of the fluoroscopic image.

Consult the tube rating chart for maximum permissible operating time, kilovoltage and milliamperage which apply to your fluoroscopic tube. Never exceed these ratings.

Keep a record of exposure factors used during the examination. Since the effect of x-radiation is cumulative, be certain that the amount applied by you to the patient, together with the amount, diagnostic or therapeutic, which the patient may have received during the period of four weeks preceding, together with the amount which will be used for radiography during the course of your examination, does not in its combined total for any area, exceed the generally accepted maximum safe limits.

As a guide in determining the safe exposure factors, consult the following tables of maximum permissible exposure values in milliamperereconds.

I.

MAXIMUM EXPOSURE VALUES IN MILLIAMPERE-SECONDS FOR ALL PARTS OF THE BODY EXCEPTING THE HEAD

TARGET SKIN DISTANCE	WITH FLUOROSCOPIC SHUTTER (Total filtration approx. 2 mm. al)	WITHOUT FLUOROSCOPIC SHUTTER. (Total filtration approx. 0.5 mm. al)
10	1300	265
12	1870	380
14	2550	520
16	3325	680
18	4210	870
20	5200	1060
22	6290	1280
24	7490	1520

NOTE: After any part has received the full exposure limit in milliamperereconds, a minimum of twenty-eight days should elapse before further exposure is given. The limit as given in the table may be repeated after twenty-eight days have elapsed.

II.

MAXIMUM PERMISSIBLE EXPOSURE VALUES IN
MILLIAMPERE-SECONDS FOR THE HEAD

TARGET SKIN DISTANCE	WITH FLUOROSCOPIC SHUTTER	WITHOUT FLUOROSCOPIC SHUTTER
	(Total filter approx. 2 mm. al)	(Total filter approx. 0.5 mm. al)
10	975	290
12	1400	290
14	1910	390
16	2500	510
18	3160	650
20	3900	800
22	4720	960
24	5620	1150

NOTES ON THESE TABLES

After any part has received the full exposure limit in milliamperes-seconds, a minimum of twenty-eight days should elapse before further exposure is given. The limit as given on the chart may be repeated after the above-mentioned period of time has elapsed.

These tables apply to both fluoroscopy and radiography.

The first table applies to all parts of the body excepting the head; the second to the head only. The second table is a reduction of approximately 25% of the values of the first.

These tables are based on operation at 85 kv. When using a lower kilovoltage, an increased value may be used but it is preferable to employ the tabulated values and take advantage of an increased margin of safety.

For adjustment of these tables when using a kilovoltage other than 85 kv., the following percentage changes may be used:

KV.	CHANGE IN MAXIMUM PERMISSIBLE EXPOSURE VALUES
-----	--

85	No Change
80	Increase by 10%
70	Increase by 35%
60	Increase by 80%

The values of these tables are based on:

- (1) The average output of a typical installation.
- (2) The average figure of 275 roentgens for a "threshold erythema".
- (3) A factor of 50% which is necessary to cover unpredictable variations in either of the first two factors.

These values are intended to serve only as a guide and should be replaced by similar styled tables based on the actual measured output of the installation and the user's estimate of the value of the threshold erythema.

For assured safety, these tabulated values shall not be exceeded until replaced by the users' own values.

OPERATING DIRECTIONS

Below is given, in condensed form, an outline of the step-by-step procedure to be followed in operating the Model D3 X-Ray Unit.

RADIOGRAPHIC PROCEDURE

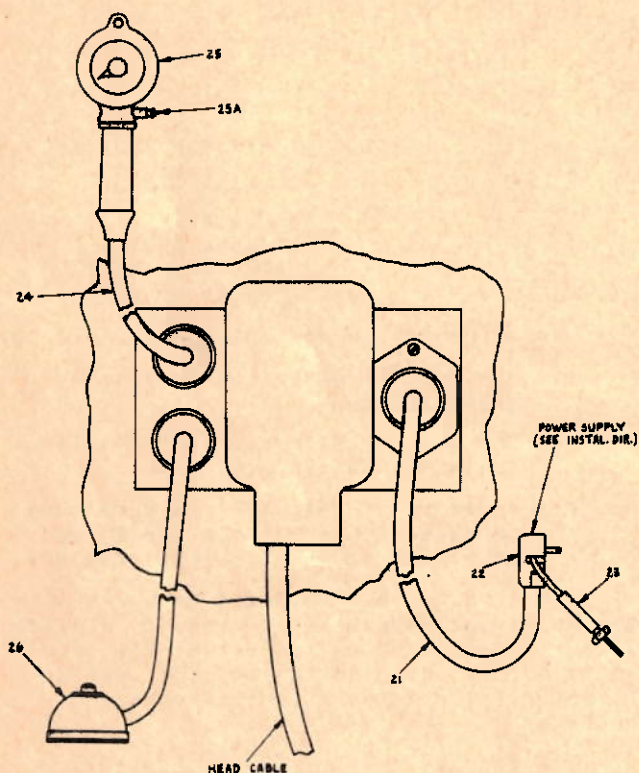


ILLUSTRATION III

Fig. 21. Plug the line cord into the receptacle at the back of the control.

Fig. 22. Plug the receptacle on this line cord into the proper power source.

Fig. 23. See that the unit is properly grounded to a good earth ground.

Fig. 24. Plug the hand timer into its receptacle at the back of the control. Determine the technic to be used from Technic Chart.

Fig. 25. Set the hand timer the desired time of exposure.

Fig. 31. Set the selector switch.

Fig. 32. Adjust the kilovoltage selector.

Fig. 33. Snap the line switch to the "on" position.

Fig. 34. Observe the compensator voltmeter.

Fig. 35. If the compensator voltmeter reads "low" or "high" adjust the voltage compensator accordingly.

Fig. 36. Observe the reading of the Filament Ammeter.

Fig. 37. Adjust the filament regulator to obtain correct reading on Filament Ammeter.

Fig. 25a. Operate the hand timer by pressing the "quick make" button.

Fig. 38. Observe the reading of the milliammeter. It should indicate the correct milliamperes.

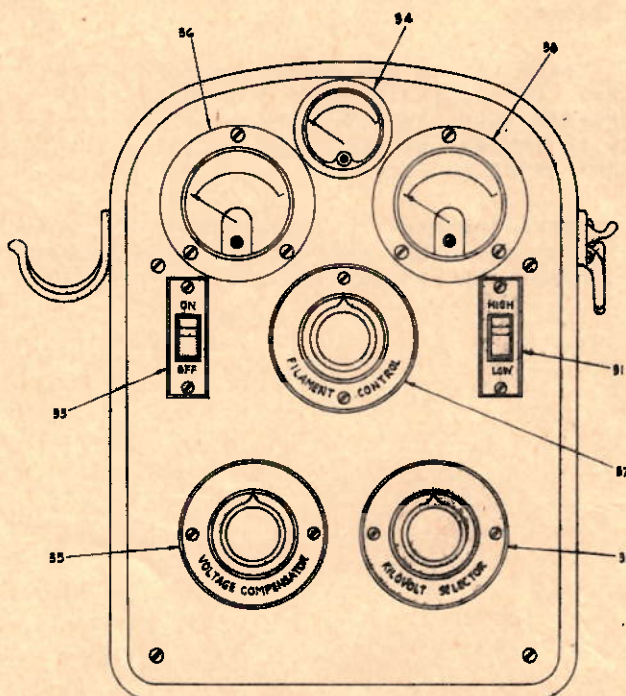


ILLUSTRATION IV

Shut off the unit and proceed to remove the cassette or film holder. Develop the film that has been exposed.

If the unit is not to be used further, the line plug (Fig. 22) Illustration III, should be removed from the power source.

This x-ray unit is equipped with an overload protective device (Fig. 33, Illustration 4) which functions to prevent excessive overloads being thrown on the control due to short circuits that might accidentally be placed there by loose connections or broken wires. When this thermal device trips out, it will only be necessary to wait a short time (possibly 1 or 2 minutes) for the heat to be dissipated from the thermal heating element of the device before again closing the line switch.

After the two minutes wait, the line switch should be re-set before trying to energize the control. This is done by pressing the toggle lever firmly to the far "off" position. This engages the heating element spring and locks the trip mechanism. The toggle switch may now be thrown to the "on" position and the control energized and another x-ray exposure made. Should the thermal unit again trip out or repeatedly do so, it is suggested that a G-E x-ray representative be consulted. This thermal protective device allows the head to be energized for long fluoroscopic or superficial therapy techniques up to the rating of the transformer and tube. These ratings are shown under "DUTY CYCLE". For ranges other than given under that heading, it is suggested that a representative of G-E X-Ray be consulted.

