X-Ray Manual

U. S. ARMY

Written at the request of the Committee on Preparedness of the American Roentgen Ray Society, with the approval of the Surgeon General.

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THE MILITARY STATUS OF MEDICAL OFFICERS AS ROENTGENOLOGISTS.

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Under existing law all male citizens of military age are a part of the military establishment of the United States, being members of the unorganized militia, and as such, liable for military duty at the call of the President in time of war or national emergency. This applies to medical men.

Members of the Medical Officers Reserve Corps when called into duty will, so far as possible, be assigned to duties requiring the practice of their several specialties. However, they may, of course, be required to perform any necessary military duty.

Military operations when conducted by armies or other large bodies of troops are always carried out in three zones of activity. These zones may overlap geographically but not administratively. They are:

(1) Zone of the Advance,
(2) Zone of the Line of Communications,
(3) Zone of the Interior.

The duties of all members of the military establishment will vary very widely, depending upon the zone in which they are serving.

The zone of the advance is the zone in which contact with the enemy is made and maintained and in which active hostilities are carried on. The zone of the line of communication is the zone through which the combatant troops are supplied with reinforcements of men and material and through which the sick and wounded are evacuated. The zone of the interior is the home territory of this country; in which supplies are fabricated and men recruited; and in which general hospitals for the treatment of the convalescent sick and wounded are located.

Zone of Advance.

The principal function of the Medical Department in the first of these zones is to evacuate the sick and wounded toward the rear as rapidly as possible; and as a rule in this zone only the medical and surgical treatment necessary to prepare the sick and wounded for transportation to the rear will be given. In this zone there are no fixed hospitals and all activities, including those of the Medical Department, must be subordinate to tactical situations and must be freely mobile. The equipment of the Medical Department units in this zone must be light, small in compass, and easily transportable.

The Medical Department units operating in the zone of the advance are:

(1) Regimental Detachments,
(2) Ambulance Companies,
(3) Field Hospitals.

The duties of the regimental sanitary detachments are to accompany the troops at all times, including actual engagements, and to give such medical and surgical assistance to the sick and wounded of their organizations as may be possible with their equipment, which they carry on their person. During and after an engagement they collect the wounded at a suitable place in the rear of the line and administer first aid. This place is known as the Regimental Aid Station.

The ambulance company is divided into the Dressing Station Section, the Wheel Transportation Section and the Bearer Section. The dressing station section establishes a dressing station in a situation where it will be protected from rifle and artillery fire, to which station the wounded of two or more regiments are brought from the regimental aid station on litters by the bearers. At this point nourishment is given and such further surgical treatment as may be necessary to prepare for transportation to the rear. From the dressing station the wounded are removed to the field hospital by the wheel transportation section of the ambulance company. Each ambulance company has twelve ambulances.

The field hospital is a mobile unit, the entire equipment of which is capable of being packed and transported in seven wagons. It is outfitted to care for 216 patients, but is not intended as a place for the permanent or prolonged treatment of patients. It will probably be here that the very first opportunity for any X-ray examinations will be possible. It is hoped that a satisfactory transportable equipment may be provided by the means of which localization of foreign bodies (bullets, shrapnel balls, shell splinters, etc.) and diagnosis and treatment of fractures may be done.

There are in each Infantry Division four infantry regiments; three field artillery regiments (each with its regimental sanitary personnel); four ambulance companies and four field hospitals. The strength of an Infantry Division will be about 27,000 men. In a moderately severe engagement an Infantry Division may easily suffer 10% casualties.

The only X-ray work possible in the field hospitals will be fluoroscopy. This will have to be done with the simplest and lightest of apparatus and probably mostly at night. This completes the medical service in the zone of the advance.

Line of Communications.

In the Line of Communications the patients will be transported from the field hospitals to the evacuation hospitals as soon as possible. There are two evacuation hospitals of 300 beds capacity each, provided for each division at the front. These are the first medical Department units in which the patient has a bed and in which a serious surgical procedure may be undertaken and it will be here that complete X-ray work with plates or films may be first carried out and complete examination made. The X-ray apparatus in these hospitals will probably be of a semi-portable type, of sufficient power to do work of any desired kind; or their X-ray service may be furnished by automobile truck units. From these hospitals the wounded will be transported to base hospitals where a large and complete X-ray department will be maintained. As their name indicates these hospitals will be located at the home end of the line of communications and they will be fixed and permanent institutions for the duration of the war.

Zone of Interior.

In the zone of the interior there will be many large general hospitals located in different parts of the United States; the X-ray departments of which will be in charge of eminent roentgenologists. At these hospitals the service will be very similar to that of the large general civil hospitals. They will also serve as teaching centers.

Requirements.

Every medical officer in the Army should, whenever possible, take the opportunity to improve himself in horsemanship and to extend his knowledge of sanitation and epidemiology in order to render his services of the greatest value to the Government.

The younger officers will be mostly required for duty in the zone of the advance where a knowledge of the principles of gasoline engines, and of handling automobiles and motorcycles will frequently be of the greatest value.

X-RAY PHYSICS

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Introduction

The following brief notes on the physical aspects of the apparatus likely to be used in military Roentgenography have been written with the hope that their study might enable the Roentgenologist to prepare for service in less time and be better able to utilize the apparatus with which he is compelled to work. With the belief that brief reasons as to why things are done are good guides in operation, rather more explanation of fundamental principles has been given than is usually included. The writer's experience in teaching this work has seemed to indicate quicker acquisition of efficiency and better results in this way. If in even a slight measure this should hold true with others, he will feel that the effort has not been in vain.

Roentgen or X-Rays

The Roentgen or X-rays are produced by an electric current in a glass-walled vacuum tube. Such a current is due to the projection of minute electric particles (electrons) from one metal terminal, the cathode, to another metal terminal, the anode or target. The rays originate at the point of impact of the electrons on the anode and travel out from their origin in all directions except where dense material obstructs or prevents their passage. When passing through bodies made up of various layers differing in density, some of the rays that enter the denser portions are permanently cut out and a new distribution of rays in the beam results.

The presence of X-rays must be determined by some of the effects they produce when acting on material bodies. These actions are:

(1) Effect on the emulsion of a photographic plate.

(2) Excitation of light in certain crystals (Fluoresence).

(3) Rendering gases conducting to electricity (Ionization).

(4) Stimulating or destructive action on living cells (Biological action).

The first, second, and fourth of these are of fundamental value in the medical and surgical uses of the rays. The third has been very useful in the study of the radiation.

These rays do not excite vision on reaching the retina of the eye, but are capable of originating light in certain crystals. A uniform beam falling on a piece of cardboard covered with such crystals would cause uniform illumination. If regions of unequal material density have been traversed by the beam before reaching the screen (fluoroscope) such dense portions will show as areas of lesser brightness. In the same way, a photographic plate or film sufficiently acted upon by such rays will, on development, give areas of unequal blackening, marking out the *projections* of volumes in the body whose densities differ from those surrounding them. On the fluoroscopic screen, dense bodies show as *dark* areas; in a photographic *negative*, they show as *light* areas.

It has been shown by various investigations that X-rays are identical in their nature with light and electric waves, except that their wave lengths are very much less than even the shortest light waves. On account of this extremely short wave length, the effect of matter upon their propagation is quite different from that in the case of longer waves. Such short waves are only produced by a change in the velocity of electrons taking place in intervals of time too short to be easily conceived. The gamma rays of radium, etc., are simply X-rays due to the sudden *starting* out of electrons by atomic breakdown. They may be shorter or longer than the X-rays we use.

The following general properties of this radiation should be understood in order to facilitate their intelligent application.

Paths.

These rays travel in straight lines into, through, and out of material bodies, except where the atoms themselves cause *scattering.* They *cannot* be *directed* by mirrors or lenses for purposes of optical focus or concentration, as is done with light.

Velocity.

The rays travel out from the target at the same velocity as light or electric waves.

Energy.

The actual energy involved in an X-ray beam is small compared with that expended in getting it started, only a few parts in a thousand of the energy supplied is converted into X-rays.

Scattering.

X-rays are scattered in passing through matter exactly as light is scattered in turbid water, fog, paraffine, etc. Only part of a beam is thus scattered, the remainder passing straight through or being absorbed. Scattering confuses shadows on screen or plate in a very troublesome way.

Passage Through Matter.

When rays pass through material, the substance is called transparent to the radiation. If little or no radiation gets through, we say the material is opaque to this radiation. The terms transparent and opaque refer to the action of the material with reference to a specific type of radiation. If one arranges a variety of materials of like thickness in the order of *increasing* density, their *opacity* to X-rays will be nearly in the same order. But this will vary somewhat according to the quality of the X-ray beam considered. That portion of the incident radiation neither transmitted nor scattered is changed into heat or, as we say, absorbed in the material. We then say that absorbing power increases with the density of the absorber. This absorbing power is best expressed as the fraction of the rays absorbed by a definite thickness of material. Thus, if 1 cm. of water should reduce the radiation so that the emerging beam is half as effective as the entering one, we might say this radiation has a *half value* layer of 1 cm. of water [Christen]. Two centimetres of water would transmit only 25 per cent. of the original, etc.

The quality of short wave length and high penetration can be secured only by means of high voltage operation. [See penetration, p. 38.]

Electrons.

The modern idea of atoms involves the idea of their electrical constitution in all cases. From any atom there may be abstracted one or more small negative charges, all precisely alike, whose properties are in no wise dependent on the atom from which they came, and all are quite capable of existence by themselves without the presence of the remainder of the atom. These little bodies have been variously named as corpuscles, cathode rays, beta rays, electric-ions, etc. The common designation of electron is derived from the latter. An electron is able to respond to electric force and to acquire velocity under such force action. When in motion, they show all the characteristics of an electric current.

The main physical features of the electrons are:

(1) Their fixed and definite negative charge.

(2) Their extremely small mass and volume.

(3) The extreme speeds they may acquire.

Production of X-Rays.

Roentgen or X-rays originate where the velocity of electrons is suddenly changed. In the radio-active breakdown of atoms, this change is a sudden *acquisition* of velocity, and they (gamma rays) are produced. In Roentgen ray tubes, the high speed electron is stopped in its flight by the interposition of a target metal of high atomic weight, placed in their path, and *X-rays* result from a *loss* of velocity.

The problem of X-ray production for our purpose, then, resolves itself into four parts.

(1) The separation of electrons from atoms.

(2) Giving them high speed.

(3) Concentrating them on a small area.

(4) Stopping them with sufficient suddenness.

The first of these is accomplished in one of two ways. In the tubes containing a *small amount* of gas, electrons are secured in part by high electric field but to a much greater extent by the disruption of atoms by the moving electrons and by the X-rays themselves. In the more recent hot cathode tube [Coolidge], electrons are set free from the atoms in a tungsten wire by the action of heat. In the former, the number of available electrons is rather hard to control; in the hot cathode tube this offers no difficulty.

