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WARTIME MILITARY ROENTGENOLOGY[1]

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IN TIMES of peace, an alert army prepares for the possibilities of war. This is especially true as far as the "combatant forces" are concerned. The duties of the Medical Department are more varied and much of our time is consumed with strictly professional work. In this, our interests and activities have been similar to those of our confreres in civil practice. We have relied upon conventional methods and accepted hospital procedures, using standard items of equipment and depending upon commercial supplies and installations in much the usual manner.

In these days, however, it behooves us to give serious thought to the types of medical activity required for expansion of our army to four, five, or possibly even greater multiples of its "normal" peacetime strength and then to adjust and readjust continually so as to be able to coördinate our services and activities with the rapid changes which may be expected. We must consider working conditions under heavy aerial attack as well as those produced by the rapidity of movement of motorized units. We can no longer depend upon plans made on the basis of trenches and "pill boxes" and slow moving fronts as in the last Great War.

Radiologically, great strides have been made during the past twenty-two years. Our science became generally appreciated during the war years 1914 to 1918. Since that time our leaders have pointed out to us very tangible criteria which to-day substantiate our diagnoses to a reasonably accurate degree. We have become used to shock-proof performance, high milliamperage, and elaborate equipment. Yet, for field activities, we must yield to some extent to the requirements of quick disassemblage of our apparatus and provide for its easy portability. Thus, there are presented indications for new planning and new designing.

A discussion of this planning resolves itself into two phases: roentgen requirements near home communities and roentgen requirements in the theatre of operations.

ROENTGEN REQUIREMENTS NEAR HOME COMMUNITIES

One might boldly assert that it is only during the last five years that doctors everywhere have come to recognize roentgenography as the most trustworthy method of studying the chest. True enough, there were certain pioneers, such as Sawyer (11), who as far back as 1923

[1] Presented before the Twenty-sixth Annual Meeting of the Radiological Society of North America, at Cleveland, Dec. 2-6, 1940.

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"seriously questioned. . . the efficiency of the stethoscope" and expressed doubts regarding the prevalent opinion that, "as compared with the physical examination, the roentgenological examination, even when done by experts, occupies a place of secondary importance in the diagnosis of tuberculosis of clinical significance."

On July 23, 1940, the committee on tuberculosis, of the Division of Medical Sciences of the National Research Council, in considering the matter of large-scale examination as planned for expansion of the U. S. Army (9), recommended that a chest x-ray film be made of each registrant, *supplemented* by physical examination and laboratory study as indicated. This recommendation, the committee explained, was based upon the following facts:

"(1) At least 75 per cent of early active tuberculosis can be discovered only by x-ray examination.

"(2) About 1.0 per cent of the male population of military age has active tuberculosis, most of which can be detected only by x-ray examination.

"(3) A high proportion of cases of early tuberculosis, detectable only by x-ray examination, are likely to break down under such strain as that entailed by military duty, incapacitating them for further service and making them a menace through contagion to their comrades.

"(4) X-ray examination is more expeditious than physical examination, thereby saving considerable time in the general examination.

"(5) X-ray film examination furnishes a permanent and authoritative record which may be useful in subsequent medico-legal adjustment.

"(6) Other conditions than tuberculosis which would make the registrant unfit for military duty may be discovered by x-ray examination.

"This procedure will amply repay the cost by saving of effective military man power, and reducing the ultimate cost to the Federal Government in pensions."

Spillman (12) estimates that "tuberculosis during and after the World War has cost approximately $960,000,000 to date in compensation, vocation training, insurance, and hospitalization," and that within the next five years these costs will pass the billion dollar mark.

The Medical Department of the U. S. Army is planning, in so far as possible, to include roentgen studies in the physical examination both at the time the recruit is examined for admission to the service, or shortly thereafter, and again just before discharge from the service becomes effective. It is planned that most of the roentgen studies of the chest will be done by photoroentgenography, using 4 × 10-inch films (two exposures), checking doubtful cases by the standard 14 × 17 inch roentgenograms. Time does not permit a detailed discussion as to why this particular method was adopted. Suffice it to say that all known possibilities of accomplishing the desired result have been analyzed in terms of relative merits as regards: (1) diagnostic reliability, (2) speed of examination, (3) preservation of records, (4) initial cost, (5) unit cost, (6) availability of supplies, and (7) ease of study. With reference to the first of these considerations, it seems only proper to quote Potter, Douglas and Birkelo (10), who state that "the 4 × 5 inch photoroentgenograph is quite accurate. (Only 2.6 per cent error in detecting 271 cases with active tuberculous lesions as found in the full size film taken of 1,610 persons.)" Similar expressions by de Abreu (2), Lindberg (7, 8), Hirsch (4), and others are no doubt well known.