The focal-skin distance ordinarily employed with the D3 when the fluoroscopic shutter and guard are mounted on the head is 12 inches. However, shorter or greater distances are possible, but shorter distances are not recommended due to the shortening of the exposure time.

From experience it has been found that when the eyes have become thoroughly accommo-

dated (7 to 15 minutes) to a darkened, fluoroscopic room that the amount of energy needed with this unit for an average size patient varies from approximately 45 to 85 kv.p. and between 3 and 5 milliamperes. The brilliancy of the screen image obtained with tube values of this order along with detail gained from the use of an exceedingly small focal spot gives fluoroscopic images far surpassing those ordinarily observed.

However, the D3 will be generally used in a lighted room and the fluoroscopic screen will be contained in an XRP (x-ray proof) box having a light proof head over it for exclusion of light. For proper diagnosis of the part being view, it is well to give consideration to the proper accommodation of the eyes to the dark interior of the hand fluoroscope. Dark glasses will be helpful in getting correct accommodation for the eyes.

The use of low energy for fluoroscopy serves a double purpose because it not only makes possible a much longer tube life and consequent lower cost of operation, but also lengthens the time permissible for the examination, because of the reduced exposure on the skin. This latter problem is important and the rule established by common practice for fluoroscopy or radiography is the same.

When the fluoroscopic shutters are opened and the x-ray beam is allowed to pass unobstructed (except for the inherent filtration imposed, consisting of the glass of the tube, oil, and bakelite window between the patient and the tube focal spot), the patient will receive a certain amount of milliamperes seconds depending on the milliamperes being put through the tube and the length of exposure.

DUTY CYCLES

The five calibration charts (A.C. and D.C.) have been prepared in such a manner as to contain fluoroscopic values listed under 2 and 5 ma. tube current settings. These settings and others are incorporated in the following duty cycles; under no consideration must these cycles be exceeded.

Note: The following duty cycles have been prepared from calibration charts 3 and 5.

DUTY CYCLES

Penetration		Milliamperes	Button		Time
A.C.	D.C.		A.C.	D.C.	
66 kv.p.		2 ma.	L-12	L-15	19 min. (10 sec. on 5 sec.
66 kv.p.		3 ma.	L-13	H-1	28 min. off for one such exposure in any 30 min. interval is permissible. The head may be operated on this cycle for a period of 4 hours)
85.1 kv.p.	84.4 kv.p.	2 ma.	H-8	H-11	15 min. (one such exposure in any 30 min. interval is permissible. The head may, be operated on this rating for a period of 4 hours)
85.1 kv.p.	84.4 kv.p.	3 ma.	H-8	H-11	10 min.
85.1 kv.p.	84.4 kv.p.	5 ma.	H-10	H-14	6 min.
76.6 kv.p.	76.2 kv.p.	5 ma.	H-5	H-9	3 min. (one exposure in any 15 minute period for 4 hours)
76.6 kv.p.	76.2 kv.p.	3 ma.	H-3	H-6	5½ min. (one exposure in any 15 minute period for 4 hours)
42.7 kv.p.	39.7 kv.p.	5 ma.	L-1	L-2	11½ min. (one exposure in any 30 minute interval for 4 hours)
46.4 kv.p.	43.2 kv.p.	2 ma.	L-1	L-1 Continuous	(for 86 minutes at 70 degrees F) NOTE: Then cool to room temperature.

FLUOROSCOPIC OPERATION

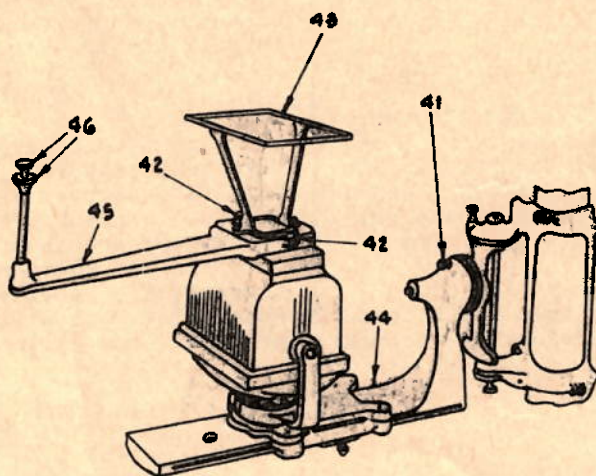


ILLUSTRATION VI

The only type of work wherein the maximum penetration values may be found to be necessary is gastro-intestinal fluoroscopy particularly if the subject is unusually large.

For Fluoroscopy of extremities, 2 ma. is ordinarily sufficient with penetration (kv.p.) values of the order of 40 to 60.

For the chest and heart, milliamperages from 2 to 3 will usually suffice, the penetration varying from 50 to 70 kv.p., depending on the thickness of the subject.

The general rule is to use the lowest energy which will provide the desired fluoroscopic visualization.

ILLUSTRATION VI

Fig. 41. Turn the head into position by releasing the lock pin and twisting the horizontal carriage, Fig. 44, into position.

Fig. 42. Position the fluoroscopic shutter, Fig. 45, to the head by use of two thumb screws.

Fig. 43. Position fluoroscopic guard to the shutter.

Fig. 42. Lock it in position by use of lock pins.

ILLUSTRATION III

Fig. 21. Plug line cord into its receptacle at back of the control stand.

Fig. 22. Plug the receptacle on this line cord into the proper power source.

Fig. 23. Properly ground the unit to a good earth ground.

Fig. 26. Plug the footswitch into the receptacle at the back of the control stand.

Determine the technic to be used.

ILLUSTRATION IV

Fig. 31. Set the selector switch.

Fig. 32. Adjust the kilovolt selector.

Fig. 33. Snap the line switch to the "on" position.

Fig. 34. Observe the compensator voltmeter.

Fig. 35. If the compensator voltmeter reads "low" or "high" adjust this control accordingly.

ILLUSTRATION III

Fig. 26. Depress the footswitch.

ILLUSTRATION IV

Fig. 37. Starting at a low setting of the filament ammeter, Fig. 36, increase the milliamperes, Fig. 38, until the correct brilliancy is obtained on the screen. Keep this value of milliamperes as low as possible (usually 5 ma. or less).