In order to secure high speed (½ to ⅓ the velocity of light) a high voltage must be available, and the electrons must all be urged toward the same small area in order to get sharp shadows. The concentration on the target is secured by proper design of the electrodes and their proper position in the tube. In all cases the path to be followed must be quite free of gas in order to avoid obstruction.

The choice of metal as a barrier is of great importance, and only a few elements satisfy the conditions. Every fast moving electron has some mechanical energy ($\frac{1}{2}$ MV^2) and this goes mainly into heat by impact; this results in a great rise in temperature at the point of electron concentration. As radiographs and fluoroscopic images are purely shadow effects, a source of radiation starting from a point is very desirable. This high concentration of heat will melt any target material at high power operation. Only metals of high melting points can be utilized, such as platinum, tungsten, osmium, and iridium. Of these the first two are in common use, the tungsten to a great extent during recent years. High atomic weight is also desirable, and fortunately this goes with high melting points in the above metals.

General Instructions and Precautions

(1) *Excessive* exposure to X-rays results in serious injury to the skin. Such injury does not manifest itself at once but may develop some weeks later. To a degree, the action is cumulative, so that a single dose in itself, too small for inquiry, may, when frequently repeated, be harmful. Read carefully the notes in the manual as to protection, p. 121. While it is unwise to be over timid, it is much easier to prevent an injury than to cure it.

(2) X-ray apparatus is expensive, and not only is it costly in money to repair damage but even more important is loss of service from breakdown. Do not try to see how much current you can pass through a tube or how long a spark the transformer will give. Do not imagine that a tungsten target cannot be melted; it can, and very quickly.

(3) Acquire the habit of observing whether high tension wires are sufficiently far from patient, assistants, etc., *before* you close the operating switch.

(4) Make all tests of tubes, etc., on low power, and do not make unnecessary speed your ambition.

(5) Always see that current is passing through the filament of a Coolidge tube before closing the main transformer switch. When through work, throw all controls to low power.

(6) Do not imagine you can make plates of thick parts on very low spark gaps. It cannot be done, but you may get some very unfortunate experience trying it.

(7) Remember that any current that passes across the spark gap or leaks from one line to the other along walls, etc., does not help to produce X-rays although it may give milliammeter reading.

(8) Try to develop a definite order and sequence in the various details of any examination. It will save time and prevent errors.

(9) The only safe time to label a plate or film for identification is at the time of exposure.

(10) Don't imagine that so and so's good plates are due to the particular machine he is using; and don't chase off after every new exposure "technique" you hear about. The fact that some individuals advocate one after another is ample evidence of their uselessness.

Electrical Terms.

Certain terms are used so frequently in all discussion of electrical matters that they are introduced at this point for convenience in reference.

The Ampere.

The ampere is the unit of electric current. It is a quantity of charge transferred in one unit of time; legally defined as the current which deposits silver from a special solution at the rate of .001118 grams per second. The unit electric charge is the coulomb. Five amperes, for example, will transfer 40 coulombs in 8 seconds.

The Volt.

The volt is the unit in which the tendency of charge to move from one place to another is measured. The electrical tension between the terminals of a special cell (Weston or Cadmium cell), is taken by legal definition as 1.019 volts.

The Ohm.

The unit of electrical resistance. Legally defined as the resistance of a uniform column of mercury 106.3 cm. long and one square millimeter section at 0° centigrade.

The Watt.

The unit of electrical *power*. The work done in one second by a current of 1 ampere flowing through a resistance such that it loses 1 volt. The product, amperes x volts lost = power in watts.

The units given above are not of convenient size in all cases, and some modifications are in common use. The current ordinarily used through Roentgen ray tubes is expressed in milli-amperes. (One milli-ampere equals 1/1000 ampere.) The terminal voltage on the tube is often expressed in kilo-volts (One kilo-volt equals 1000 volts). The power used to operate electric devices is generally expressed in kilo-watts when the number of watts is large. 1 kilo-watt equals 1000 watts and is very nearly $1\frac{1}{3}$ horse power. 1 kilo-watt maintained for one hour is named a kilo-watt hour.

As applied in particular cases, a 4 KW, 110 volt generator, is a machine that delivers 4000 watts at full load and is designed to operate at 110 volts. The full load *current* would be 4000/110 amperes. If a machine gives 50 *milli-amperes* at 70 *kilo-volts*, the power *delivered* is 50/1000 x 70 x 1000 = 3500 watts, or 3½ K.W.

Measuring Instruments.

The electrical measuring instruments that may concern the radiologist are the ammeter, the volt-meter for low voltage currents, the milli-ammeter, and the kilo-voltmeter for high tension circuits. Most of the latter are of little real value as they vary with the secondary current. The milli-ammeter is a most valuable aid to the work. It is often designed for two ranges. From 0 to 15 m.a. on one scale and 0 to 150 m.a. on the other is the best for most work.

Do not try to draw 150 m.a. when the meter is set for a maximum of 15 m.a. If the pointer gets bent due allowance must be made in reading.

Electric Charges.

When any physical or chemical action breaks down the connection between an electron and the remainder of the atom, the electron constitutes the elementary particle of negative electricity. All negative charges are simply countless numbers of electrons kept away from the positive portions of the atoms from which they were separated.

Generators.

Generators do not create electricity. They take electrons and positive atomic remainders apart and push them in opposite directions against their natural tendency to keep and come together. Thus, if G, Fig. 1, represents a generator, A and B metallic plates connected to its terminals, A is covered with electrons and B with enough positive to neutralize the negative on A. If we call *e* the negative charge of one electron, and Q the total charge on A, N the number of electrons, then Q equals N*e*, where N is an incredibly large number in most cases.

Voltage.

Charges separated as shown in Fig. 1, show: (1) a mechanical pull on the bodies A and B. (2) a decided tendency to pass between A and B.

When this tendency for transfer is properly measured, its value is expressed in volts. A voltmeter does *not* measure electricity but something like a pressure or strain trying to pass a charge between two regions.

Current.

When connections are made to the generator, the charges do not assume full value without the lapse of some time. If we could count the number of electrons passing on to A per second, say N, we would call *Ne* the current passing through G. An electric current may then be regarded as a measure of the number of electrons passing per second. It must be observed that after A and B are charged as highly as is possible for the particular generator, there will be no further current, but the voltage is present. We may have *voltage existing and no current, but never a current without some voltage.*

Conductors.

It requires but little voltage to move a big supply of electrons through some materials, while with others a very great voltage will cause but little electron movement. The former are named conductors; the latter, insulators. Note carefully that the difference is one of degree, and that perfect insulators do not exist so far as high applied voltage is concerned. Thus, dry clean glass may be considered an insulator for moderate voltages, but may conduct to a considerable extent at high volt-

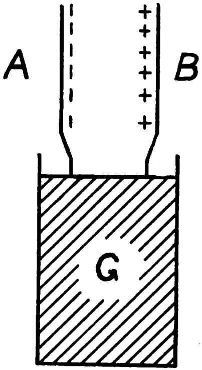


FIG. 1. Generator on open circuit.

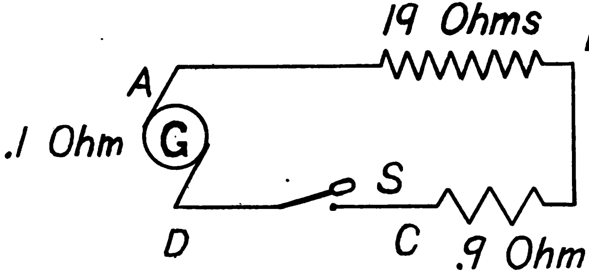


FIG. 2. Simple electric circuit.

age. The conducting quality of a wire is expressed in *ohms*, the ohm being a purely arbitrary standard.

Units.

Electric current or the charge transferred per second,—is expressed in amperes for large currents, and in 1/1000 amperes, or milli-amperes, for small currents.

Voltage,—expressed in volts for moderate voltages, and in kilo-volts for large voltages. Thus, 5500 volts = 5.5 K.V.

Resistance,—expressed in ohms as a rule.

Electric Circuit.

An electric circuit consists of some sort of a generator and a more or less complex conducting path between its terminals. Electricity outside a generator always passes from high to low voltage, and the current may properly be said to *lose voltage* en route from one generator terminal to the other.

Consider a very simple circuit, Fig. 2, consisting of a generator, G; generator resistance one-tenth ohm, two other resistances as shown. The fundamental law of such a circuit is that if when the switch, S, is open we have, say 220 volts, then for any total resistance, R, we will have a current, on closing S, such that

Current x total resistance = 220, or in this case,

No. of amperes x $(.1 + .9 + 19) = 220$

Current, $I = \frac{220}{20} = 11$ amperes.

The voltage is used up as follows:

In the generator	11 x .1 =	1.1 volts
Between A and B	11 x 19 =	209.0
Between B and C	11 x .9 =	9.9
Total,		220 volts

This relation is true for all circuits, viz., volts lost due to resistance of R ohms when a current of I amperes is flowing = I R.

Direct Current (D.C.).

When the electron-flow is in only one direction, the current is named direct. Dry cells, storage batteries, static machines, and D.C. dynamos deliver direct current. A current may be intermittent or pulsating, and still be called a direct current.

Alternating Current (A.C.).

When the electrons flow in one direction for a short time and then the flow decreases and a reverse flow occurs, we say the current is alternating. A.C. dynamos are the only sources of true alternating current.

Such a current in its simplest form may be pictured by a suitable time-current diagram. In Fig. 3 times is shown as increasing from left to right.

$$\text{Let} \quad OC = \frac{1}{60} \text{ second}$$

$$\text{Then} \quad OC = BD = CE = P_1 \; P_2 = \frac{1}{60} \text{ second}$$

This current takes all its variable values once over in 1/60 of a second, and repeats the operation 60 times in one second. It is designated as a 60 cycle A.C. current. If drawn from a 220 volt service, its complete name is, 220 volt—60 cycle—A.C. current of a certain number of amperes.

During the times OB, CD, EF, etc., current flows in the opposite sense to that during the times BC, DE, etc. Note that there are two *alternations* to each cycle, or 120 per second in this case.

X-Ray Current-Voltage Requirements.

At present X-ray tubes are used with currents varying approximately between 5 and 100 milli-amperes, and at voltage running between 25 and 100 K.V., i. e., 25,000 to 100,000 volts. This high voltage requirement cannot be met by simple D.C. generators.

High Voltage.

The requisite voltage is secured by the use of:

(1) The so-called static machine (direct but impractical).

(2) The periodic *interruption* of a direct current through one coil, causing high voltage in a neighboring coil (induction coil).