It is anticipated that the chest studies will be one of the first steps in the examination of the candidate and that by the time he reaches the chest examiner, a report of the roentgen study will be available. In this way, the actual physical examination of the chest will be expedited, for the examiner will be given a lead as to whether he should concentrate on the heart or the lungs and, in the case of the latter, on which part. Where photoroentgenographic equipment is provided, two exposures rather than one are planned for each applicant, as this appears preferable and the additional cost is slight. At first, it is planned to use two positions. One exposure will be made with the chin raised and the scapulae rotated laterally and forward, the candidate standing in front of the fluoroscopic screen in the conventional manner, as when 14 × 17 inch films are used. The second exposure will be made with the clavicles raised by elevating the upper extremities. It is anticipated that this procedure will be changed to the extent of making a true stereoscopic pair (providing for shifting of the x-ray tube) as soon as equipment is available for proper and rapid viewing of the miniature films and then, possibly, utilizing 35-mm. films as well. The objectives are more than merely to provide for depth perception. Consideration is also given to the increased accuracy of interpretation provided by true stereoscopic projections because of (1) the separation of parenchymal densities from overlying soft-tissue densities, such as the cardiac silhouette and diaphragm, and from osseous densities such as the ribs and spine; (2) the distinguishing of peribronchial irregularities which may be due to involuntary movements of the pulmonary vessels, from actual changes in the lymphatics or fibrous tissues; (3) control against deceptive artefacts which may occur either because of transient changes in radiographic performance or improper handling of the films. Particular attention will be given to the apices and the infraclavicular regions, and for these portions of the chest we believe that either the two-position technic or the stereoscopic pair will so add to the procedure that we may expect our diagnostic accuracy to reach, if not to exceed, that which would be obtainable with a single 14 × 17 inch film. At the same time, the unit cost will be much reduced, comparatively, and we shall have actual lifetime graphic records, of dimensions which will permit filing with the other records of the individual. The use of 14 × 17 inch film would require separate filing, with the probable result that the films would be stored in one part of the country while the remaining records were filed in another, thus defeating the object of comparative studies. For the same reason, fluoroscopy has not been considered practical. Fluoroscopy, moreover, could hardly be given a comparable degree of diagnostic trust (3), particularly as the roentgenologist would have to view from 200 to 400 or more candidates in a day.

The photoroentgen studies, as well as other roentgen studies (as requested), will be conducted at the army examining boards, of which it is anticipated there will be approximately one hundred scattered throughout the United States. An examining team will consist of approximately twelve officers, and it is anticipated that each team will be able to examine at least 200 men in an eight-hour day. A radiological group will include one roentgenologist and five to seven technicians. The equipment will consist of a high milliamperage capacity unit (200 ma. or higher), an adjustable tube column, a cassette changer, a photoroentgenographic unit (for many of the installations), and provisions for film-processing. Much of this apparatus is already available, in suitably situated army posts. Most additional purchases will provide actual war reserves of materials which may later be used in general hospitals.

ROENTGEN REQUIREMENTS IN THE THEATRE OF OPERATIONS

The front five to seven miles in a theatre of operations will be manned by troops of the divisional units. With these units there will be two types of medical troops: the so-called "attached medical troops" and those of the "medical battalion" (in the case of the stream-lined or triangular divisions) or the "medical regiment" (in the case of the square type of division). The attached medical troops will serve with the combatant troops, as in the last Great War, and will move along with their respective units, getting out onto the battleground, if necessary, to recover casualties and carry them back to "battalion aid stations." Beginning with the battalion aid stations, the personnel of the "medical battalion" or the "medical regiment" will take over the care of such casualties. It is not within the province of this paper to discuss the various activities which will be conducted in the several installations of the medical battalion or regiment except to say that after emergency dressings, tourniquet applications, or splintings at the battalion aid stations, the wounded men will be evacuated as quickly as possible to "collecting stations" and from thence to "clearing stations," comparable to the "hospital stations" of the last war. There, the "non-evacuables" will be selected and turned over to the care of the "mobile surgical hospital." Those who are in condition to stand further evacuation will be transported by ambulances of corps troops, to an "evacuation hospital."

These details are presented merely to indicate in a general way just where the personnel and equipment of the x-ray service fit into the general scheme. It does not seem practical to plan on any x-ray activities for the divisional area. X-ray personnel are not included with the attached medical troops, nor with the medical battalion or medical regiment. The most advanced installation in which x-ray services will be available is the mobile surgical hospital, which, as just mentioned, will be located in the vicinity of the "clearing station" of the medical battalion (or hospital station in the case of the medical regiment); that is, approximately five to seven miles to the rear of the front lines. The mobile surgical hospital is an army unit which moves forward, as needed, into the zone of communications, particularly into a position near a clearing station. The accompanying diagram (Fig. 1) shows these