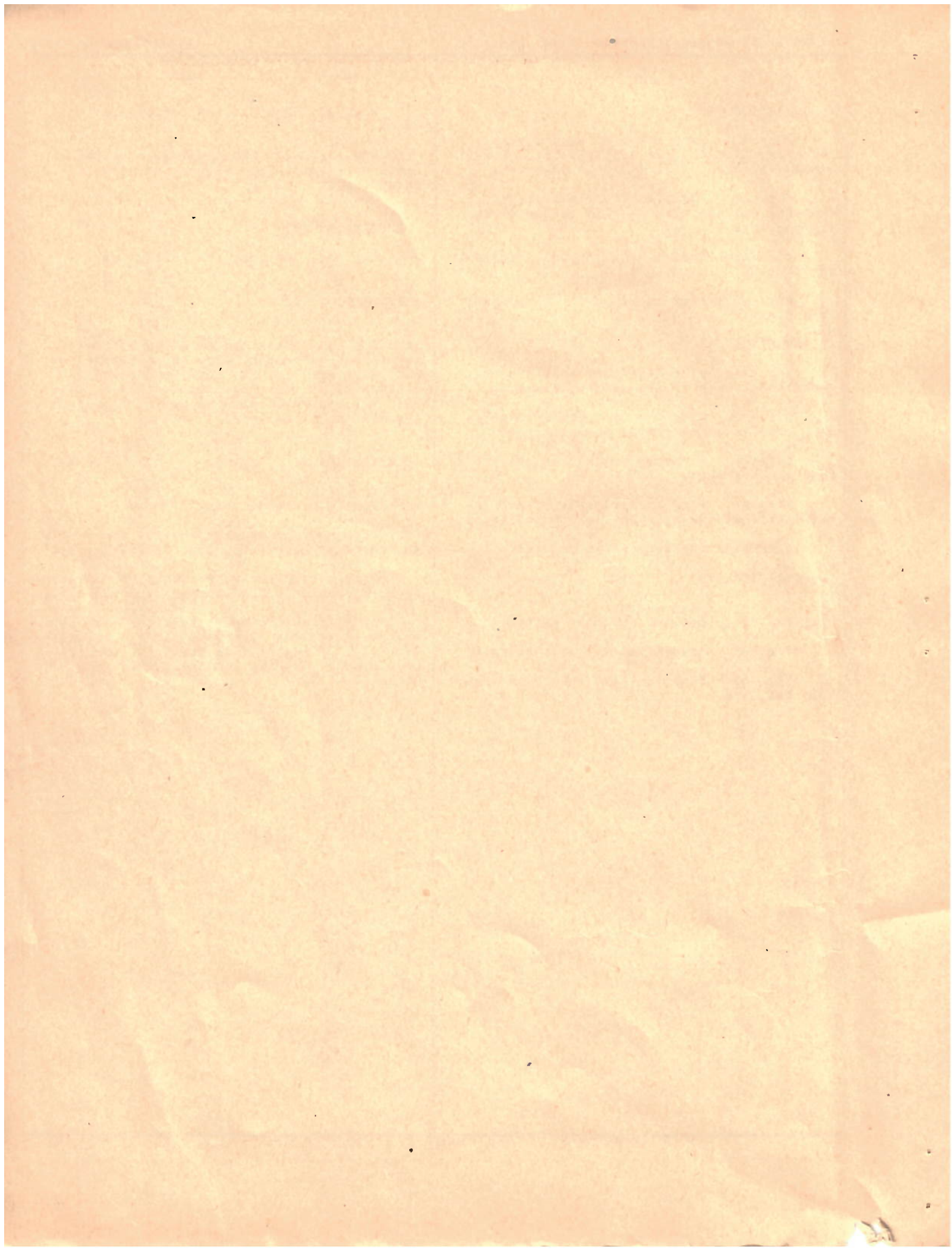
ILLUSTRATION VI

Position the patient.

With hand on shutter control knobs, Fig. 46, depress footswitch, Fig. 26 (Illus. III).

Determine aperture necessary for examination, by manipulating shutter controls Fig. 46.

After examination be sure the line switch on the control is shut off, Fig. 33, Illustration IV. If the unit is not to be used for some time remove the line plug, Fig. 22, Illustration III.

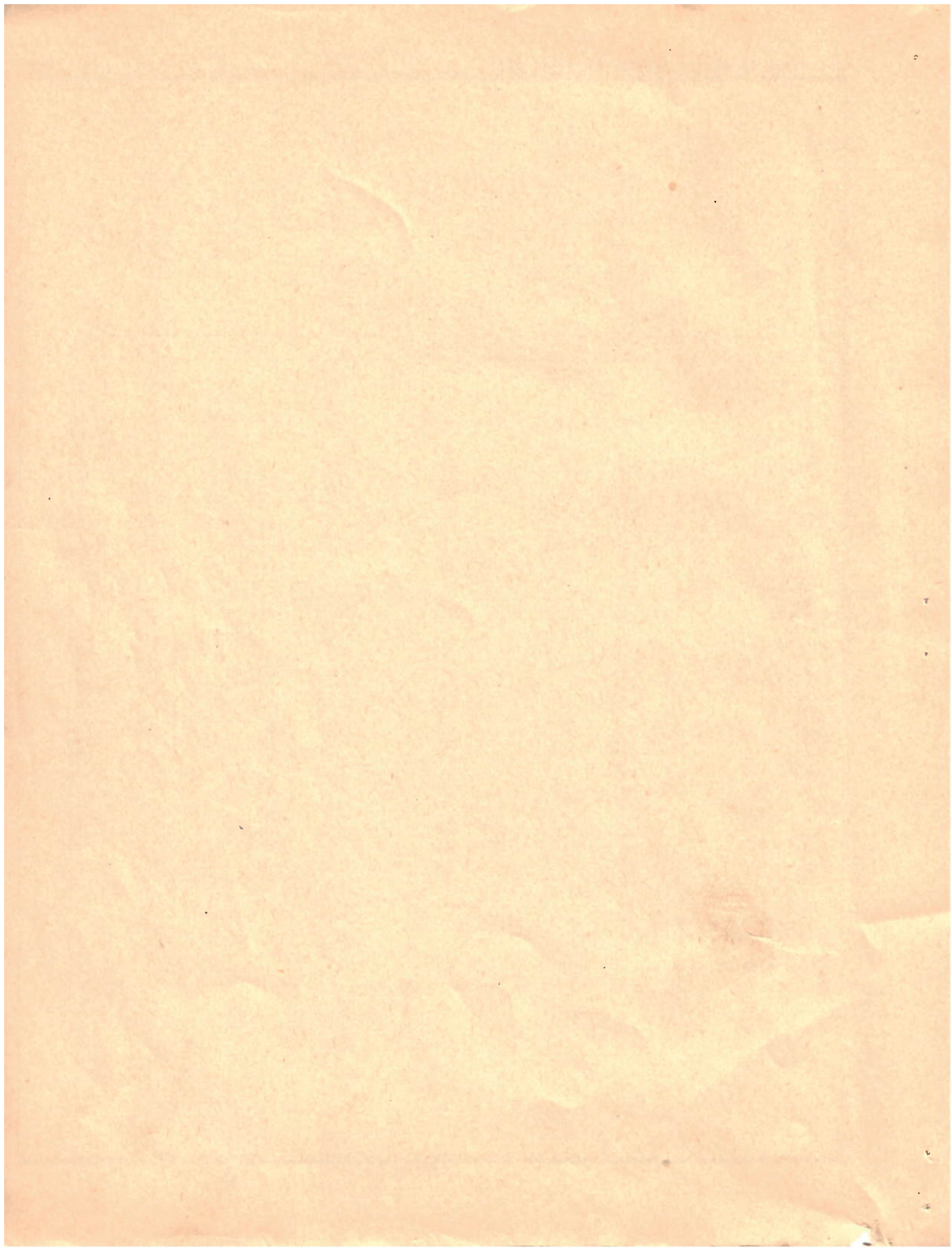


CALIBRATION CHART #3

Kv.p.	2 Ma.	5 Ma.	10 Ma.	15 ma.
33.5				L3
35.4				L4
37.3			L1	L5
39.1			L2	L6
40.9			L3	L7
42.7		L1	L4	L8
44.4		L2	L5	L9
46.4	L1	L3	L6	L10
48.2	L2	L4	L7	L11
50.2	L3	L5	L8	L12
51.9	L4	L6	L9	L13
53.7	L5	L7	L10	L14
55.5	L6	L8	L11	L15
57.3	L7	L9	L12	H1
59.1	L8	L10	L13	H2
60.8	L9	L11	L14	H3
62.7	L10	L12	L15	H4
64.4	L11	L13	H1	H5
66.1	L12	L14	H2	H6
67.8	L13	L15	H3	H7
69.7	L14	H1	H4	H8
71.3	L15	H2	H5	H9
73.1	H1	H3	H6	H10
74.8	H2	H4	H7	H11
76.6	H3	H5	H8	H12
78.3	H4	H6	H9	H13
80.0	H5	H7	H10	H14
81.7	H6	H8	H11	H15
83.4	H7	H9	H12	
85.1	H8	H10	H13	

L - Selector switch in "low" position.
H - Selector switch in "high" position.

Calibration accuracy $\pm$ 2 kv.p.