(3) Using a low voltage alternating current in one coil and getting a high voltage A.C. current in an adjacent coil (transformer).

The second device is still used to some extent, but has largely been displaced by the transformer in recent years.

The use of an induction coil or a transformer to increase voltage involves two distinct circuits, one connected through some control device to the supply line or generator, and known as the primary circuit; the other, insulated from the primary and connected to the tube terminals, known as the secondary circuit.

The primary is always:

(1) Of relatively low voltage.

(2) Moderately large wire.

(3) Carries a current of some amperes.

(4) Is reasonably safe to touch.

(5) Requires good metallic contacts at all connections.

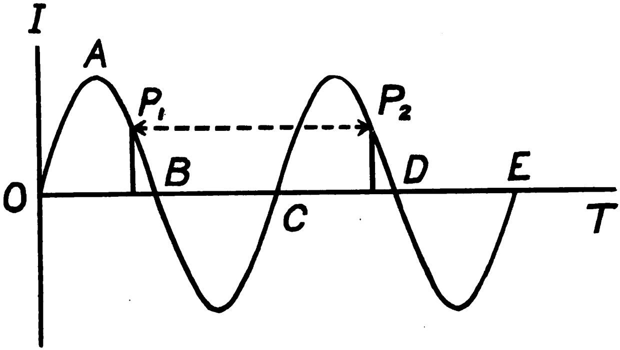


FIG. 3. Current-time curve of a simple A. C. circuit.

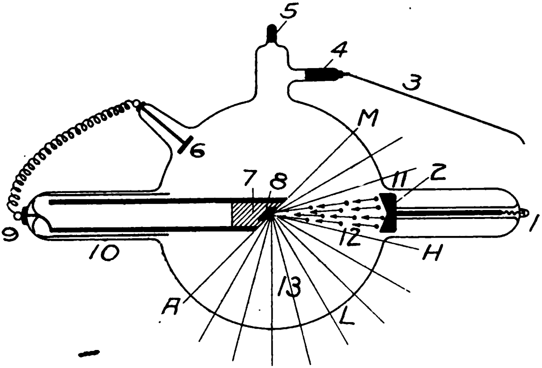


FIG. 4. Regular gas containing tube.

The secondary is always:

(1) High voltage.

(2) Quite small wire.

(3) Carries a current of some *milli-amperes.*

(4) Is unpleasant and often dangerous to touch.

(5) Will pass across loose connections or even through some insulating material.

The induction coil and a few transformers have both coils wound on hollow concentric cylinders, the primary within the secondary, and the space inside the primary coil is filled with thin iron sheets or wires. That is named an open magnetic circuit device.

Most transformers now in use have the iron in the form of a closed rectangle, and the two coils wound so as to slip on the sides of this rectangle. These are known as *closed magnetic circuit* transformers. The best practice is to have the coils immersed in a water-free oil, for good insulation.

The Gas Tube.

While a great variety of special forms of gas containing tubes have been introduced from time to time, the *general* form shown in Fig. 4, alone has survived for general operation.

1. Negative or cathode terminal.
2. Cathode of aluminum.
3. Adjustable connections for softening.
4. Softening material.
5. Sealing off tip.
6. Auxiliary anode.
7. Copper block.
8. Tungsten button.
9. Positive or anode terminal.
10. Anode neck.
11. Cathode neck.

12. Cathode particles.
13. Path of Roentgen rays.

A L M Anterior hemisphere showing fluorescence.

The target material has a great influence on the behavior of the tube and the quality of the rays. The atomic weight must be high, as the fraction of cathode ray energy transformed into Roentgen rays increases with increase of atomic weight. The melting point must be high or the metal will melt at the focus. It should conduct heat well, and must not vaporize readily below its melting point. The following table gives the approximate data relating to possible metals for this purpose. Taking platinum as a standard radiator:

Metal	At. Wt.	Amt. of Roent. Radiation	Melting Pt.
Platinum	195.2	1.	1760. C.
Iridium	193.	.98	2300
Osmium	190.9	.97	2700
Tungsten	184.	.91	above 3000
Tantalum	181.	.90	2900

The essential features of *all* modern tungsten target gas containing tubes are shown in Fig. 4. Various minor modifications may be seen in tubes from different makers, but each part shown must be present in some form.

The cathodes may differ in shape, but only aluminum gives good results and long tube life. The mounting of cathode and target must be firm, and the position in the neck carefully chosen. The adjustable arm (3) is often absent, and a third wire is run to a variable spark gap connecting with the negative terminal of the machine. The auxilliary anode (6) has a great variety of forms; in many water-cooled tubes, and sometimes in others (6) and (10), are interchanged. Numerous special devices for conducting heat away from the target are in use and are more or less effective. For treatment or for long fluoroscopic examination with this type of tube, water cooling is essential, and a good stream of air directed against the glass adjacent to the cathode is also of considerable assistance. A satisfactory tube must have a stable position of anode and cathode; all attempts to use an adjustable cathode have been unsatisfactory. The metal parts must be pre-heated and the tube itself heated during exhaustion. A well made and properly exhausted tube shows a good hemisphere on the anterior portion, and the remainder of the tube should show but little fluorescent light; a working tube should not be "flashy" or "cranky." When one attempts to operate a moderately hard tube at too low potential, this unstable state may result and either the voltage must be raised or the tube softened. The vacuum must be within fairly well defined limits, averaging not far from .001 mm. pressure of mercury, and must be in some manner under control if the life of the tube is of consequence.

The tendency of all gas containing tubes on low current is to "harden," i. e., to require more voltage for the same current, or, if the voltage is not changed the current decreases. On operation above a certain current peculiar to each tube and operating device, the tube softens on account of heating; when this proceeds so far that the tube shows and maintains a purple glow marking out the cathode stream, it is useless until repumped.

Many devices have been used to soften tubes. The more common are the following:

(a) A side tube containing mica, asbestos, etc., and through which a small discharge current may be sent, thereby liberating gas. (No. 4, Fig. 4.)

(b) A special target is placed in a side tube to be bombarded by rays from a small auxiliary cathode.

(c) A fine palladium tube projects through the walls of the tube; when this is heated by a small flame it allows hydrogen to pass into the bulb. This has been modified by Snook where the tube is heated by a spark discharged from the operating transformer.

(d) Heating the entire bulb. (Useless except in an emergency.)

(e) A mercury-controlled porous valve allows air to pass slowly into the bulb when the inlet is not covered by the mercury (Heinz-Bauer).

b, c, and d are rarely used in this country. although c (osmosis) regulators are sometimes seen outside the more useful Snook form.

The Coolidge Tube.

The great difficulty in the operation of the ordinary Roentgen tube lies in the irregular supply of electrons and the impossibility of control of their development. When operated above very moderate power, the trend is always toward larger quantities of ions and a consequent drop in penetration unless the current is greatly increased when a still greater supply is developed, so that there is no automatic self-protection of the tube.

Wehnelt found that a platinum ribbon coated with lime would allow of current transfer through a high vacuum at moderate voltages. Several attempts to use such a cathode for Roentgen tubes were unsuccessful, and no modification of the standard tube appeared until it was found by Richardson and others that electrons were emitted by hot metals.

The simplest application of this principle to Roentgen ray development has been worked out by Dr. W. D. Coolidge in the Research Laboratory of the General Electric Company at Schenectady. In this tube, the cathode is a spiral filament of tungsten wire, A, Fig. 5, heated to a high temperature by a current from a small *insulated* storage battery, or small special transformer. The form of electro-static field needed for focussing the electron

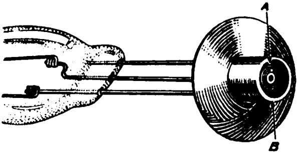


FIG. 5. Coolidge cathode construction.

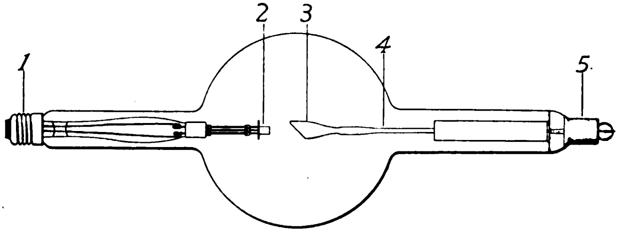


FIG. 6. Coolidge tube.

stream is fixed by a small molybdenum cylinder, B, within which the cathode is placed. The target is a solid piece of wrought tungsten mounted on a molybdenum rod around which collars are placed to distribute the heat conducted from the target.

Fig. 6. Coolidge tube.
1. Cathode terminal.
2. Focussing cone.
3. Solid tungsten target.
4. Molybdenum supporting rod.
5. Anode terminal.

In order to operate properly, it was found that the highest possible vacuum must be attained. Not only was the greatest care required in pumping, but the metal parts had to be freed from occluded gas by heating in a vacuum nearly to their melting point. In this tube there is no source of electrons except from the hot filament, and as this supply *depends only on the temperature of the filament*, the operator has perfect control of the number of available electrons by simply changing the ressistance in the auxiliary circuit, Fig. 7.

T—Tube.
S—Shunt spark gap.
SB—Storage battery.
A—Ammeter.
R—Resistance in battery cathode circuit.
MA—Milliammeter.

The *current* through the tube cannot be increased after the supply of electrons is entirely utilized, no matter how much the *voltage* is raised. This maximum current for each particular filament temperature is named the *saturation* current, and until this is reached the voltage maintained between cathode and target may be too low for use. (Note: So long as the current reaching the tube does not exceed the number of electrons emitted per

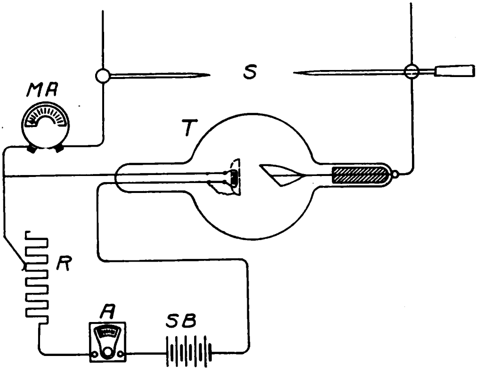


FIG. 7. Coolidge set up with storage battery for lighting filament.

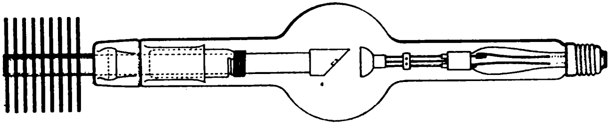


FIG. 8. Air-cooled self-rectifying Coolidge tube.

second multiplied by the charge of each electron, there can be no charge piled up on the electrodes—i. e., no effective terminal voltage.)

No Inverse.