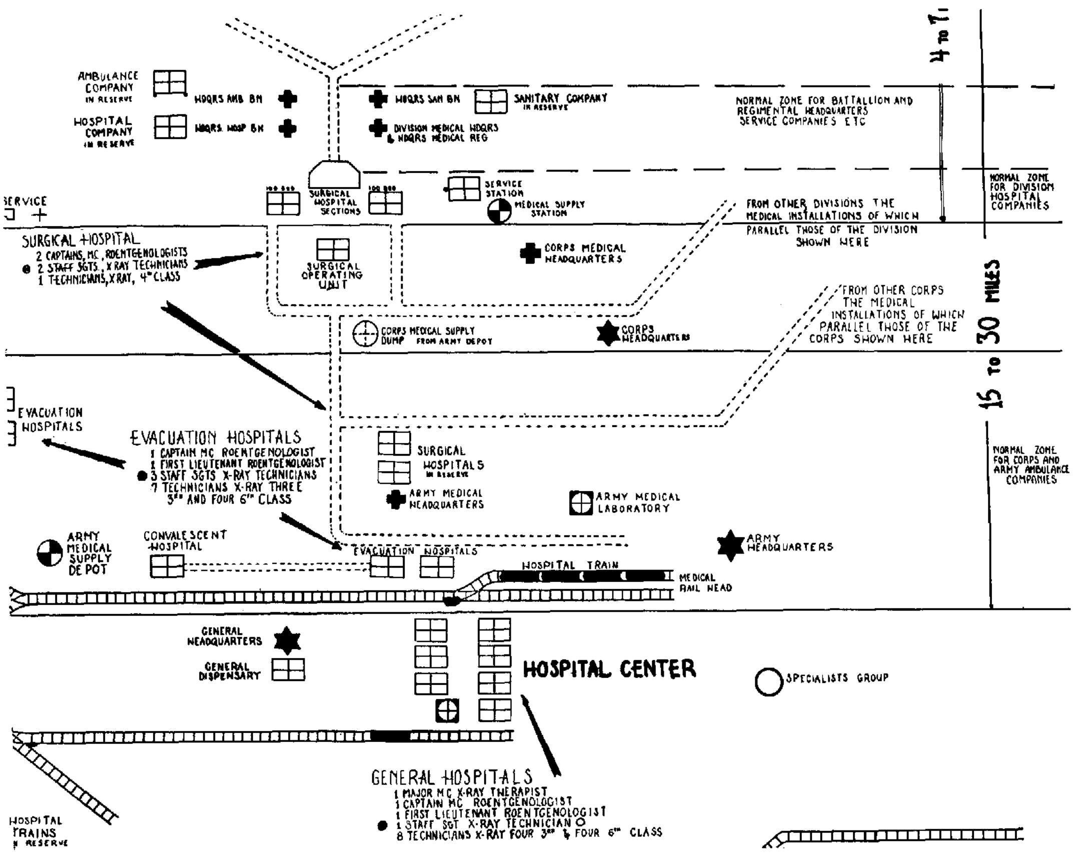

Fig. 1. Showing the relative positions of the three important installations in the theatre of operations where radiological activities will be provided for front line casualties.

relations and lists the x-ray personnel of this installation as well as of other installations engaged in roentgen activities further to the rear.

The Mobile Surgical Hospital.—The mobile surgical hospital is composed of two sections: a mobile operating unit and a hospitalization unit. The former, especially, can be quickly moved, as its important components are motor units (operating, x-ray, sterilization, and supply). The personnel and equipment of this "operating unit" will move into position where "non-evacuables" have accumulated, and there proceed with roentgen and surgical activities before moving on to another similar location. After surgical treatment of these "non-evacuables," postoperative and shock care will be conducted by the "hospitalization unit," comprising one or two sections, each consisting of a tent hospital with accommodations for one hundred beds. After being treated to a sufficient extent to permit further carriage to the rear, the casualties who were previously considered as "non-evacuable" will be transported to evacuation hospitals.

As indicated on Figure 1, two roentgenologists and three x-ray technicians are included in the personnel of the mobile surgical hospital. As in the last Great War, it is believed that most of the x-ray activities here will be fluoroscopic, including localization of foreign bodies. For general fluoroscopy, our equipment provides for considerable movement of the x-ray tube. Not only will horizontal fluoroscopy be easily managed, but in cases where fluid may be suspected in the thorax, or free gas in the abdomen, it will be possible to support a patient in a sitting position and quickly shift the x-ray tube and screen for vertical fluoroscopy.

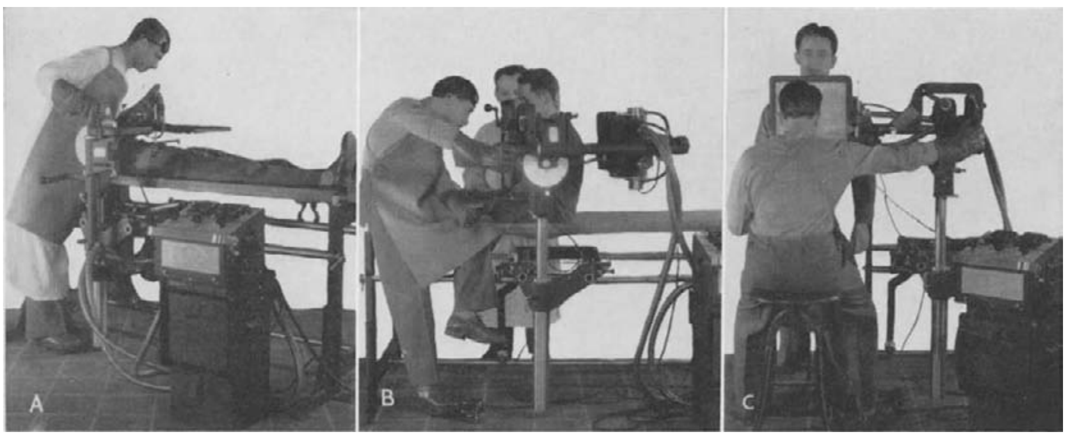

Fig. 2. The fluoroscopic adaptations of the x-ray table unit. Figure *A* shows the position of the C-shaped member for horizontal fluoroscopy and for foreign body localizations. Note the depth scale and skin marker manipulated by the left hand of the operator. The localization scale is in its position, fixed on the operator's end of the horizontal carriage. Figure *B* shows the adaptation of the C-shaped member for sitting fluoroscopy. A spacer falls into position to indicate the minimal focal-skin distance (12 inches). Figure *C* shows the adaptation of the C-shaped member for standing fluoroscopy. The range of movement provides for studies both of the chest and the abdomen.