CALIBRATION CHART #4

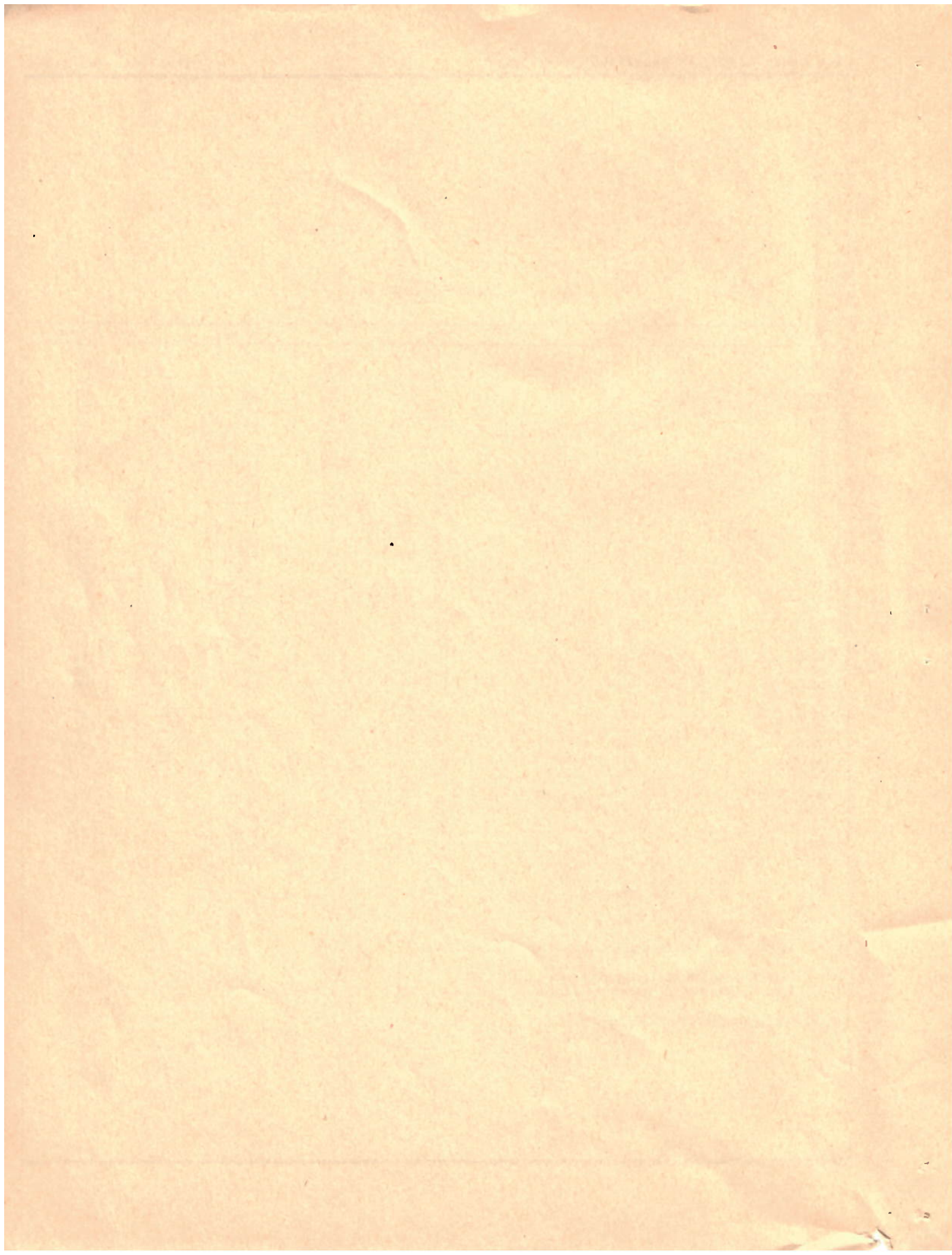
kv.p.	2 Ma.	5 Ma.	10 Ma.	15 Ma.*
32.5				L2
34.2				L3
35.9			L1	L4
37.6			L2	L5
39.2			L3	L6
40.9			L4	L7
42.4		L1	L5	L8
43.9		L2	L6	L9
45.7	L1	L3	L7	L10
47.4	L2	L4	L8	L11
49.2	L3	L5	L9	L12
51.0	L4	L6	L10	L13
52.8	L5	L7	L11	L14
54.7	L6	L8	L12	L15
56.4	L7	L9	L13	H1
58.5	L8	L10	L14	H2
60.2	L9	L11	L15	H3
61.8	L10	L12	H1	H4
63.7	L11	L13	H2	H5
65.3	L12	L14	H3	H6
66.9	L13	L15	H4	H7
68.6	L14	H1	H5	H8
70.2	L15	H2	H6	H9
71.9	H1	H3	H7	H10
73.7	H2	H4	H8	H11
75.3	H3	H5	H9	H12
77.1	H4	H6	H10	H13
78.8	H5	H7	H11	H14
80.2	H6	H8	H12	H15
81.7	H7	H9	H13	
83.3	H8	H10	H14	
84.8	H9	H11	H15	
86.2	H10	H12		

* - 15 ma. loads may be impractical on the poorest lines

L - Selector switch in "low" position.

H - Selector switch in "high" position.

Calibration accuracy ± 2 kv.p.



D.C. CALIBRATION CHART #5

For use with units equipped with small inverted rotary converter.

kv.p.	Kilovolt selector Button		
	2 Ma.	5 Ma.	10 Ma.
39.7		L2	L7
41.5		L3	L8
43.2	L1	L4	L9
44.9	L2	L5	L10
46.6	L3	L6	L11
48.2	L4	L7	L12
49.9	L5	L8	L13
51.5	L6	L9	L14
53.1	L7	L10	L15
54.8	L8	L11	H1
56.5	L9	L12	H2
58.2	L10	K13	H3
59.8	L11	L14	H4
61.4	L12	L15	H5
63.0	L13	H1	H6
64.7	L14	H2	H7
66.3	L15	H3	H8
68.0	H1	H4	*H9
69.6	H2	H5	*H10
71.2	H3	H6	*H11
72.9	H4	H7	*H12
74.6	H5	H8	*H13
76.2	H6	H9	*H14
77.8	H7	H10	*H15
79.4	H8	H11	
81.1	H9	H12	
82.8	H10	H13	
84.4	H11	H14	
86.0	H12	H15	

L - Selector switch in "low" position.

H - Selector switch in "high" position.

* - These loads may be impractical on some power lines.

Calibration accuracy ± 2 kv.p.

INSTRUCTIONS FOR CHANGING THE X-RAY TUBE

The following directions give the procedure for opening the head, removing and replacing the x-ray tube, and resealing the head. The following is furnished with each replacement x-ray tube; one main head gasket and one oil plug gasket. In addition, the following material originally furnished with the unit is required: one glass oil-filler tube and two bellows-compression screws, and cork stopper and filler tube gasket.

Removal of Tube (Illustration VII)

1. Position Head: Bring the tube-head down as low as possible on the tube column and turn the head so that the port is directed vertically upward. Lock it securely in this position. If it is desired to remove the head from its supporting bracket, it will be necessary to remove the four screws from the bracket arm on one side of the head and the three screws in the other end of the head.

2. Compress Bellows: All pressure should be released by compressing the bellows. (a) Turn the thumbnuts, Fig. 61, with fibre washers into the holes at each end of the head. (b) Screw the bolts, Fig. 62, into the bellows until they resist further turning, (c) Turn the knurled collars, Fig. 63, by use of the fingers until they resist further turning; the oil level in the head will now be low enough to allow opening it.

3. Remove X-Ray Tube: (a) Remove the ornamental cover and cone adapter. (b) Loosen all screws in the bakelite cover plate, Fig. 64, one-half turn before removing any of them completely. (c) Remove all screws. (d) Lift off cover plate, Fig. 64, being careful not to spill oil into the screw holes of the head casting. If the cover plate is hard to remove, insert a knife blade or screw driver between cover plate and tube head and carefully pry the plate loose. Do not damage the sealing surface. The gasket is to be replaced. (e) Disconnect the two filament leads, Fig. 71, (Ill. VIII), from the cathode end of the bakelite shield by removing the two contact screws. (f) Turn out the two anode clamping screws, Fig. 72 to release the x-ray tube. Do not loosen the anode clamp or shift the lead shield. (g) Remove the x-ray tube through the cathode end of the bakelite shield.