A further valuable feature of the tube is its inability to transmit inverse so long as the target is not too hot. On account of the increased strain on the glass, when inverse is present, it is well to include a valve tube when operating on a heavy coil.

Penetration Limits.

The highest operating voltage on the present tubes is about 100 K.V., as measured on a special electrostatic voltmeter. This refers to "effective" voltage; the peak voltage is larger than this.

No doubt this can be increased by modification of the design but insulation difficulties and danger of puncture will be increased as higher voltages are used. Such high penetrating rays as may now be reached are *not* useful in fluoroscopic work or in radiography partly on account of the enormous amount of scattered radiation developed in the tissues of the body. Such scattered and corpuscular rays may, however, be most essential in therapeutic work. Very soft rays may be produced in great abundance if the glass will allow them to pass out. Attempts to use too soft rays in radiographic work are always fraught with grave danger.

No Fluorescence in the Glass.

In marked contrast to the usual tube, there is no fluorescence of the glass walls except a slight illumination in the cathode neck. Sometimes a minute chip in the glass or a slight evolution of tungsten vapor will give a momentary flash of green, but on further operation at moderate power this disappears. The bombardment of the walls of the tube by electrons reflected from the target or scattered from the gas atoms in the gas containing tube is the cause of the fluorescence and of a very considerable amount of soft Roentgen radiation originating in the glass. As there is in a gas tube as large a supply of positive ions as of negative, continual recombination results and no negative layer can form on the glass walls to prevent bombardment by scattered and reflected electrons. In the Coolidge tube the absence of positive ions probably allows the accumulation of a negative charge on the glass, and as soon as established this layer repels electrons and the glass is no longer a target.

New Form of Coolidge Tube.

The ordinary form of Coolidge tube will operate satisfactorily without a rectifier so long as the target is at a temperature below that at which it gives off an appreciable number of electrons. It follows that part of the problem of eliminating the rectifier is keeping the target cool. A new form of tube which will help greatly in this mode of operation has recently been developed by the General Electric Research Laboratory. Fig. 8. The target is a tungsten button set in a heavy copper backing which is continuous with a large copper rod extending out of the tube neck. To this are attached a series of discs acting as radiators. Operated within limits set by the manufacturers, this tube suppresses completely each alternate half wave and may be operated direct on a *suitable transformer.* At present these are designed for 10 M. A. at a 5 inch gap. The wiring diagram then becomes very simple and easily understood.

In Fig. 9 are shown a current-time curve and a voltage-time curve for the self-rectifying tube. In the latter AO is the working peak voltage which determines the tube radiation, and BC is the peak voltage of the suppressed wave which would give the spark gap reading.

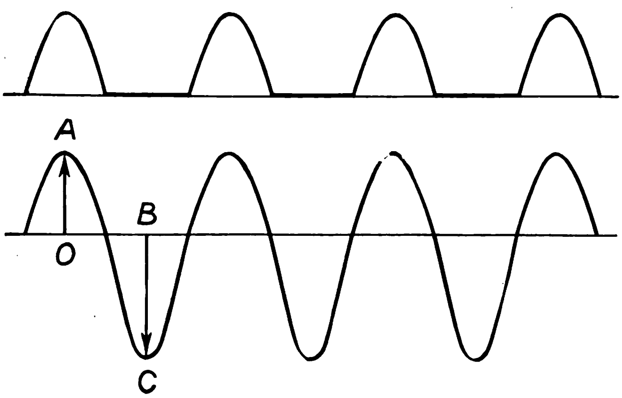


FIG. 9. Upper: Current-time curve for self-rectifying tube
Lower: Voltage-time curve.

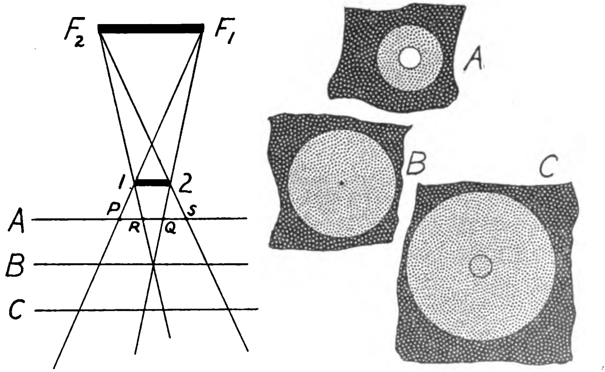


FIG. 10. Variation of size of shadows of small objects when a wide focus is used close to the plate.

A transformer should be used which will not vary its voltage too much from no current to that needed to operate it properly, since the voltage of the suppressed wave is quite decidedly higher than that of the one used, thereby causing spark-over and giving an incorrect idea of the actual working voltage.

The value of this arrangement for field work can hardly be overestimated, as there is no heavy and complicated rectifier. Operated from a small gas engine-driven generator, it should be ideal for fluoroscopic work and satisfactory for emergency radiography. See U. S. Army Portable Unit, page 58.

Tube Focus.

The X-rays cannot be focussed by any known method, so that the terms focal point, etc., are misleading. *Electrons* can be directed by suitable cathode construction so that the greater portion strike a small area on the target. The diameter of this area is known as the "focus," and it is customary to speak of broad, medium, and fine foci. One can hardly state precise limits between these designations, but anything below 2 mm. would be fine focus; 2 to 4 mm. medium focus; and over 4 mm., broad focus.

The size of focus is found by the use of a pin-hole camera, and should be given by the maker. Its size is important in two ways. First, in relation to the sharpness of image on plate or screen; second, as fixing the energy that may be used without damage to the target. When an electron stream is maintained at high velocity against the target, there is a rapid rise in temperature which may result in vaporization or fusion of the metal. The rate of removal of heat by conduction is increased by broadening the focal spot and the amount of metal suffering extreme rise in temperature is increased, so that for two reasons there is less danger of target damage.

The effect on sharpness of image is shown by using an exaggerated diagram as in Fig. 10. F_1 F_2 are the boundaries of the focal spot and 1-2 is the object. With the plate in plane A, had the only source been a point, F_1, a sharp shadow PQ would result; had F_2 been the only source, then RS would result. The only portion entirely shaded is RQ, and if the object is round we have a central white spot with a variable shading out to a diameter PS. If the focal spot were very wide and the object very small a plane B could be found beyond which there would be no white image.

The ring PR and QS is narrower the closer the object to the plate, the smaller the focal spot and the greater the target plate distance. The apparent size of the shadow will vary somewhat with exposure, as regions partly shaded may be under-exposed when the exposure is brief and the true shadow may not appear at all.

Fine focus tubes are not needed in gastro-intestinal work, and should be used in other work with such care that the target does not become pitted.

Conditions for Operation.

Two things must be considered in the operation of X-ray tubes. The first is a proper supply of electrons as current carriers, the second a proper electric drive to force these electrons against the target. These two must be so related to each other that a proper voltage can be maintained when current is actually used.

No amount of milliamperage will serve to do radiographic or fluoroscopic work without a proper voltage consumption at the tube. Potential difference or voltage drop between cathode and anode is due to a piling up of charges and negative electrons at the target and anode respectively and this must be done by the *generator*. When electrons move across from cathode to target they tend to relieve the congestion and if the generator failed to maintain the supply, the voltage and charge would disapear. The greater the number of electrons passing across in a given time the more the terminal voltage will be reduced for a given ability of the generator to pump a new supply. The current is the charge of one electron multiplied by the number passing per second. Hence the greater the milliamperage, the greater the power demanded from the generator to maintain voltage and the more the drop in voltage from that shown on open circuit or on small current.

When the current increases, irrespective of the type of tube used or the design of the machine, the operating voltage will be reduced unless the rheostat or auto-transformer control is moved to apply more power to the primary. The spark gap on *open circuit* is no guide to the ability of the transformer or induction coil to keep up voltage when current is drawn.

Inasmuch as reduced voltage very much more than offsets the effect of change of current in X-ray production as regards quantity and likewise decreases the ability to pass through material, the proper maintenance of voltage is the most indispensable requisite in any X-ray installation. *By increasing exposure time nearly all work may be properly done at low current but no increase of exposure time will compensate for too low voltage.*

The transformer must be designed for the voltage supply on which it is used, and it is very essential that the proper terminal voltage on the transformer primary should be maintained at all times and at all loads. After a machine is once installed the operator has no control over these matters. The size of wire required to transmit current from the usual power transformer to the X-ray room will depend on the distance between the two transformers and on the voltage used. To transmit the same power at 110 volts as at 220 will require twice the current. Whenever a given current is passed over a resistance there is a voltage drop or loss. This loss is greater, the greater the current and the greater the resistance.

When the line resistance and the current are known the voltage loss is found by taking their product. A loss of 2% on 110 volt operation or 4% on 220 volt may be permissible. See low tension wiring p. 70.

The operator must take care that the current through the tube does not drop the potential too much for the work required. For increased tube current the rheostat or auto-transformer setting must be raised accordingly.

Gas Tube Characteristics.

The earlier type of tube depended for its supply of electrons on the breakdown of the atoms of its gaseous atmosphere whereby the negative electrons and the remainder of the atom were separated and driven in opposite directions. This breakdown or ionization may be due to several causes.

(1) The high electric stress between cathode and target.

(2) The shooting of electrons through the atmosphere.

(3) The passage of X-rays through the atmosphere. The number of electrons set free will depend largely on the tube vacuum. If too few can be had, the tube is of too high vacuum and is called "hard." It backs up a very high spark gap, and may become "cranky." If too much gas is present the tube carries so much current that it is quite impossible to keep up voltage. The amount of free gas in the tube will increase as the

parts of the tube rise in temperature, since gas tends to stick to a cold surface, therein often lies the explanation of failure in radiography on prolonged exposure.

The rate of softening of a gas tube operated at a given initial current and voltage varies with its original exhaustion and its use afterward. On low power with small current and high voltage there is a marked tendency to *reduce* the amount of free gas and thus raise the vacuum. When this tendency is just balanced by the evolution or release of gas by heat the tube runs at a nearly uniform current and voltage. On slightly higher power it will soften and the rate of softening will generally be greater with a new tube than in case of a well seasoned one.

Danger in Testing.

It is unwise to test a gas tube at the power used in gastro-intestinal or other heavy work as it is likely to over-soften before a milliammeter can be read or spark gap really ascertained. The usual recourse is to note current and gap at low power and assume that when this is properly adjusted on say button X, it will give a proper result on a higher button Y. Careful study of these tubes shows that this is only approximately the case, for not only will tubes vary one from another but the same tube will behave differently on different days. No better method has been suggested, however, so the operator should endeavor to season a tube if possible before attempting fast work.

Coolidge Tube Characteristics.