To provide for this range of manipulation, it was necessary to make use of shock-proof cables with the x-ray tube detached from the transformer tank. This requirement presented several problems, notably (*a*) limitation of fluoroscopic capacity—for, as is well known, the conventional arrangement of this sort has permitted fluoroscopy with 3 to 5 ma. and kilovoltages up to 80 for a maximum of only ten to twenty minutes—and (*b*) the risk of breakdown of the shock-proof cables. The utmost co-operation has been given by the manufacturers in solving these two problems. Thanks to their keen interest[3] a continuous fluoroscopic rating (using milliamperages up to 5 with kilovoltages up to 85) has been provided by means of such improvements in tube housing design as the inclusion of an air circulator about an inner housing, the provision of an oil agitator, and the special construction of an unusually substantial x-ray tube insert. There has also been improvement of the design of shock-proof cable terminals. The U. S. Army is adopting a terminal slightly longer than that used conventionally (the male adaptor measuring 5 11/16 inches in length) and including a concentric ring type of contacts. With this terminal, pulsating potentials as high as 130 kv. (peak) have been withstood for two hours continuously, and 140 kv. for as long as one hour (test period). The concentric ring contacts provide for release of torsional strains and thereby reduce the likelihood of bending of the cables. Since breakdowns of cables usually occur at sites of strains or bends, it is believed that these improvements have eliminated difficulties which might ordinarily have been expected.

Figure 2 demonstrates the adaptation of the table unit for horizontal fluoroscopy and for fluoroscopy in the sitting and standing positions.

Many methods of foreign body localization have been studied and tested with experimental models.[4] It seemed essential that a method be adopted requiring no detachable small parts which might easily be lost. Equally important seemed to be speed of performance and the minimizing of exposure of the patient to radiation. Our method fulfilling these prerequisites involves two construction features and two adjustable attachments. The construction features include (1) the utilization of a "C-shaped" arm supporting the x-ray tube and the fluoroscopic screen, providing for a fixed focal-screen distance of 66 cm., and (2) the incorporation of three sets of intersecting lines, inscribed for alignments on the fluoroscopic field (one of these intersecting lines is located in the center of the fluoroscopic screen while the other two are spaced 11 cm. in opposite directions from the central set, *i.e.*, 22 cm. apart or one-third of the focal-screen distance). The two attachments are (1) a combination skin marker and depth scale, for measurement of depth of the skin level beneath the level of the fluoroscopic screen (located on its staging) and (2) a localization scale for indicating the depth of the foreign body beneath the skin level, similar in construction to a slide rule and mounted on the horizontal carriage of the table chassis. For the procedure of localization see Figure 3.

It has been mentioned that two roentgenologists are assigned to each mobile surgical hospital unit. At times, no doubt, both may be busy with fluoroscopy of incoming casualties, foreign body localization, and general studies in co-operation with the operating teams. Actually, however, one is really assigned to the hospitalization unit and the other to the operating unit. When the latter moves away to operate in another location, the hospitalization unit will be left with one roentgenologist (plus the other physicians assigned to it). His subsequent x-ray

[3] Credit is due Mr. E. R. Goldfield and the Picker X-ray Corporation for developing the special tube housing and shock-proof cable terminals, and to Mr. Ray Machlett and the Machlett Laboratories for developing a special x-ray tube insert having unusually high capacities.

[4] After a number of models of the table unit had been constructed at the Army Medical School, the manufacturers were invited to construct similar models on the basis of specifications descriptive of function. The H. G. Fischer Co. was the first to respond; then, in order, models were submitted by J. Beeber & Co.; Picker X-ray Corporation; Westinghouse X-ray Co., and the Kelley-Koett Mfg. Co. Further designing at the Army Medical School included the favorable features incorporated in these models and finally, on the basis of biddings, the Westinghouse X-ray Co. was given a contract for construction of the first quantity supply of the table unit as described in terms of function and construction features. Recognition is accorded to these several companies for their splendid co-operation and particularly to Mr. F. M. Hoben, Mr. J. H. Davis, and Mr. O. C. Hollstein of the Westinghouse X-ray Co.

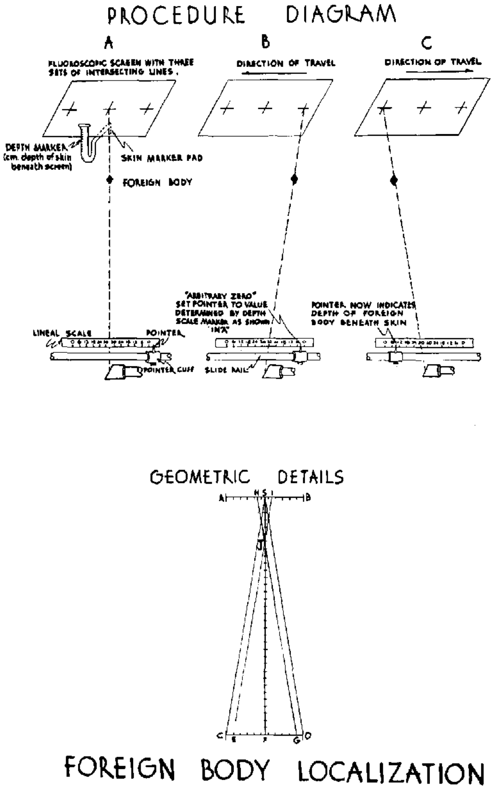

Fig. 3. Foreign body localization. Before proceeding with localization of a foreign body at an unknown depth, place depth phantom in position and check measurements. If indicated, adjust reading level on depth scale marker (this level is adjustable to provide for variations in the position of the focal spots of one or another x-ray tube).

1. Check fixation locks on "C-shaped" member; secure alignment of focal spot to center of fluoroscopic screen.
2. Align a prominence on foreign body to intersection of central intersecting lines.
3. Dampen skin marker pad with tincture of iodine or ink and adjust it to this alignment (foreign body and intersection of central intersecting lines); lower skin marker pad, until it rests on the skin, thereby marking it.
4. Read distance between fluoroscopic screen and skin by way of scale on depth marker (*A*).
5. Shift tube and fluoroscopic screen so as to align the same prominence of the foreign body, as considered in Step 2, to the intersection of either of the outer intersecting lines (*B*).
6. Slide localization scale and adjust pointer to the centimeter value coinciding with the centimeter distance between the fluoroscopic screen and the skin as measured in Step 4, above; clamp cuff for fixation of pointer to side rail of table.
7. Slide x-ray tube and fluoroscopic screen in direction opposite to that used in Step 5, above, until the same prominence on the foreign body becomes aligned to the intersection of the opposite outer intersecting lines (*C*).
8. Read on localization scale, the depth of foreign body beneath the skin.