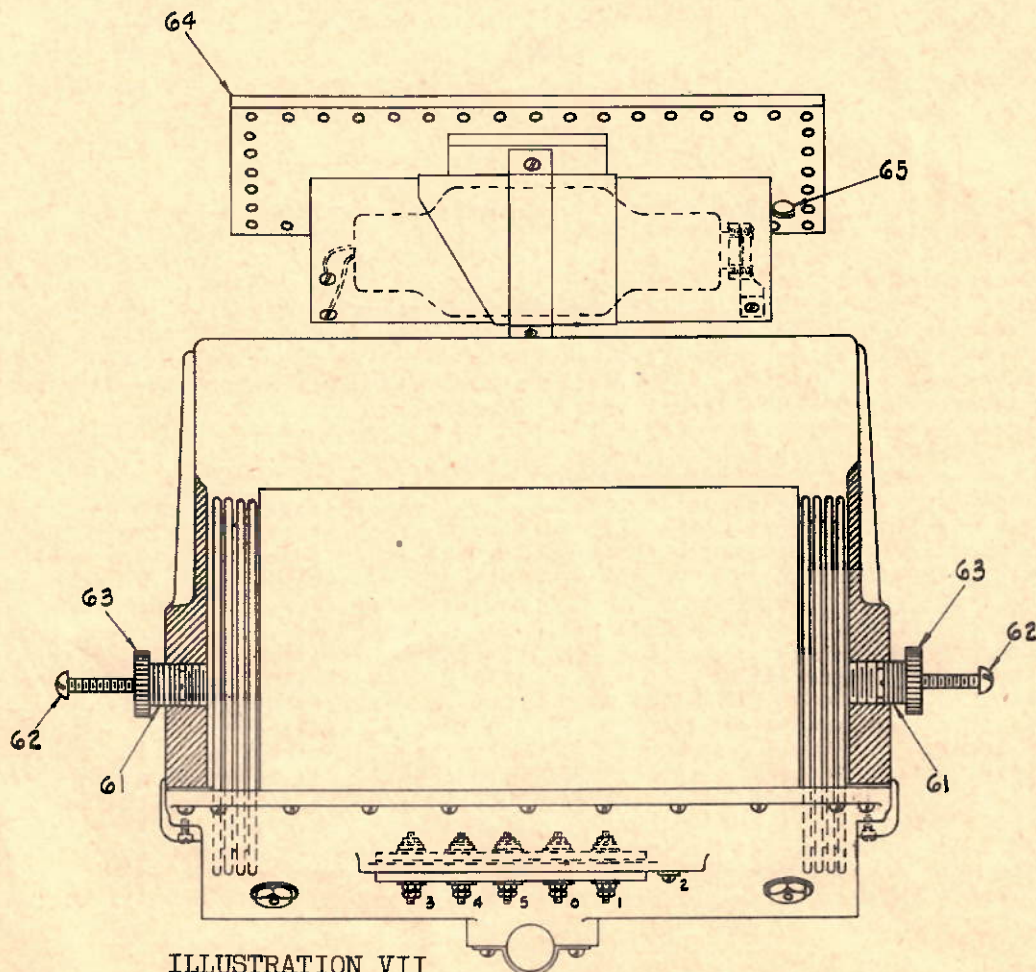


ILLUSTRATION VII

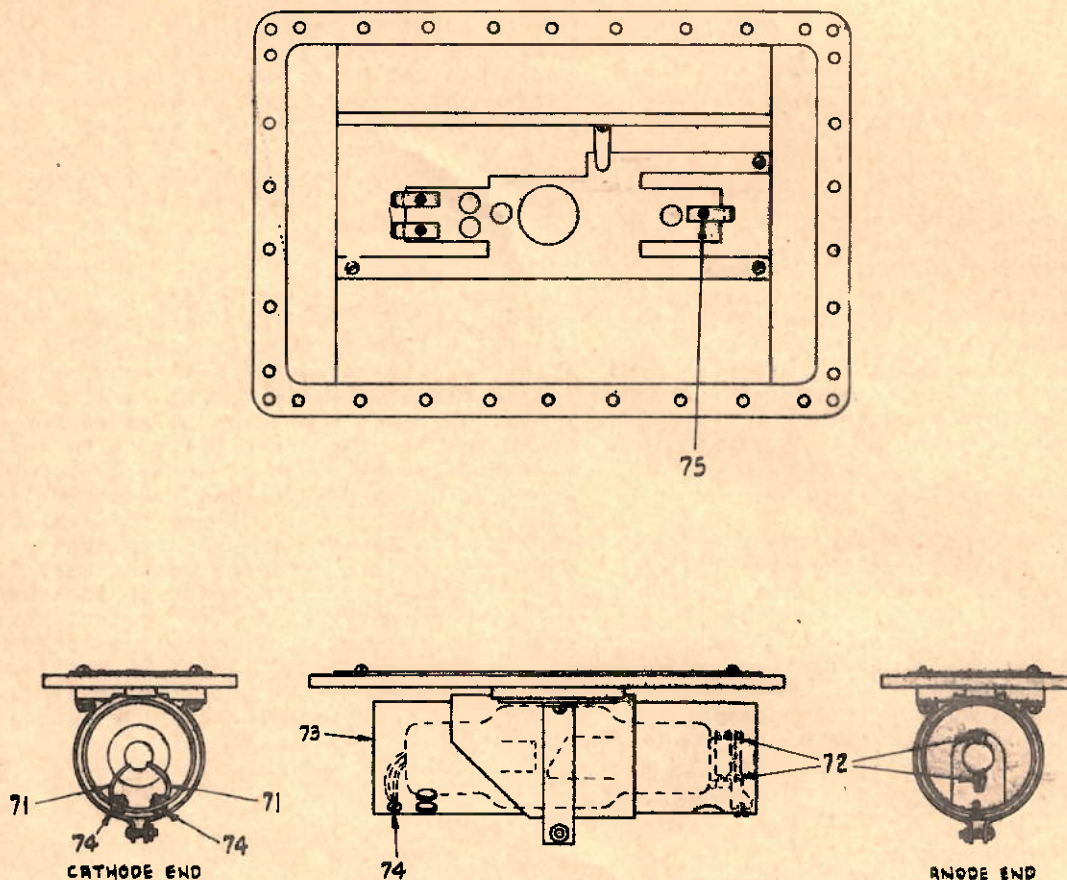


ILLUSTRATION VIII

4. Install New Tube: (a) Thoroughly clean the new tube with carbon tetrachloride and dry with clean lint-free cloth. (b) Slide the tube anode first into cathode end of bakelite shield, Fig. 73. (c) Center the tube with the window facing the tube support so that the x-ray beam will be directed outward from the head through the opening in the lead shield. (d) Attach the anode collar of the tube to the anode support by use of the two screws, Fig. 72. Carefully position the tube so that the glass window of the tube touches the bakelite cylinder when the anode is clamped. (e) Connect the two filament leads, Fig. 71, to the contact screws, Fig. 74, with the cord tips positioned along the edge of the bakelite cylinder. This provides spread for the filament wires. (f) Remove all the old gasket from the sealing surfaces. (g) If the oil has not been contaminated in any manner, it will not be necessary to replace it. However, if it is damaged, then replacement should be made with G.E. 10C Transil oil (Cat. No. A8002A), being careful to flush thoroughly before filling the head. (h) Clean the sealing surfaces with carbon tetrachloride. If any oil is spilled in the screw holes, clean it out thoroughly. (i) Be sure the new gasket is clean and dry. (j) Place the gasket on the head and

squarely position the tube into the head with the anode end of the tube towards the single spring contact, Fig. 75. (k) Hold the cover firmly in place and turn four screws into the head diagonally opposite each other. Do not seat these screws. (l) Turn in the remainder of the screws and tighten them down & turn at a time uniformly around the head until all are snug.

Sealing the Head

It is necessary to remove all air that might have been trapped within the head during the above procedure. The tube head is left in the same position to do this. (a) Unscrew the plug cap from the hold, Fig. 65, (Illustration VII), and screw into this hole by hand a glass filler tube. Before using this glass, however, make sure that it is cleaned with carbon tetrachloride. (b) Turn the knurled collar, Fig. 63, to the left (counter-clockwise), allowing the bellows to expand until oil appears in the glass filler tube to a height of approximately 2 inches. If oil does not appear in this tube, some should be added. (c) Angulate and shake the head as much as possible without spilling oil, frequently returning the head to the horizon-

tal position to allow the air to escape into the filler tube. Work the bellows in and out to assist in the process of removing air. This process is completed when no further air bubbles come out.

Adjusting Oil Volume and Sealing Head:
(a) Determine the temperature of the oil and turn the bellows thumbnut (according to the following table) from the position where it just makes contact with the head with the bellows fully released. (Add as much LOC oil as necessary to maintain a visible column in the filler tube).

Oil Temperature Degrees F.	Bellows Turns	
	Anode	Cathode
60	0.0	0
65	0.8	0
70	1.6	0
75	2.4	0
80	3.2	0
85	4.0	0
90	4.8	0
95	5.6	0
100	6.4	0
105	7.2	0
110	8.0	0
115	8.8	0
120	9.6	0
125	10.0	0.4

(b) Push the cork into the filler tube and remove this tube from the head. (c) Clean the surface around the opening with a clean piece of cloth. (d) Replace oil plug using new gasket furnished. (e) If the oil has previously all been removed from the head and the head refilled, it should stand for 24 hours before energizing. (f) Remove the bellows screw, Fig. 62, along with the knurled screw, Fig. 63. (g) Clean the head with carbon tetrachloride. (h) Replace the ornamental cover and cone adapter.