The electron supply in the Coolidge type of hot cathode tube is due entirely to the hot tungsten filament as all the gas it is possible to remove has been taken out in pumping. The current carried by the tube is limited by the rate of electron supply and is thus determined solely by the filament current. This maximum *tube* current at a given *filament* current is only attained at a sufficiently high voltage and this voltage *increases* as the filament temperature is raised. When all the electrons are being driven across as fast as they are produced the corresponding current is named the *saturation* current. After such a current is reached the voltage may be greatly increased without a rise in tube current. Fig. 11 shows this is the characteristic of the tube, quite different from the gas containing tube where higher applied voltage brings increased current. On account of the *great* increase of tube current resulting from a *slight* rise in filament current the writer has found it impractical to depend on the filament ammeter as a guide to tube current, especially when using rheostat control.

Outflow of Radiation.

As radiation proceeds from the origin on the target it spreads out and flows through the surfaces of larger and larger spheres. The amount received in a given time by any *fixed* area then decreases as the distance of the receiving surface is greater. This decrease always follows the *inverse square* law. Thus if 100 arbitrary units reach a given area at ten inches from the target, the *same area* twenty inches from the target will only get ¼ as much in the same time, i. e., 25 units. At 30 inches the *same area* receives but 1/9 as much or 11 1/9 units. Or to get the *same* radiation to this area at the increased distances the time must increase as the *square* of the *distance*, i. e., if at 15 inches 2 seconds are required, at 20 inches $2 \times \left(\frac{20}{15}\right)^2 = 2 \times \frac{16}{9}$; at 25 inches $2 \times \frac{25}{9}$, at 30 inches $2 \times \left(\frac{30}{15}\right)^2 = 2 \times 4 = 8$ Sec., etc.

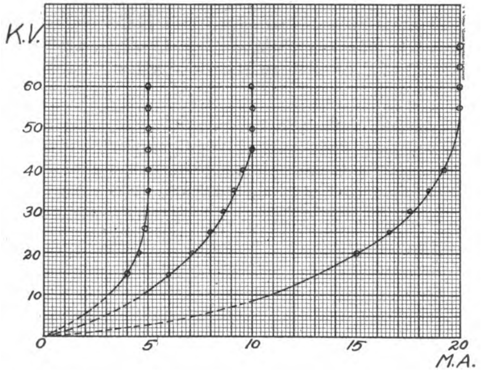


FIG. 11. Current-voltage lines of Coolidge tube for fixed filament temperatures.
Vertical portions are above "saturation" points.

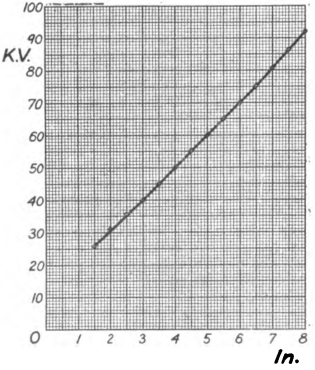


FIG. 12. Relation between kilo-volts and spark gap between blunt points. A four inch gap should read 50 K.V. etc.

Amount of Radiation.

The measurement of Roentgen radiation has proved a rather difficult matter and need not be fully discussed here. For our purpose the photographic measure is sufficiently accurate and determines the usefulness of the rays in practice. Whatever the conditions of operation, we might take a time of exposure so as to get the same blackening on a photographic plate and then say that the two *had the same exposure*, when exposure does not mean time of tube action alone.

Such a method measures only the effect of rays used in changing the emulsion, *not* the total beam, the greater portion of which passes through the film.

Quality.

Fully as important as the amount of radiation is the quality or distribution of radiation between various wave lengths. Quality determines the ability of the rays to pass through flesh and bone and was roughly gauged by the use of penetrometers. It depends on the voltage used to drive the current across the space between cathode and anode and is best expressed in terms of voltage or gap.

Dependence of Quantity on Electrical Conditions.

It is very important to realize that the amount of radiation as measured by the photographic effect is simply related to the electrical conditions under which a tube is operated.

If we let I = Current in milliamperes
V = Effective voltage in K. V.

Then radiation leaves the target at a rate depending on the product of current and the *square* of the voltage. The amount reaching a given area placed at right angles to the flow and at a distance *d* from the target and in a time *t* is measured by $\frac{I V^2 t}{d^2}$

Thus if $I_1 = 40$ M.A., $V_1 = 30$ K.V., $d = 20$ inches, $t = 1$ second, in one case, and

$I_2 = 10$ M.A., $V_2 = 60$ K.V., $d = 20$ inches, $t = 1$ second in another, then $Q_1 = 40 \times 30 \times 30 \times 1/400 = 90$ arbitrary units where Q_1 = amount of radiation in the first case and $Q_2 = 10 \times 60 \times 60 \times 1/400 = 90$ units in the second case. That is, 40 M.A. at 30 K.V. and 10 M.A. at 60 K.V. will produce the same quantity of X-rays as measured by photographic effect.

However, the radiation produced at 60 K.V. is better able to penetrate any piece of matter and a higher percentage passes through, so that a plate exposed partly to one and partly to the other through a block of material will show much more darkening for the second case even though the quantities of radiation generated at the tube are equal.

No matter what amount of current is passed through a tube it is useless for radiographic or fluoroscopic work unless a voltage able to break down from 2 to 6 inches of air between blunt points is used. For thick parts the higher voltage (gap) must be used.

The relation of sparking distance (between blunt points) to kilovolts is shown in Fig. 12. The kilovoltage is approximately ten times the gap in inches plus ten.

Penetration.

The most characteristic feature of X-rays is their ability to pass through material quite opaque to other types of radiation. In all cases there is some absorption but the rate of absorption or the amount left after passing through any layer of material varies according to the composition of the X-ray beam. The most penetrating rays are produced only at higher voltages. This penetration could be accurately defined in the case of a beam of one wave length but it is quite difficult in the case of an actual complex beam.

It is essential for the operator to realize that increasing the tube voltage will (a) add shorter and more penetrating rays; (b) increase the quantity of the less penetrating which were produced at the lower voltage.

X-Ray Transformer.

The transformer consists of two coils of wire around a common iron core. For complete insulation of the coils from each other the system is immersed in oil or in wax. If in the latter, it is shipped complete; when oil insulated, the oil is usually shipped separately. In this case, it should be siphoned into the transformer; the inlet side should be raised an inch or so to get complete expulsion of the air. It is well to operate at a low power, allowing sparks to pass across an inch gap for some time to dislodge small air bubbles before putting it into service.

Use no oil not furnished for the purpose by a reliable manufacturer, it *must contain no moisture.*

Examine the oil level every two months to be sure it fills the tank. An exposed coil is sure to break down by puncture of the insulation. The top of the case should be kept free from oil and dirt. For protection against surges or sudden high tension pulses which are likely to damage the transformer, a resistance should be placed in shunt with the low tension terminals. If this is not provided by the maker, ordinary lamps may be used. Fig. 13.

The middle of the secondary is usually connected to the case (grounded); this insures a distribution of potential equally above and below the "earth" potential. Thus, if the terminal voltage is 40,000 volts, then the

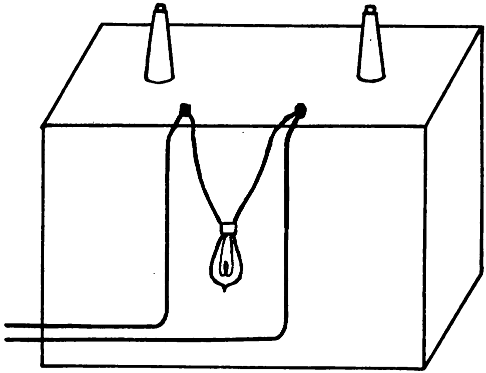


FIG. 13. Protection from surge by use of a lamp.

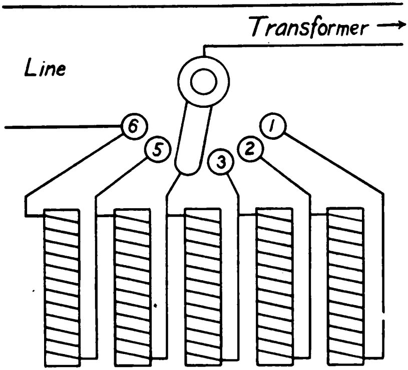


FIG. 14. Rheostat construction and connections.

tendency to pass a spark to any grounded conductor is 20,000 volts. This arrangement avoids in some measure the tendency to discharge to patient, stand, and tube that would result if the full terminal voltage were effective to earth.

Care must be taken to keep contacts on low voltage side tight. See that low tension wires are kept as far away from the high tension terminals as possible. If trouble actually occurs, due to short circuit or break in the transformer, there is no use in trying to repair it, as a rule, unless the trouble is close to the terminals. If there is trouble arising from sparking across between the high tension terminals of the transformer attaching small spheres will relieve the tension and usually cure the trouble.

Rheostat.

An adjustable resistance is used to control the power delivered to the X-ray transformer. It consists of coils of wire connected end to end; one end of the series is permanently connected to one wire of the power line. An adjustable contact is used to join one transformer terminal to the desired point on the rheostat. Fig. 14 shows the essential parts of a rheostat.

The usual numbering makes the power increase as the control lever is moved over to higher numbers. A good rheostat should be of substantial construction, well ventilated, and of such current capacity as not to get overheated under any operating conditions; for treatment work it should adjust to from 3 to 5 M. A. on a 9 or 10 inch gap, and be so graded as to give 30 to 80 M. A. on a 4 to 7 inch gap.

Troubles.

Open circuit, due to: (a) loose contacts; (b) break in one or more coils; (c) burn out by overheating. (a) will result in either no transformer current or an irregular current. (b) Current breaks as soon as lever passes broken coil. To remedy (a), tighten contacts, and (b) solder broken ends together; (c) get a new control.

Short Circuit.

Unusually high power results when the rheostat lever is moved past a pair of coils fused together by overheating. A short circuit may also be caused by nails or other metallic bodies allowed to fall between coils. Be sure that covering does not permit this to happen.

Rough Contacts.

Caused by arcing when rheostat handle is moved while power is on or by leaving contact partly on a button. They may be smoothed up by a fine file followed by OO sandpaper. A very thin film of vaseline will help make the contactor slide easily, 3 in 1 oil is also good for this purpose.

Making and Using a Transformer Chart.

Several years' experience in teaching with a great variety of machines has convinced the writer that a proper procedure in handling machine and tube is indispensable. Such a method should be adopted as will:

(1) Save time and tubes.

(2) Render reproduction of results possible.

(3) Apply to all machines.

(4) Require a minimum amount of instrument reading when operating.

(5) Indicate the working range of the machine.

The working spark gap with moderate sized blunt points for gap varies from about 3 inches to 6 inches and currents vary from 5 to 100 milliamperes in fluoroscopic and radiographic work. Any possible combinations on the machine giving settings outside these limits, are practically useless.