In the diagram showing geometric details *A-B* equals spacing between outer intersecting lines; it is equal to 22 cm. *F-S* equals focal-screen distance (focal spot to intersection of central intersecting lines); it is equal to three times *A-B*, or 66 cm. (plus or minus minor deviations in the position of the focal spot).

If a foreign body were located at *S* (*i.e.*, just beneath the intersection of the central intersecting lines), for its alignments to the intersection of the outer intersecting lines at *A* and then at *B*, the x-ray tube would have to be moved with the fluoroscopic screen for a distance equal to *C-D* (*C-D* equals *A-B*, *i.e.*, 22 cm.). In the case of foreign bodies located at other levels below the plane *A-B*, the same ratio relationship would hold, that is, the range of travel of the x-ray tube and fluoroscopic screen for the alignment of the foreign body with points *A* and *B*, respectively, would be one-third the distance *F-J*.

Since the triangle *E-J-G* is similar to triangle *J-H-I*, the distance *S-J* bears the same ratio relationship to *H-I* as does *J-F* to *E-G;* that is, a three to one ratio.

H-I is equal to *H-S* plus *S-I*.

H-S equals *G-D* while *S-I* equals *C-E;* therefore, *H-I* equals *C-E* plus *G-D;* *C-E* plus *G-D* is the untraveled distance, with reference to the scale (22 cm. minus the distance of travel), which actually measures the location of the foreign body beneath the fluoroscopic screen.

The distance between the fluoroscopic screen to the skin is subtracted by making the adjustment of the pointer to an "arbitrary zero" as indicated in diagram *B*. Thereby, the reading of the untraveled distance (indicated on the localization scale) provides the measurement of the foreign body beneath the skin level.

work will include fluoroscopy of various types and probably roentgen therapy for superficial infections, including gas gangrene (6).

Our x-ray machine unit provides for superficial therapy. Because of employment of a detached x-ray tube and shockproof cables, it was necessary to specify a high degree of transformer regulation. We have limited the inverse voltage to 12 kv.p. in excess of the useful voltage under a load of 30 ma. (meter reading) and at a useful potential of 85 kv.p. With such regulation of transformers and an x-ray tube of high heat capacity (as provided for continuous fluoroscopy at 5 ma. and 85 kv.p., allowing for safety margin), we found ourselves in a position, without further provision, to carry out superficial roentgen therapy at 4 ma. and 100 kv.p., continuous operation. Many believe that very little roentgen therapy can be expected in the mobile surgical hospital. Others (1, 5) insist that provision must be made for it. This has been done without any special apparatus except aluminum filters. The dosages for this work would, of course, be small and would be based upon predetermined calibration of r performance. Whether or not time will permit the administration of roentgen therapy at the mobile surgical hospital, this x-ray machine unit will doubtless be used for that purpose in one or another installation, for the same unit will be found in the evacuation hospital, in the general hospital, and in the station hospital.

Fluoroscopic examinations might be conducted in a light-proof truck or in an "insert tent," which has been designed for either fluoroscopy or film processing. For fluoroscopic purposes, the inner front curtain is adjusted close behind the outer front curtain and flap arrangements are provided to admit the litter bearers and patient, as shown in Figure 4. After these have passed in or out, the curtains fall by their own weight, thereby providing for closure and a dark compartment. A light-proof motor-powered ventilator is installed in the upper portions of the framework of the tent. So that it may be erected out of doors a one-foot pitch is provided for the purpose of shedding rain. It can also be erected in any room, cellar, or dugout, since ground poles and ground pegs are not used. If necessary, the side and rear curtains can be held down by piling sand bags, rocks, or even dirt upon their 18-inch over-length aprons. For adaptation as a film processing compartment, the inner front curtain is set back 20 inches and three light-weight auxiliary drapes are extended so as to provide a labyrinth. It is not likely that this arrangement will be needed for the ordinary activities of the surgical hospital, since in that installation the rush of work would hardly permit roentgenography. Two of these tents, however, will be included for purely fluoroscopic purposes. It is anticipated that there will be times, when the tide of battle is favorable, at which this hospital will take over the activities of