Final Adjustment of Milliamperage: (a) Test for normal operation at L10 on whatever calibration chart the unit is to operate on. (b) If the maximum milliamperage cannot be obtained through the tube or if it is obtained over a limited section of the filament control, then a wiring change is necessary. (c) Remove the control stand unit from its housing and disconnect the filament control lead from the line voltage compensator button "7" when viewing top of control and counting from the left. Connect it to the short lead on button "8" to decrease the ma. or to lead on button 6 to increase the ma. Tape up the short lead disconnected and tie it to one side. (d) Reassemble the control and test the unit again.

Failure of the apparatus to operate satisfactorily may be due to the following causes, which should be checked before calling a representative of the G.E. X-Ray Corporation.

1. Poor line plug connection to the wall receptacle.
2. Voltage compensator not set squarely on the contact button.
3. Kilovolt selector in between buttons.
4. Filament control too low.
5. Fuses burned out.
6. Badly fluctuating power line.
7. Incorrect power supply.
8. Failure of power supply.

MAINTENANCE

The owner of General Electric X-Ray apparatus is assured of the best equipment obtainable, which assurance does not, however, permit overlooking the fact that every machine requires a certain amount of service to maintain its maximum efficiency.

The extent of this service varies with the amount of use given the machine. Where a piece of apparatus is run continuously throughout the day and evening, it follows that a correspondingly increased amount of attention must be given.

This General Electric X-Ray apparatus has been designed to require the minimum of expert servicing. There is nothing in the ordinary course of maintenance but what can be easily cared for by the doctor or the technician.

When some unforeseen difficulty arises, the General Electric X-Ray Service Organizations, permanently located in well-distributed points over the world stand ready and willing to assist.

TROUBLE CONSIDERATIONS

The length of time an x-ray tube can be used is dependent on many factors, most of which are under control of the operator. When used properly, tube maintenance cost becomes one of the smallest items to be considered. However, any device which depends upon a vacuum for successful performance cannot be expected to last indefinitely.

With proper manipulation of the apparatus, tube life will be greatly extended. Do not exceed the operating limits. Exercise caution in turning the unit on and off. Because the tube cannot be seen, it is possible to leave the filament lighted.

Erratic unstable behavior of the milliammeter is often caused by a damaged or gassy x-ray tube. When the meter pointer goes off scale at low kilovoltages and milliamperage settings, the x-ray tube may be considered to be gassy. If the meter pointer goes off scale only at high settings of the kv.p. and ma., then the tube may have a damaged focal spot. If the milliammeter needle wavers or kicks erratically, the x-ray tube may be surging.

Failure of the filament ammeter to read shows that the primary circuit to the filament transformer is open. A slight deflection, however, indicates that the filament of the tube may be burned out or open circuited.

If the radiographic output is unsatisfactory, the inverse reducer should be checked and although it seldom causes trouble, if the tungar bulb is burned out or otherwise defective, the radiographic or fluoroscopic output will be subnormal because the 10 ohm resistor in parallel with the bulb may be directly connected in series with the high voltage transformer, thereby limiting the x-ray tube output.

If the tungar bulb should come loose in its socket and prevent lighting the filament, the above fault would also result.

An open-circuited inverse reducer resistor connects the tungar bulb directly in series with the primary of the high voltage transformer. Consequently, the resulting abnormally high pulsating direct current overloads the tungar bulb thus reducing the tube output.

Under no condition should the apparatus be operated with the inverse reducer defective because of the danger of impressing abnormally high voltage on the head.

Sparking may occur inside the head at intervals and if it becomes persistent the equipment should be shut down and a G.E. X-Ray representative called to examine it before further work is done. It is strongly advised that those unskilled in the servicing of this equipment should not be allowed to work on it. Trouble is often encountered by the unskilled even when the difficulty manifested is of an insignificant nature.

GUARANTEE

All parts of this General Electric X-ray Corporation apparatus with the exception of the x-ray tube and high voltage cable are guaranteed for six months from date of installation, to be free from defects in workmanship or material. Any parts so failing will be replaced or repaired without charge. This guarantee, however, does not cover damage resulting from carelessness or failure to follow these instructions. The liability of the company arising out of the supplying of this apparatus, or its use, whether on warranties or otherwise, shall not in any case exceed the cost of correcting defects in the apparatus, and after the said six months period, all such liability shall terminate.

The General Electric X-ray Corporation reserves the right to change, modify or redesign any equipment of its manufacture without notice and without obligating itself in any way to incorporate such changes or modifications into existing equipment. Insofar as possible, improvements are engineered in a way to permit users of existing equipment to take advantage of such improvements, but because the nature of such improvements cannot be anticipated no obligation can be incurred.

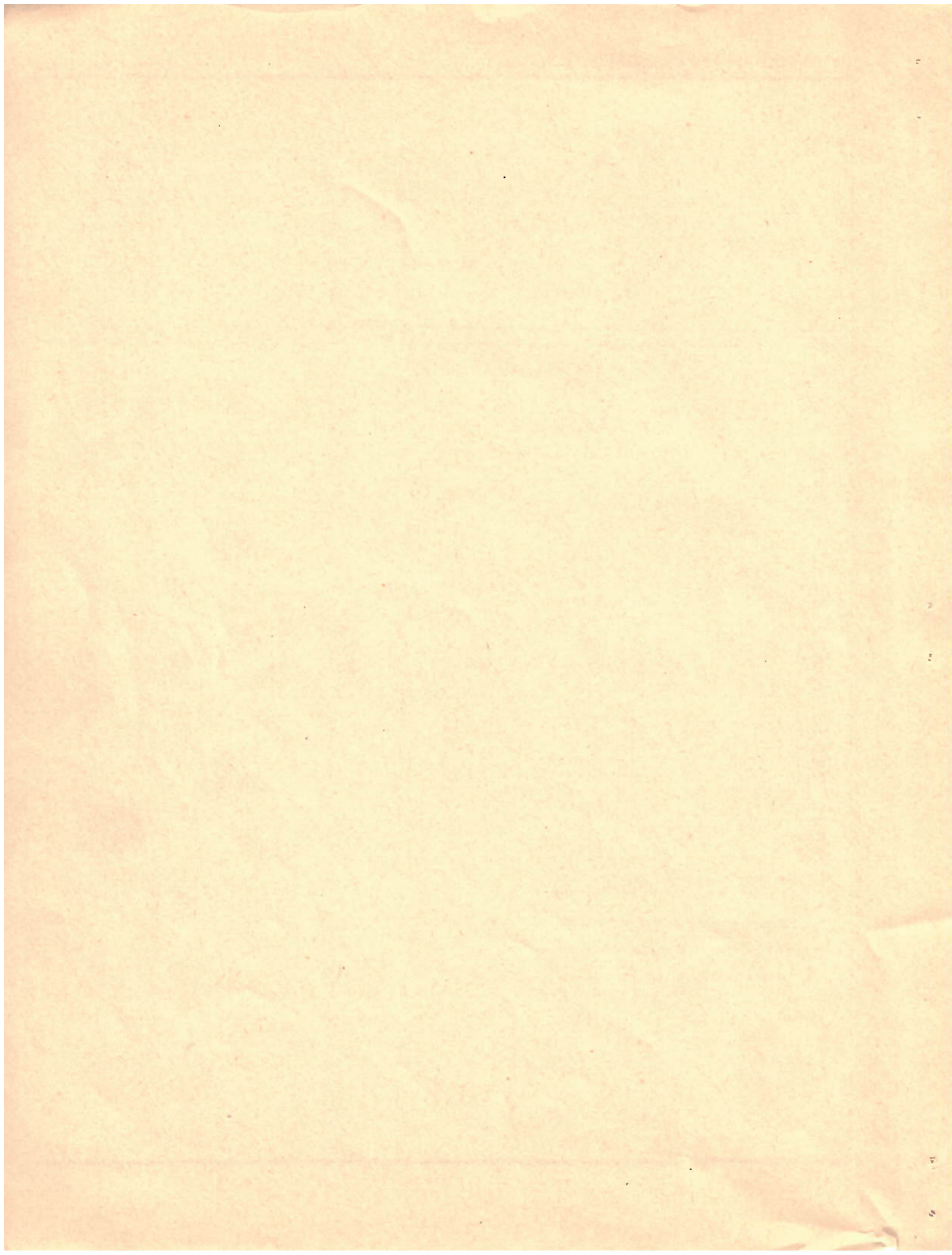
Years of experience in the design and construction of x-ray apparatus combined with fine workmanship and materials are built into all General Electric X-ray Apparatus. This, however, does not obscure the fact that any apparatus may be abused. This equipment when properly operated, will render years of useful and satisfactory service. It is designed for a specific purpose. Complete data is contained in these directions which should be carefully consulted before the equipment is put into service. Unusual or special techniques or procedures should never be attempted without assurance that it is within the normal capacity of the unit. To do so voids the guarantee and relieves the manufacturer of liability for failure of the equipment. The General Electric X-ray Corporation assumes no responsibility for injuries or damages to persons or property arising out of the use of any technique or procedure. In case of doubt the Engineering Service Department of the General Electric X-ray Corporation is ready and willing to give assistance and advice. This department should always be consulted before attempting any work wherein there is any question as to the ability of the apparatus to perform.