On any transformer outfit find first a 5 M. A. 6-inch gap setting, then a 40 or 50 M. A. 6-inch gap or an 80 M. A. 4-inch gap setting. Study no settings outside these limits. In Fig. 15 take rheostat setting G as an example. *Read the current through the tube when a 6-inch gap just fails to break* (25 M. A.). Record your setting and the current. Leaving the X-ray transformer *control unchanged* find the tube current at which a 5-inch gap just fails to break. Do the same for a 4 and for a 3-inch gap. When these readings are plotted to scale as in Fig. 15, they should fall nearly on a straight line. If they do not do so, repeat the observations.

So long as the power line is kept at the voltage prevailing when this line was determined the co-ordinates of this line, give all the currents and voltages at any time available on this rheostat setting. H gives the currents at which gaps between 6 and 3 inches are broken on button H. Fig. 16 shows five such lines for a particular machine on auto-transformer control.

How to Use Such a Chart.

Using chart, Fig. 15, one needs for a particular case 20 M. A. at a 4-inch gap. The vertical line through 20 cuts the line marked F at the 4-inch gap. Hence we must use button F. Have spark gap at seven inches and forget it entirely. Move rheostat lever to F, look at your milliammeter, use one hand on transformer primary switch and the other on the Coolidge control. Close transformer switch and bring filament control to a setting giving 20 milliamperes tube current; there is no need of testing the spark gap.

Do not try to read the milliammeter on the throw. Learn to start and set your machine within 10 seconds.

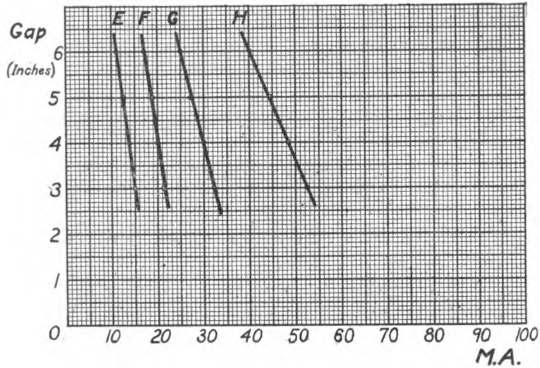


FIG. 15. Partial "chart" of a particular machine with rheostat [control. Note that gap change as tube current increases is very rapid. On G, for example, we have a 6 inch gap at 25 M.A. and only a 3 inch gap at 27.5 M.A. or a change of an inch for each 2½ M.A. Compare with Fig. 16.

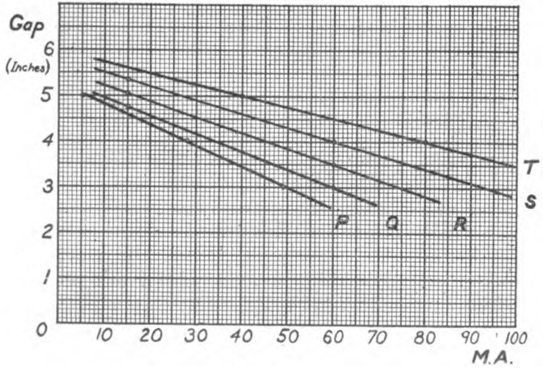


FIG. 16. Partial "chart" of the same transformer using auto-transformer control. Note line marked P shows all useful currents that can be had on this setting: changing from 5 M.A. to 50 M.A. lowers gap from 5 inches to 3.

On 20 M. A. desired, a current of 19 or 21 M. A. is close enough for this work.

Using chart, Fig. 16, for 45 M. A. at a 4-inch gap go at once to R and proceed as before. A little time spent in making this chart and in using it will reduce time lost and failures. Note that the faster the spark gap falls with increase of tube current the more accurately must the filament current be adjusted and maintained.

Coil Characteristics.

A good induction coil should be able to give a heavy discharge at a voltage high enough to break a 10 or 12 inch gap. Many coils are wound for 18 inch, 20 inch, or more, spark gap, but do not pass enough current for moderately rapid work.

The insulation between primary and secondary and between portions of the secondary, should be guaranteed by an experienced and responsible maker. Under no circumstances must a coil be operated at high power long enough to heat the insulation, as the insulating power is much reduced at high temperatures. Each coil has its own characteristics which determine its best working conditions. These characteristics depend on the primary and secondary resistances, the amount and quality of iron in the core, on the number of turns in the coil, and on the mode of winding.

As in operation, coils are using variable instead of steady current, measurements of the direct primary current are not very useful except to determine resistance. The most undesirable feature in coil operation for Roentgen work is the unavoidable inverse which must be minimized in the use of the ordinary tube. The amount of inverse depends both on the coil, the interrupter and the tube. A coil having a considerable number of primary turns and but little "magnetic leakage" gives less trouble with inverse than other types.

The direction of secondary current while the primary is increasing is opposite to that during a *decrease* of primary current. Generally, it is possible to reduce primary current at a greater rate than that at which it can be built up. Hence the "break" voltage is usually higher than that at "make." The current of higher voltage is useful in the tube, but the inverse is not only ineffective for ray production but is a source of positive injury to the ordinary tube. If the make current could be caused to rise slowly enough, the resulting secondary voltage would not force current through the tube. In practice, this is not possible although the voltage giving "inverse" may be very much smaller than that giving direct.

Valve Tubes.

In order to reduce "inverse" as far as possible, various unsymmetrical tubes, Fig. 17, have been devised; these offer much greater resistance to discharge in one direction than the other. Such valve tubes are often supplemented by a series of small spark gaps which are readily broken down by the "direct," but not by the lower volttage "inverse." These devices all reduce the energy available for Roentgen ray production. Fig. 18 shows a tube designed to indicate the presence of inverse. If there is no inverse, only one of the metal terminals at the gap will glow. If both glow to the same extent, the inverse current is present.

Fig. 19 shows the wiring diagram for a coil with mercury interrupter, condenser, oscilloscope, valve tube, and series spark gap. Note that the milliammeter is next to the tube.

When the spark gap is placed between the meter and the tube, leakage across the gap may make the reading much above that passed through the tube.

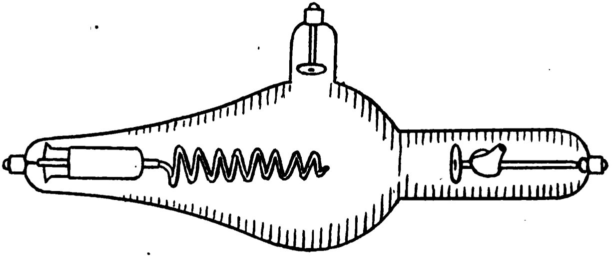


FIG. 17. Valve Tube.

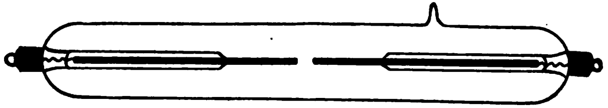


FIG. 18. Vacuum tube oscilloscope.

Interrupters.

The secondary voltage of an induction coil is the result of *change* of current in the primary. It is evident that we cannot have the primary current grow indefinitely, so we must allow it to decrease and increase alternately. The value of the secondary voltage for a given coil depends entirely on the *rate* at which the *primary current* is changed. Thus, if a current of 80 amperes should be reduced to 0 amperes in .02 seconds, the current has changed at a mean rate of 4000 amperes per second. If it required .04 seconds for the same change, the rate is 2000 amperes per second. The mean secondary voltage is twice as great in the former case as in the latter.

As induction coils are usually operated on an interrupted direct current, some device must be used to open and close the circuit. The early interrupters were of the vibrating hammer type, but these have largely been superseded by others much better adapted to Roentgen ray work. They are still used on small outfits where large power is not drawn.

The Wehnelt Interrupter.

The Wehnelt interrupter consists of a lead and a platinum electrode immersed in a solution of sulphuric acid. The amount of platinum exposed to the solution is usually variable at will. When connected as shown in Fig. 20, the application of sufficient voltage will result in the formation of a non-conducting layer between the solution and the platinum, thus interrupting current flow. The layer is very quickly dissipated, re-establishing current only to be again formed, etc. When only a small amount of platinum surface is exposed, the number of interruptions per second is high and the current is small. Greater immersion lowers the number of interruptions and draws more current.

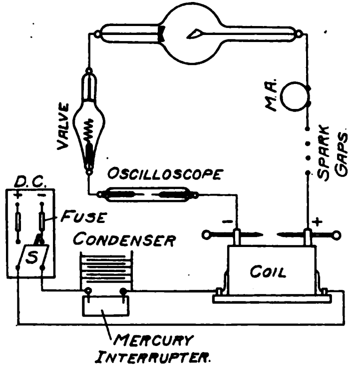


FIG. 19. Wiring for induction coil using a mercury interrupter.

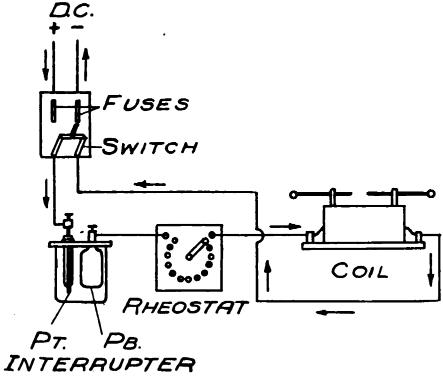


FIG. 20. Wiring for induction coil with electrolytic interrupter.

Operating Notes.

(a) The solution should contain 30 to 35 per cent. pure sulphuric acid. In mixing, be sure to add *small* amounts of *acid to water*, allowing the mixture time to cool after each amount is added. *Never pour water into the acid.*

(b) *Do not use a condenser*, as is done with the mechanical interrupter.

(c) If your point or points are adjustable, use little or no resistance in series with coil and interrupter on a 110 volt circuit.

(d) Your coil may not have the correct self induction for use with a Wehnelt, at least over a wide range of frequencies of interruption. If *inverse* is prominent, try a greater amount of platinum exposed thereby lowering the frequency of interruption.

(e) Do not run too hot, and if possible enclose interrupter in a sound-proof box.

(f) Be sure that connections are made to the proper terminals.

(g) Do not try to operate on alternating current without a rectifier. This has been done in a few instances, but is not advised.

The Mercury Interrupter.

Various forms of interrupters using mercury have been invented and have some advantages for use with heavy coils. They allow variation in two essential particulars, viz., number of interruptions per second and relative duration of make and break. Two forms are in common use. In the jet type, Fig. 21, a centrifugal pump throws small streams of mercury against V-shaped iron terminals. The motor speed determines the number of interruptions and raising or lowering the iron decreases or increases time of flow relative to that of no current.