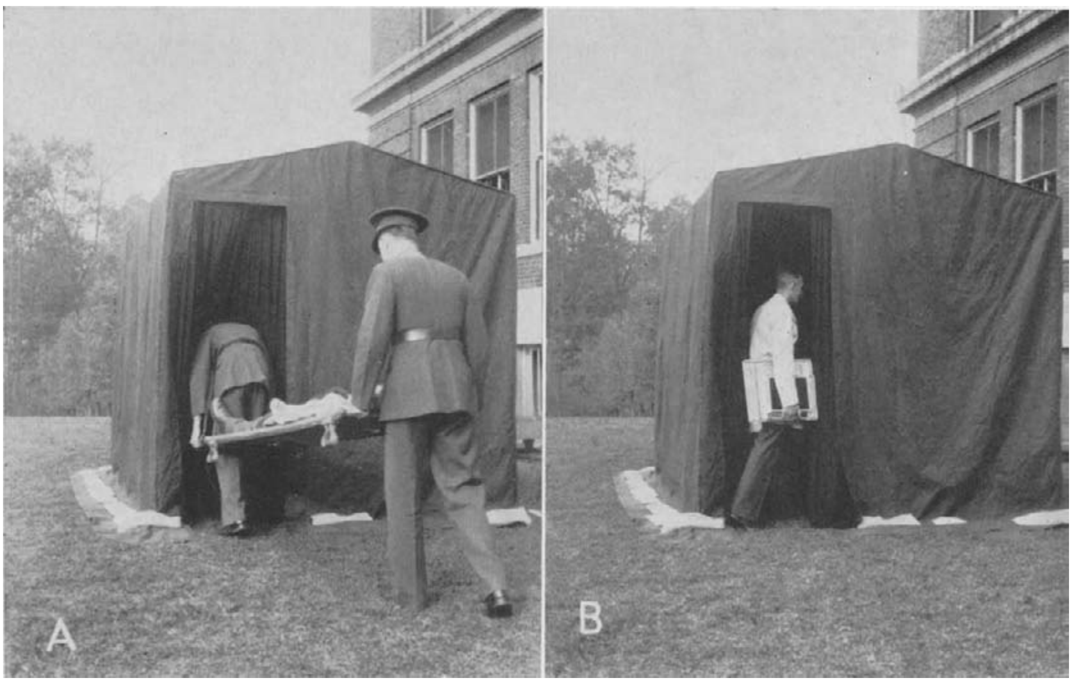

Fig. 4. Tent for fluoroscopy and/or film processing. *A* shows the position of the adjustable inner curtain for fluoroscopy while *B* shows the inner curtain set back in position for film processing. In this latter position, three drapes are extended for the development of a labyrinth—into which the technician is shown walking.

the evacuation hospital and under such conditions at least one additional tent will be needed for film processing.

A gasoline electrical generator will be supplied for each mobile operating unit and each hospitalization unit, as a community electric supply can hardly be expected to be available. This generator is of special design such as to provide for a wave form very similar to that of the average community line. This feature is important for several reasons. Otherwise, the kilovoltage calibration values might not hold true, unfavorable surge values might result, and excessive inverse occur. Moreover, the performance of this gasoline generator must be sufficiently steady that when the high-tension circuit is opened by stepping off the fluoroscopic switch, there will be no appreciable racing of the engine with resultant overload of the filament circuit and destruction of the filament of the x-ray tube.[5] This generator has a rated capacity of 2500 watts. Its weight, including its special field chest, is under 200 pounds. Because of the special requirements, it is listed in the supply catalogue as a separate item to be used exclusively for x-ray purposes. It will provide for operation at 30 ma. with a kilovoltage of 85 though, for the sake of a safety margin, warnings are appended that the operation be limited to 15 ma. The values for roentgen therapy can easily be satisfied.

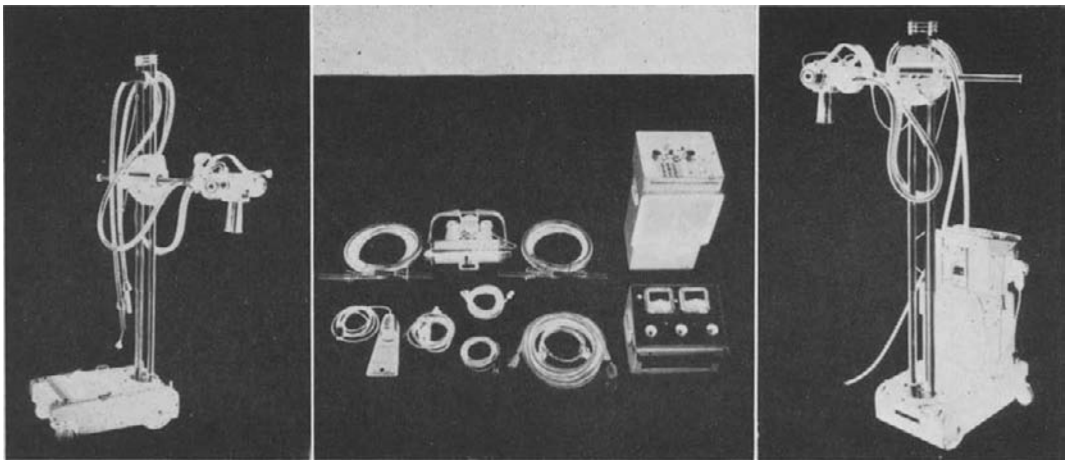

Fig. 5. X-ray machine unit and the mobile x-ray chassis. The figure to the left shows the chassis unit complete with a tube unit, cone, and pair of shock-proof cables. All of these parts will be included with this unit as supplied in times of war. Otherwise, the tube unit and cables shown with the x-ray machine unit (middle figure) will be assembled as needed. The figure to the right shows the complete assemblage as this unit would be used for ward work.

Still another item will be included with the hospitalization unit of the mobile surgical hospital. This item we call a "mobile x-ray chassis." The component parts of the x-ray machine unit can be mounted upon it and with this combination there is developed a bedside unit, particularly for the administration of superficial x-ray therapy in the ward (and bedside roentgenography for installations other than the mobile surgical hospitals). This arrangement is shown in Figure 5.