Code #3-2541

DEC. 18 / 1945
C.C.M.

JAN 8 / 1946 h.e.m.

NOV 2 / 1951 C.C.M.



CALIBRATION CHART #1

kv.p.	2 Ma.	5 Ma.	Kilovolt Selector Button 10 Ma.	15 Ma.	20 Ma.
32.2					L2
34.0					L3
35.9				L1	L4
37.8				L2	L5
39.7			L1	L3	L6
41.6				L4	
43.5		L1	L2	L5	L7
45.4	L1	L2	L3	L6	L8
47.3	L2	L3	L4	L7	L9
49.3	L3	L4	L5	L8	L10
			L6	L9	L11
51.3	L4	L5	L7	L10	
53.2	L5	L6	L8	L11	L12
55.1	L6	L7	L9	L12	L13
57.0	L7	L8	L10	L13	L14
58.8	L8	L9	L11	L14	L15
					H1
60.7	L9	L10	L12	L15	H2
62.6	L10	L11	L13	H1	H3
64.5	L11	L12	L14	H2	H4
66.4	L12	L13	L15	H3	H5
68.4	L13	L14	H1	H4	H6
70.3	L14	L15	H2	H5	H7
72.2	L15	H1	H3	H6	H8
74.1	H1	H2	H4	H7	H9
75.9	H2	H3	H5	H8	H10
77.8	H3	H4	H6	H9	H11
79.6	H4	H5	H7	H10	H12
81.5	H5	H6	H8	H11	H13
83.4	H6	H7	H9	H12	H14
85.3	H7	H8	H10	H13	H15

L - Selector switch in "low" position.
H - Selector switch in "high" position.

Calibration accuracy $\pm$ 2 kv.p.

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**GENERAL ELECTRIC
X-RAY CORPORATION**

2012 JACKSON BLVD.

CHICAGO, ILL., U. S. A.

What You Should Know
About **X-RAY**
PROTECTION

IMPORTANT . . . X-RAY PROTECTION

X-ray equipment, if not properly used, may cause injury. Accordingly the data and suggestions herein contained should be thoroughly read and understood before any attempt is made to place the apparatus in operation. The General Electric X-Ray Corporation will be glad to assist and cooperate in placing this equipment in use.

Although this apparatus incorporates protection against x-radiation other than the useful beam, no practical design of equipment can provide complete protection. Nor can any practical design compel the operator or his assistant to take adequate precautions, or prevent the possibility of authorized or unauthorized persons carelessly, unwisely, or unknowingly exposing themselves or others to direct or secondary radiation.

It is important that everyone having anything to do with x-ray work be fully acquainted with the recommendations of the National Bureau of Standards, and of the International Roentgen Ray Committee on x-ray protection, and take adequate steps to insure protection against injury.

It is assumed that all persons authorized to use the equipment are cognizant of the danger of excessive exposure to x-radiation, and the equipment is sold with the understanding that the General Electric X-ray Corporation, its agents, and representatives have no responsibility for injury or damage which may result from exposure to x-radiation.

Effects harmful to the health may be experienced by anyone exposed to an excessive amount of x-radiation. This must be avoided by adequate protection for which various protective materials and devices are available.

Greatest consideration should be given to protection of the operator and all others against the direct beam. However, when x-radiation strikes any material there is produced a secondary or scattered radiation and, since this is as potentially dangerous as the direct radiation, protective measures must be adequate to guard against it as well.

Adequate protection should be confirmed by r-unit measurements taken to determine that the x-radiation at any location does not exceed the accepted tolerance dose; or a less accurate but frequently used means for confirming protection is by plac-

ing unexposed films at several strategic locations for a given period before development; or by use of a fluorescent screen after the eyes have become accommodated. Another worth while procedure is that of the semi-annual blood examination of the personnel engaged in radiological work.

Before operation those qualified and authorized to operate this equipment should become familiar with and, where pertinent, conform to the established safe exposure factors and other recommendations contained in this manual as well as in "National Bureau of Standards HB-20," "The United States Army X-Ray Manual," "The Recommendations of the International Roentgen-Ray Committee on X-Ray Protection," and other standard authorities.

FLUOROSCOPY & RADIOGRAPHY

The following precautions and procedures shall be observed.

Eye accommodation preceding fluoroscopy. The operator shall allow his eyes to become fully accommodated to the darkness before starting a fluoroscopic examination. This may be done by remaining in a dark room or wearing fluoroscopic goggles provided with special dark lenses. **At least five to ten minutes are necessary for proper accommodation of the eyes.**

Failure to observe this rule will result in unsatisfactory fluoroscopic vision and will tempt the operator to increase the milliamperage, kilovoltage, or time beyond the recommended maximum value and thus expose the patient and, under certain conditions himself, to dangerous amounts of radiation.

Eye accommodation before beginning a fluoroscopic examination applies with particular emphasis to the use of head type fluoroscopes.

Use of x-ray protective devices imperative. X-ray protective devices, such as lead rubber gloves, lead rubber aprons, lead protected fluoroscopic chair, etc., shall always be used. The operator's unprotected hands, wrists, arms, or other parts shall never be exposed to the x-ray beam.

Observance of focal-skin distance. For fluoroscopy the distance between the target of the X-ray tube and the patient's or operator's skin shall be at least ten inches. Greater distances are preferable since they reduce the likelihood of over-exposure and improve the fluoroscopic image. The intensity of the x-radiation reaching the patient's or operator's skin varies inversely with the square of the distance from the target of the x-ray tube. For example, the x-ray intensity at 10 inches distance is 4 times that at 20 inches distance, all other factors remaining the same.

Use of filter as a standard practice. The best practice is to use a minimum of 1 mm aluminum filter, or its equivalent, between the X-ray tube and the patient, particularly for fluoroscopy.

Lowest possible current value advisable in all fluoroscopy. For fluoroscopy the milliamperage setting shall be as low as possible without sacrificing satisfactory fluoroscopic vision. **Milliamperage shall in no case exceed 5 ma.**

Kilovoltage is set in accordance with the thickness and density of the body part being examined. For best vision, it shall be kept as low as possible, and although 100 kv is available in some installations, it is a rare instance that requires more than 85 kv. It is common practice to use not more than 3 ma at 85 kv for abdominal fluoroscopy; 3 ma at 70 kv for chest; 3 ma at 60 kv for extremities.

Recommended procedures during fluoroscopic examination. During fluoroscopic examination make short intermittent exposures rather than long, continued ones. This practice allows the eyes to re-accommodate during the dark intervals and increases the visibility of the image. It reduces the amount of radiation the patient receives and prolongs the life of the x-ray tube.

Restrict the size of the radiation aperture (shutter) to the smallest area necessary to cover the part being examined. This prevents needless exposure of other parts of the patient's body and improves the visibility of the fluoroscopic image.

Palpation with the hand or other manipulation under the fluoroscope for setting of fractures, foreign body localization, or other such procedures should be kept to a minimum. Under no circumstance should an operator use any part of his body for fluoroscopic demonstration nor should he hold any cassette, medical or dental film in position during exposure.

Tube ratings and maximum permissible exposure values. Consult the tube rating chart for maximum permissible time, kilovoltage and milliamperage which apply to your fluoroscopic tube. Never exceed these ratings.