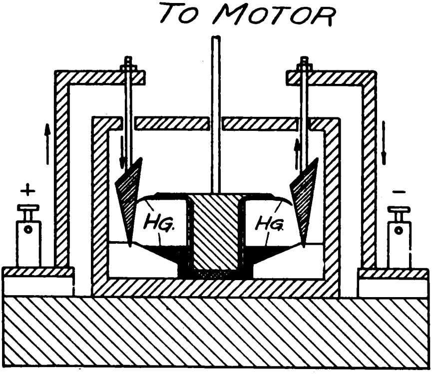


FIG. 21. Centrifugal jet mercury interrupter.

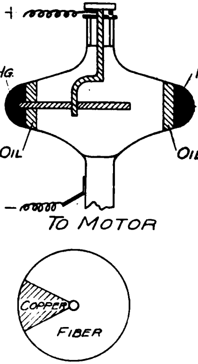


FIG. 22. "Rotax" Interrupter.

In the Rotax interrupter, Fig. 22, the mercury is thrown into a ring revolving with the case. An insulating disc with a small conducting sector is mounted so that it may be moved to and from the circumference. When in contact with the mercury, the disc rotates at a speed depending on the mercury speed and the amount of immersion of the disc. The latter is insulated from the case and is connected to an external binding post. The relative time of current "on" and "off" varies with the immersion of the disc in the mercury. A small amount of paraffine oil is used, forming a ring inside the mercury to prevent oxidation. A better plan when the apparatus will permit is to use illuminating gas in the case which reduces contamination of the mercury and enables long periods of operation without refilling. If gas is used, a small burner should be connected to the cavity and kept burning, and the current should never be turned on until this light continues to burn, as severe explosions may result by spark ignition of an air-gas mixture. Recent forms have a safety valve to protect against explosion.

A suitable capacity must always be connected to the terminals of interrupters of this type. The amount of this capacity will vary with different inductances of the primary and to some extent with the frequency of the interruption.

Operating Notes.

Carefully read and preserve any directions furnished by the maker of the interrupter used. If none are at hand, and trouble arises, some one or more of the following may be found to account for it.

(a) *No current in any position of the disc.* Look for poor contacts, either from bad brush on revolving case, loose binding, or broken wires. The mercury should be examined to be sure that there is enough and that the oxide does not prevent contact.

(b) *Very heavy primary current and little or no secondary current or voltage.* Examine capacity to see if it is punctured; if so, renew at once. If condenser is all right, see if disc is free to turn and is not immersed too far by reason of an overcharge of mercury.

(c) Be sure to keep the required amount of oil in the case, as if there is too little it becomes carbonized by the arc and gives trouble.

(d) The mercury must be kept clean. When it is dirty, oxidized, or emulsified with oil, either clean by filtering and washing or put in new mercury. The latter is expensive in those using large quantities but not in others.

A coil in which a current is changing always develops an active opposition to the alteration of current. On an attempt to increase the current, the coil acts as an opposing generator, and when current falls the generator action reverses. This action is due to *self induction.* The opposing voltage when we change current at the rate of 1 ampere per second is an important factor in behavior of the coil, and is named the *coefficient* of *self induction.*

On account of self induction, no really instantaneous change of current can take place, and the response to variable voltage will depend on this feature of the coil and on the rate at which we attempt to make current changes. Each coil is an individual in this respect and one should find by trial the conditions under which it operates best for each purpose, and then adhere to these conditions. A little time spent in this way will save much time and annoyance later.

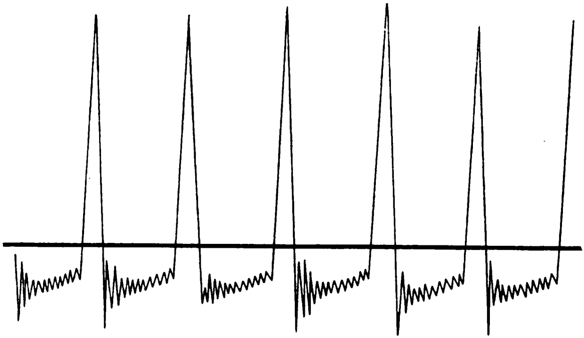


FIG. 23. Oscillogram—Induction coil current with a gas mercury interrupter.

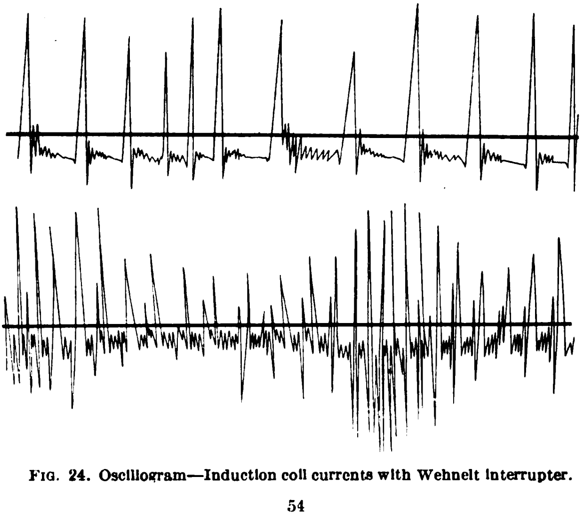


FIG. 24. Oscillogram—Induction coil currents with Wehnelt interrupter.

Tubes for Use with Coils.

The current wave through a coil is quite different from that from a transformer. The current consists of a series of short rushes with considerable time between each impulse. Fig. 23 shows the variations of current with time on an induction coil with a good mercury interrupter. Fig. 24, two curves with a Wehnelt break. Note the large amount of inverse in the latter. In order that the tube current may not lower the voltage below the required point it is essential to have gas tubes at relatively high vacuum, or hard. Thus we must have *small* tube currents.

Readings.

Milliampere and spark gap readings are far less reliable guides for radiography when using coils than on transformers. The gap shows peak voltage which may be high but transient, the ordinary milliammeter indicates the *difference* between direct and inverse. So that one may get 0 reading and yet have the tube operating.

Portable Coils.

Portable coil outfits are so varied as to make brief description impossible. Those heretofore in use were largely of the "Tesla" type.

The electric lighting current is stepped up to about 2000 volts by a small step-up transformer if the supply is from an alternating current line.

If the current is direct, the circuit is made and broken by some form of vibrating interrupter, giving much the same effect in the transformer as though an alternating current was used.

The 2000 volt current from the secondary of the step-up transformer charges a condenser. The discharge of this condenser is through a few turns of wire wound around the outside of a secondary consisting of a large number of turns of fine wire. The discharge of the condenser is at an enormous frequency and high voltages of high frequency are generated by the Tesla coil.

As the current delivered by the Tesla coil is alternating, a different form of tube must be used from that for other types of X-ray generator if best results are desired. This special tube has a valve arrangement built into it which tends to suppress one wave of the current.

U. S. Army Bedside Unit.

Realizing the great number of fractures to be cared for in military work and the importance of making examinations without disturbing the patient it was deemed desirable to work out a convenient portable outfit for bedside work.

At the time of writing the development of this unit is not quite completed, but a brief description of the main features may be useful.

The air-cooled Coolidge tube will be used exclusively and very little, if any, adjustment of current and voltage will be left to the operator. The tube will require no rectifier and will carry safely 5 milliamperes at a suitable voltage for fluoroscopic work. All radiographic work should be done with intensifying screens and films. The exposure times with screens using this outfit are approximately the same as for large machines without screens. See page 99.

The outfit includes a suitable rotary converter to change 110-volt direct current to a proper alternating voltage. A switch is closed in one direction to operate on 110 volt A.C. and in the opposite direction for 110 volt D.C. Fig. 25. A single push-button switch operates both the filament and X-ray currents. For voltages above 110, the additional parts needed for adaptation can be supplied, but are not included in the case. Since

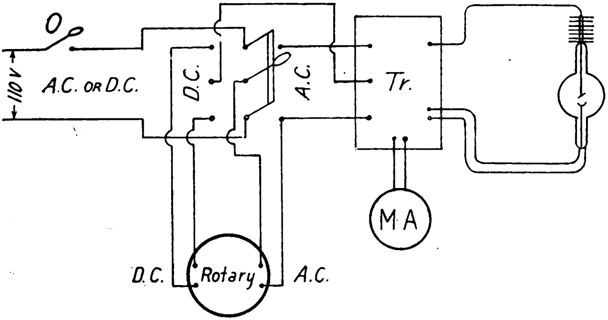


FIG. 25. Wiring diagram of U. S. Army Bedside Unit.

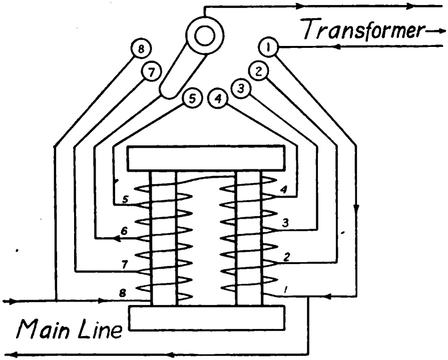


FIG. 26. Auto transformer construction and connections.

there is no synchronous motor, the unit will operate over a wide range of frequencies of alternating current.

The user is warned to use this outfit exactly as directed in the instruction sheet issued therewith. Do not expect as much power as from large machines and do not connect it to any circuit before you ascertain the type of current. Properly used this will be found a very valuable addition to any hospital equipment.

The U. S. Army Portable Unit.

By the co-operation of various manufacturers a semi-portable outfit has been developed which may be used in mobile units.

The important features of the outfit are the portable power plant, the self-rectifying Coolidge tube, and the special table. Having a complete generating equipment it is admirably suited to service in strange territory where the electrical supply is not suitable for standard machines or is likely to fail because of war conditions.

The gasoline engine is direct-connected to a generator which supplies power for the main and filament transformers (A. C.) and a small amount of current (D. C.) for the control circuit. The primary circuit requires no control resistance, regulation for the two working settings being made by shifting the throttle by means of the D. C. control circuit, thereby changing the speed and output of the generator. The secondary circuit contains no rectifying device since the tube allows only each alternate half wave to pass. (See p. 28 for a description of the tube.)

Fluoroscopic work is done at 5 M.A. and all radiographic work at 10 M.A. The maximum operating gap is about 5 inches, but may be reduced if desired by control of the machine speed. All work is done at the standard distance of 20 inches, time alone being the variable factor.