The Evacuation Hospital.—The evacuation hospital provides treatment of a fairly definitive sort for those casualties which can be immediately transported to the rear by way of the "clearing station." Such casualties should reach it in twenty-

[5] Credit is due Mr. E. R. Goldfield and the Picker X-ray Corporation for their special testings of these performances and for recommendations which have led to the construction of a satisfactory gasoline electrical generator. Recognition is also accorded Mr. Robert Worth of the Homelite Corporation and Mr. D. W. Onan of D. W. Onan & Sons for their splendid co-operation in redesigning and reconstructing their generators.

four to forty-eight hours. It also receives patients treated at the mobile surgical hospital, as soon as they are in condition permitting further transportation. The evacuation hospital is usually located at a railhead, 15 to 30 miles behind the front lines. It may have accommodations for as many as 750 patients. It is a more substantial installation than the mobile

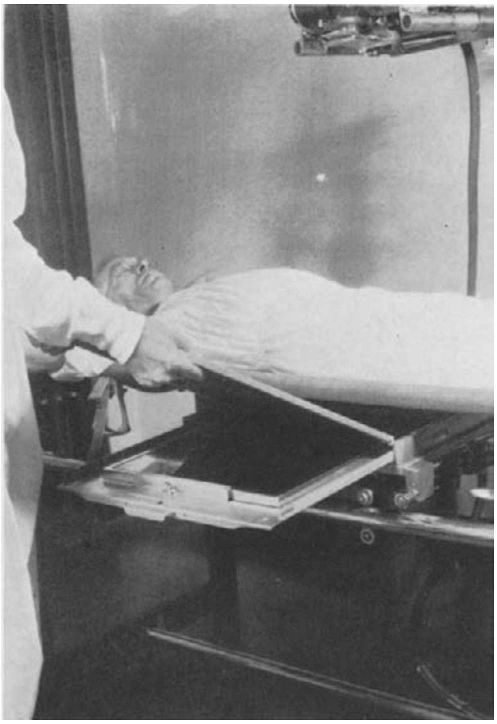

Fig. 6. The portable grid unit mounted on the horizontal carriage, in position for roentgenography. Note that vertical adjustment has been made so that the grid is at the level of the litter sag. The wafer grid itself is being lifted out from its housing, as is possible when it is needed for use in the ward. Note the cassette beneath the grid and its accommodation in a standard cassette tray.

surgical hospital; it is usually set up in a temporary building or in some building taken over for the purpose. Ordinarily, it can be expected to remain in one location for some months; therefore, heavier types of equipment are not impractical for it. For x-ray activities, however, it is expected to use the same types of equipment as described for the mobile surgical hospital. As shown in Figure 1, the personnel of the x-ray department will include one captain and one lieutenant (as roentgenologists), and seven technicians. Most of the work will be fluoroscopic, though it is estimated that perhaps 10 per cent of the activities may be roentgenographic. Therefore, films and cassettes and dark room equipment must be provided. The films and cassettes will be transported in standard Carlisle field chests; the ones accommodating films will be lead lined. The light-proof insert tent, described above, can be installed in any room so as to provide quickly for film processing.

A special loading bin and dryer combination has been developed,[6] consisting of two compartments, providing for easy portability. One compartment is lead lined for the protection of films and loaded cassettes. This compartment is designed for mounting upon the dryer compartment, and with this combination a loading bench is provided. The dryer compartment contains a heating element and an air circulator and accommodations for eighteen films in hangers.

A special processing tank unit has likewise been developed.[7] This unit also consists of two compartments, providing for portability. The base compartment contains a heating element and a refrigeration element, plus a mixing chamber, thermostatic regulator, and water circulator. The tank compartment has a capacity of 50 gallons and accommodations for two insert tanks of sizes varying from 3 to 10 gallons. A rack is provided for suspension of no less than eighteen hangers for washing of films. This tank compartment is designed for mounting upon the base compartment and the unit is ready for operation after merely connecting two water circuit couplings, filling the master tank compartment with water, and connecting the line cable to a socket for electrical supply. Community plumbing connec-

[6] Appreciation is expressed for the co-operative interest given this problem by Mr. J. S. Cowles and the Buck X-Ograph Company.

[7] Credit is due Mr. C. F. Moores and the Westinghouse X-ray Co. for their coördinate interests in developing a special unit to satisfy our needs.

tions are not necessary, though provision is made to utilize either a cold water supply alone or cold and hot water supplies. The insert tanks are of stainless steel, providing for durability, ease of cleaning, and rapid temperature exchange. If necessary, an auxiliary wash tank may be introduced into the circulating system.

As mentioned, the equipment for fluoroscopy and roentgenography will be the same as that used at the mobile surgical hospital. The tube-supporting member of the table unit can be rotated over the table chassis for roentgenography with the patient in the horizontal position. The table top itself is a removable litter. This feature would seem to be ideal, since it makes it unnecessary, for either fluoroscopy or roentgenography, to move the patient from a litter to a table-top and back again to the litter. In order to obviate the necessity of even raising the patient for placing a film beneath him, there has been designed a special grid arrangement. As shown in Figure 6, this grid can be mounted upon the horizontal carriage of the table unit. Its design is such as to provide for elevation adjustments of the grid and cassette to variable levels depending upon the sag of the litter with the weight of the patient. The grid itself is of wafer type. It is planned that a spring arrangement shall be incorporated to provide vibration of this grid for reduction or elimination of the grid markings. This is still in the developmental stage. The design does provide, however, for completely detaching the grid and carrying it as a cassette for use at the bedside.

The supporting arm for the x-ray tube can be adjusted in the vertical plane so as to provide for varying focal-film distances, the cassette being placed in the cassette tray, immediately beneath the grid. The true radius of this grid is 36 inches, but it can be used with focal-film distances varying from 28 inches to 48 inches without appreciable cut-off. Moreover, the grid itself may be removed and the cassette simply placed in the tray beneath the part to be studied. The x-ray tube can be adjusted to a 90° rotation whereby sitting or standing roentgenography may be performed with focal-film distances varying up to 6 feet or more. Moreover, the tube may be adjusted so that 6-foot focal-film distances may be utilized with the patient lying on the litter upon the floor.