As a guide in determining the safe exposure factors for fluoroscopy or radiography, consult the following tables of maximum permissible exposure values in milliampere seconds. Milliampere seconds are the product of milliamperes and total actual exposure time in seconds. In using these tables, the maximum permissible exposure time in *seconds* is obtained by dividing the milliamperes used into the value of *milliampere seconds* tabulated; as for example, if the milliamperes used are 5, and the permissible exposure value in milliampere seconds totals 1000 at a given filtration, kilovoltage, and distance, the milliamperage (5) is divided into the milliampere seconds (1000) which gives the time—200 seconds. This figure constitutes the maximum exposure time at such a voltage.

Table I.

MAXIMUM PERMISSIBLE EXPOSURE VALUES IN MILLIAMPERE-SECONDS FOR ALL PARTS OF THE BODY EXCEPTING THE HEAD

(AT 85 KV.P.)

Target—Skin Distance Inches	X-RAY, Filter (mm Al) External—None Inherent—0.5 Total —0.5	USING SHUTTER Filter (mm Al) External—0.5 Inherent—0.5 Total —1.0	X Filter (mm Al) External—1.0 Inherent—0.5 Total —1.5
10	265 m.A.s.	510	810
SHUTTER — 12	380	730	1090
14	520	1000	1500
16	680	1300	1950
18	870	1650	2500
20	1060	2050	3000
22	1280	2450	3640
24	1530	2900	4360
30	2400	4500	6800
36	3460	6500	9800
42	4700	8850	13300
48	6150	11600	17400

Table II.

MAXIMUM PERMISSIBLE EXPOSURE VALUES IN MILLIAMPERE-SECONDS FOR THE HEAD (AT 85 KV.P.)

Target—Skin Distance Inches	X-RAY Filter (mm Al) External—None Inherent—0.5 Total —0.5	Filter (mm Al) External—0.5 Inherent—0.5 Total —1.0	Filter (mm Al) External—1.0 Inherent—0.5 Total —1.5
10	200	380	610
12	290	550	875
14	390	750	1190
16	510	970	1560
18	650	1240	1980
20	800	1530	2450
22	960	1840	2970
24	1150	2150	3540
30	1790	3360	5540
36	2585	4840	7950
42	3600	6560	10850
48	4600	8550	14100

Tables I and II, which apply to both radiography and fluoroscopy, are based on operation at 85 kvp. When using higher kilovoltage, a reduced value *must* be used. When using a lower kilovoltage, an increased value may be used but it is preferable to employ the tabulated values and take advantage of any increased margin of safety. The maximum permissible exposure value in milliamperere seconds for distances other than those given in the above tables can be determined by application of the inverse square law of light which is to the effect that the amount of radiation striking a given area varies inversely with the square of the distance from the target of the tube.

For adjustment of these tables when using a kilovoltage different than 85 kv, the following percentage changes may be used:

Table III.

<i>KV.</i>	<i>Change in maximum permissible exposure values</i>
100	Reduce by 25%
90	Reduce by 8%
85	No change
80	Increase by 10%
70	Increase by 35%
60	Increase by 80%

The first table applies to all parts of the body excepting the head; the second to the head only, and is a reduction of approximately 25% of the values of the first.

Since the effect of x-radiation is cumulative, be certain that the amount applied by you to the patient, together with the amount—diagnostic or therapeutic—which the patient may have received during the period of four weeks preceding, together with the amount which will be used for radiography during the course of your examination, does not in its combined total for any area, exceed the generally accepted maximum safe limits.

For the user's information, the total filtration value heading each column of Tables I and II is divided into inherent and external. The values of permissible milliamperere seconds still apply when this same total is obtained by a different division of the inherent and the external filter. The inherent is dependent upon the particular filtering characteristics of the tube aperture and any other permanently interposed filter.

The values of these tables are based on:

1. The average output of a typical installation.

2. The average figure of 275 roentgens for a "threshold erythema."
3. A factor of 50% which is necessary to cover unpredictable variations in either of the first two factors.

These values are intended to serve only as a guide and should be replaced by similar styled tables based on the actual measured output of the installation and the user's estimate of the value of the "threshold erythema."

For assured safety, these tabulated values *shall not be exceeded* until replaced by the user's own values.

Keep a record of exposure factors used during the examination.

THERAPY

(Superficial—Intermediate—or Deep X-Ray Therapy)

In using x-ray equipment for therapeutic purposes it may be necessary to administer dosages which approximate those dangerous to normal tissue. Adequate but safe dosage is dependent upon the diagnosis of each individual case, the location of the pathological condition and the peculiarities of the patient. Therefore, the responsibility for prescribing dosage and its method and schedule of application must rest solely with the physician as it is impossible for the manufacturer to indicate dosages, methods, or schedules of application.

Warning, however, is given that the use of x-ray therapy should, under no conditions, be attempted by a physician without previous thorough training in the principles of radiation therapeutics.

Calibration of equipment. Although before shipment this equipment was operated and thoroughly tested at a number of settings in accordance with its test specifications, following installation it should not be used in any therapeutic application until its output is measured by a radiation physicist to provide standardization or calibration.

Re-check standardizations or calibrations should be made periodically, and also following any change in location, tube, equipment, filter, or power supply which may alter the radiation output.

Importance of complete treatment records. Because of the hazards of the cumulative effects of radiation in x-ray therapy, as well as for other reasons, complete records should be maintained in each case. These should include all past history

which may have an influence on the diagnosis or treatment of the pathological condition and should particularly include all details of any previous exposure to x-radiation or radium. These records should be kept in accordance with recommendations of the scientific societies or recognized text books on this subject and should accurately record the radiation intensity in roentgens per minute, dosage, location and size of treatment area, treatment distance, kilovoltage, milliamperage, filter used, time, etc.

Facilities for accuracy of dosage measurement. Various types of treatment timers, constancy meters and integrating dosimeters are available for use as means of providing convenient measurements of desired dosage.

There are cones of various sizes and lengths available to limit the size of the treatment area and more easily gauge the treatment distance.

INTERNATIONAL RECOMMENDATIONS

The following is quoted from "International Recommendations for X-Ray and Radium Protection," revised by the International X-Ray and Radium Protection Commission at the Fifth International Congress of Radiology, Chicago, September, 1937. (NOTE: These recommendations were completely published in Radiology, Vol. 30, No. 4, p. 511, April 1938.)

"I. INTERNATIONAL RECOMMENDATIONS

"1. The dangers of over-exposure to x-rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of x-ray and radium departments to ensure such conditions for their personnel. The known effects to be guarded against are:

- a. Injuries to the superficial tissues;
- b. Changes in the blood and derangements of internal organs, particularly the generative organs.

"The evidence at present available appears to suggest that under satisfactory working conditions, a person in normal health can tolerate exposure to x-rays or radium gamma rays to an extent of about 0.2 international roentgens (r) per day, or 1 r per week. On the basis of continuous irradiation during a working day of seven hours, this figure corresponds to a tolerance dosage rate of 10^{-5} r per second. The protective values given in these recommendations are generally in harmony with this figure under average conditions.

"III. X-RAY PROTECTIVE RECOMMENDATIONS

"10. An x-ray operator should on no account expose himself to a direct beam of x-rays.

"11. An operator should place himself as remote as practicable from the x-ray tube. It should be borne in mind that valve tubes are capable of producing x-rays.

"12. The x-ray tube should be self-protected, or otherwise surrounded as completely as possible, with protective material of adequate lead equivalent.¹

"13. The following lead equivalents are recommended under average conditions:

<i>X-rays generated by peak voltages</i>	<i>Minimum equivalent thickness of lead</i>
Not exceeding 75 kv.	1 mm.
100	1.5
125	2
150	2.5
175	3
200	4
250	6
300	9
350	12
400	15
(600)	(35)

"1. The lead equivalent of a given thickness of protective material is that thickness of lead which is equally opaque to x-rays excited at some specified peak voltage."

The objective sought by the position, type, and amount of protective material which should be used for a given installation is to limit the amount of radiation reaching a given location to not more than that quantity which "corresponds to a tolerance dosage rate of 10^{-5} r per second."

For such reasons as distance from the primary emitting source, material used in the building structure, location of others with respect to the primary beam, equipment construction and inherent filtration, the thickness of protective material required to provide adequate protection to all may for some locations be less than shown in the above table.

The essential requirement is not the thickness nor the type of protective material used but rather, that it shall be used in such quantities and locations as to prevent any individual from being subjected to a dosage rate in excess of 10^{-5} r per second.

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