The General Hospital.—After treatment at an evacuation hospital, casualties might be returned to duty or they might be evacuated further to the rear, in which case they would be transported to a general hospital. General hospitals are usually located thirty miles or more behind the front lines. They serve to provide special and prolonged treatment, when indicated. As a unit, a general hospital may be considered to accommodate 1,000 patients. There may be multiples of such units, whereupon there would be developed a "hospital center," having accommodations for 2,000 or more patients. These installations are usually of permanent or semi-permanent construction. The radiological requirements are as varied as would be expected for any large institution in civil practice. To each 1,000-patient unit there will be assigned one major (as radiologist), one captain and one lieutenant (as roentgenologists), and eight enlisted technicians. Equipment such as described for the other installations will be found here, and, in addition, larger equipment of conventional commercial design. There will be a 100 ma. single tube, double-duty unit, as well as a 200 ma. unit and four to six conventional bedside units. Roentgen therapy equipment will be included, as well as various other types of special apparatus.

The Station Hospital.—Station hospitals are not included in the line of evacuation for actual battle casualties. They provide for medical and surgical care of personnel connected with units which are not actually engaged in conflict. Their location is usually 10 miles or more behind the front lines. These hospitals vary in capacity from 25 to 250 beds, or more. Provided the professional activities warrant, a roentgenologist may be included among their doctor-personnel. This roentgenologist may be of rank as high as a major and he may be assisted by as many as five technicians. It is believed, however, that all the roentgenological needs for this installation can be provided with the equipment which has already been described for the evacuation hospital.

SUMMARY

It is planned that roentgenological studies will be included as an important phase of the physical examination of candidates for service in the U. S. Army. Ultimately, roentgenographic studies of the chest, using the method of photography of the fluoroscopic image, will be accomplished routinely before acceptance and again before discharge. In this, the objectives are threefold: (1) to eliminate those whose physical condition would not withstand the rigors of army life; (2) to avoid dissemination of tuberculosis because of the close contacts incident to groupings of large numbers as required in the service; (3) to maintain graphic records of chest conditions in order to provide for proper adjustment of any claims which might be made against the Government.

For the theatre of operations the designing of equipment has been governed by at least three axiomatic principles: (1) versatility of adaptation to the extent that each piece of equipment will function not merely for a single purpose, but for several requirements and installations; (2) portability to the extent that disassemblage of each item can be easily accomplished and that the component parts can be easily carried, the weight of any one part not exceeding two hundred (200) pounds, and (3) practicality of design to the extent that the equipment can serve the requirements of function in peace-time installations as well as in zones of combat. Relative to this last principle, certainly this equipment should be thoroughly understood by those who are to use it under occasions of combat. A thorough acquaintance as to handling it can best be obtained by using it day after day for ordinary routine activities. Moreover, its use in times of peace will no doubt lead to improvements so that it will not be necessary on mobilization day suddenly to develop new designs in order to incorporate new principles that may be discovered. In addition, two other attributes are provided by this general principle of designing war-time equipment in such a way that it is practical for use in peacetime installations: (1) a war reserve stock of supplies is provided so that, in case of a sudden emergency, equipment will be available for moving into the field without awaiting supply from manufacturers; (2) because of steady purchases, the manufacturers will be informed as to just what the army will need in large quantities, and they will therefore have set up the necessary jigs, dies, and other tools necessary for uniform and large-scale constructions.

Applying these principles, the combination x-ray table unit, x-ray machine unit, and mobile x-ray chassis were designed to provide for a nine-way adaptation; (1) horizontal fluoroscopy; (2) foreign body localization by means of a rapid fluoroscopic method; (3) sitting fluoroscopy, the design of the x-ray tube and screen supports providing for easy and quick shifting for the study of a patient supported to a sitting position on the litter; (4) standing fluoroscopy, to the extent of accommodating routine chest studies and also gastro-intestinal studies; (5) horizontal roentgenography, with conventional focal-film distances from 25 to 40 inches; (6) six-foot vertical chest studies; (7) six-foot horizontal chest studies, the patient lying on a litter, upon the floor; (8) ordinary bedside work in the wards, by means of mounting the component parts of the x-ray machine upon a mobile chassis; (9) superficial roentgen therapy, to the extent of milliamperage capacities of 4 and kilovoltage potentials up to 100.

In conjunction with this apparatus, there has been developed a wafer type of grid arrangement, adaptable two ways: (1) for use with the table unit referred to

above, and (2) for bedside work in the wards.

A light-proof tent has been designed in such a manner that it may be erected on the outside, within an ordinary corridor or ward tent, and within a room, cellar, or dugout. This tent likewise has been designed for a two-way adaptation: (1) with one arrangement, it provides for a fluoroscopic compartment; (2) with another arrangement, it provides for a film processing "dark room."

The two-compartment film and cassette loading bin, dryer, and loading bench combination has been designed in such a manner that it is believed to be practical for our small hospital installations. And yet by using multiples of this same unit, it is believed that the needs for our largest hospitals are provided. Moreover, it is believed that this equipment is of a design practical for use not only in any of our peace-time installations, but also for the installations in the field.

A two-compartment processing tank has been designed for large or small hospitals as set up for peace-time needs or for use in the theatre of operations.

The gasoline electrical generator is the only item which so far might be considered a "special item." This is due to our particular requirements, such as constancy of performance and an electrical wave form closely paralleling that of the average community line. These requirements have been rather unusual for the manufacturers of these small electrical generators since they have not had to contend with half-wave loads and loads as intermittent as are required for x-ray purposes.

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