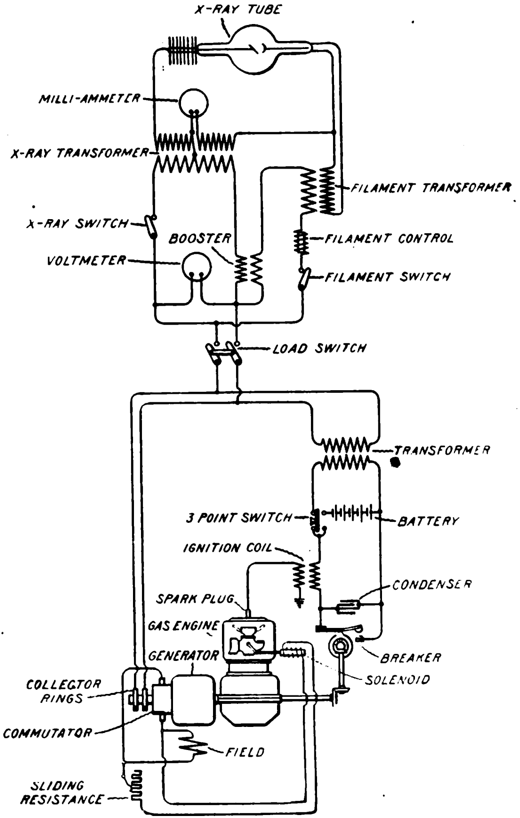


FIG. 27. U. S. Army Portable Unit set up with self-cooling and self-rectifying Coolidge tube.

Owing to the drop in line voltage upon closing the operating switch it is necessary to secure a uniform filament current by inserting a "booster" in the primary circuits of the two transformers. This is merely a small transformer which by carrying the main transformer primary current adds enough voltage to the filament transformer primary to compensate for the drop of voltage in the line.

The transformers and electrical apparatus may be conveniently assembled in a case which also serves to protect them in transportation. The table knocks down and the whole outfit may be very quickly set up or taken down. The tube is carried beneath the table as in the usual "trochoscope."

Operation.

After setting up the outfit check over the connections by comparison with the diagram furnished with the machine. Fig. 27 gives a good idea of the connections. Make certain that the secondary leads are properly spaced and will not spark to each other or to the metal frame of the table.

To start, set the control resistance at a point marked "start" and leave the operating switch open. Look to the oil and gasoline levels on the engine and bring them to the proper points. Fill the priming cups half full of gasoline, set the air intake to a normal running position, turn the engine over rapidly and hold down the starting button. *Do not press the starting button until the engine is turning over, or the engine may back-fire* and a sprained or broken wrist may result. If it fails to start, prime and try once more. It often proves effective to hold the throttle closed for one or two turns and then let it drop to an open position. In very cold weather it may be necessary to wrap the carburetor in cloths soaked it hot water to start the engine after it has been standing for some time. When the engine comes up to speed release the starting button and set the air intake at a position where the engine runs smoothly without missing. To stop the engine remove the conductor leading to the spark plug. Should the engine fail to start easily there is quite likely something wrong, and brains will start it far sooner than elbow grease. Ignition troubles are generally due to broken connections, poor contacts, wrongly connected, worn out or short-circuited battery, and dirty or improperly spaced sparking points. All connections should be firmly made between clean metal. The starting button contacts may become corroded from exposure and should be scraped clean. The dry cells should be connected in series, the central carbon of one cell to the outer zinc of the next and always in the same direction, carbon to zinc, carbon to zinc, throughout the circuit. The paper cases which cover the cells must not be removed or the battery will short-circuit through the metal battery box. The connecting wires between the cells should be insulated so they will not short-circuit through the cover of the box. If the rest of the ignition circuit appears all right and a good fat spark may be obtained outside the cylinder, there may still be trouble with the spark plug. It should be removed, the points scraped clean and set about 1/32 inch apart, or if the porcelain is cracked and the insulation has failed it will be necessary to insert a new plug.

Mixture troubles are usually due to letting the gasoline get too low in the tank, or letting water and dirt get into the gasoline. Always fill the tank to the proper level before starting a run, filter the gasoline through chamois to exclude foreign matter. Keep the engine covered when not in use and keep the air intake free from mud and dirt.

If the engine is given proper care and oil and protected from the elements there should be no trouble, but if not, it will become temperamental and cranky and will fail to give good service when it is needed. It always pays to take good care of the engine.

The filament control must be adjusted carefully to give the proper current and primary voltage and once adjusted it will stay fixed. Make sure the filament is lighted before throwing on power: this may easily be forgotten with an enclosed tube.

Should a spark pass in the secondary circuit when the operating switch is closed, it may be due to a temporary surge, unless an "arc" results do not open the operating switch. Keep secondary wires well apart and well away from other objects to prevent corona and leakage. It is a good plan to connect the frame of the table to any convenient "ground."

If wiring inside the apparatus case is disturbed be sure to connect it up as it should be, with the booster coupled as a booster and not as a retarder.

Auto-Transformer.

The use of a rheostat to control the voltage applied to a tube has one disadvantage in that an increased tube current results in a marked decrease in working voltage. This is due to the fact that an increase in tube or secondary current demands an increased current in the primary. The latter current must pass through the rheostat and there occurs a loss of voltage greater for a heavy load than for a light one. Thus, if we have a resistance of 1.5 ohms and 10 amperes current the voltage consumed will be $1.5 \times 10 = 15$ volts. If we have the same resistance and 60 amperes, $60 \times 1.5 = 90$ volts will be used up in the control; and if the line voltage is 220, only 130 volts can be useful on the X-ray transformer primary.

To avoid this, an auto-transformer is often used. It consists of a continuous coil of wire wound around an iron core, with taps taken out to control buttons at proper intervals, as shown in Fig. 26. It is essentially the same as any other transformer, except that primary and secondary are part of the same continuous wire, rather than separate windings. The ratio between the number of turns in the primary and in the secondary is changed by setting the control on the various buttons. As the control handle is moved to higher readings, higher voltage is applied to the primary of the X-ray transformer. When increased current is demanded in the tube, it will be supplied with far less voltage drop than is the case with a rheostat. Fig. 28 shows the behavior of the two devices on a particular machine. Starting at 10 M.A. and 60 K.V., and raising the tube current on a fixed rheostat setting, gives the series of currents and voltages shown by the line AC; while on a fixed auto-transformer setting we have the line AB. Since the quantity of radiation (measured photographically) increases as the current and the square of the voltage, we may compute the *relative* amount of radiation regardless of penetration. Curve DE shows the rheostat delivery down as low as useful rays are produced; DF shows the delivery on the auto-transformer up to 60 M.A.

This form of control is of special value when the filament current of a Coolidge tube is not entirely steady. Thus, if the tube current changed from 10 to 15 M.A., with a rheostat control the radiation would be reduced in quantity from 32 to 25 arbitrary units and also would be much less penetrating; while with the auto-transformer the same change would result in an *increase* in quantity from 32 to 50 units very slightly less penetrating than at 10 M.A.

Synchronous Motor.

A synchronous motor is one that makes either the same number of revolutions per minute as the generator feeding it or a fixed fraction thereof. Thus, if fed by a 60 cycle A.C. current, there are 7200 alternations per minute. One alternation is produced whenever a conductor passes one pole piece of the generator. Thus, a 60 cycle current from an 8 pole machine requires 900 R.P.M. (revolutions per minute), since 7200 = 8 x 900. For a four-pole machine we must have 1800 R.P.M., etc. A four-pole motor must then make 1800 R.P.M. for synchronism if on such a circuit, and it must not make 1801 or 1799. Since the rectifier for a 60 cycle current must make a quarter-turn each 1/120th of a second, the motor must turn at 1800 R.P.M. It must be observed that such a motor is designed for a given frequency and cannot be expected to work on one greatly different from that intended.

Starting.

Many motors require connection to a special starting device in order to bring them up nearly to the required speed before making the running connection. Do not delay too long, and do not throw over the switch too quickly. A little practice will enable you to tell by the sound of the machine when the speed is about right.

Oil.

Do not expect a machine to run for long periods without lubrication. Follow the maker's instructions, if any are given. Do not use too light an oil. An oil like 3 in 1 is good for sewing machines but must not be used on power motors. Use real machine oil.

Protection.

It is well to have the field and the armature of an X-ray motor protected from small sparks due to tran-

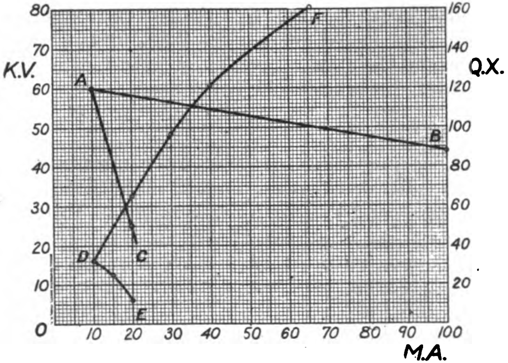


FIG. 28. Relation of X-ray production on two types of control. AC, rheostat voltage current line. Voltage ordinates at the left. DE, corresponding X-radiation, quantity ordinates at the right. AB auto transformer chart line. DF., corresponding quantity line. Quantity in arbitrary units.

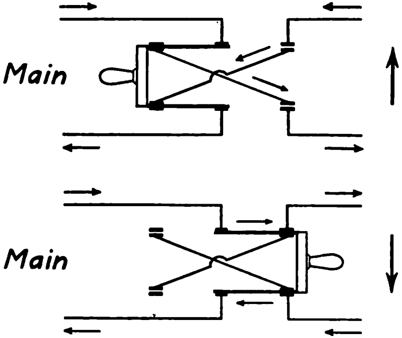


FIG. 29. Wiring of "polarity" switch.

sient surges in this kind of work. Ordinary incandescent lamps in shunt serve very well for this purpose. Some machines have such protection using either lamps, or special high resistances, or condensers.

Brushes, Etc.

Brushes bearing on slip rings or commutators will wear out in time. When they do not make good contact, sparking results and the metal gets rough and black. Inspect any such parts at reasonable intervals. Blackening of the copper rings or bars may be removed by the use of 00 sandpaper (not emery paper), then wipe with a cloth and lubricate slightly by a little paraffine; then wipe off as much as you can. New brushes should be inserted *before* any serious trouble occurs. Be sure and put them in right, noting carefully how the old ones were placed.

Burn Out.

If a motor sparks badly after the brushes and commutator have been put in good condition, it is too badly damaged to use and must be repaired or rewound by some one familiar with such work.

Polarity.

Some machines have a field winding which ensures the same terminal polarity each time the machine is started. In other cases, there is as much chance of a given terminal starting + as —. Polarity indicators are often used to show which way the rectifier comes into step. Either a primary reversing switch, Fig. 29, is used or the motor switch is opened for an instant and again closed, thus allowing the motor to drop back with the chance of reversing connection to the high tension line. Learn how to do this quickly.

Rectifier.

Two forms of rotating circuit changers are in common use, the cross-arm type and disc type. Both are run by a synchronous motor and they must be correctly placed relative to the motor armature if efficient delivery is to be secured. Fig. 30 shows the current path for the four-arm type, Fig. 31 for the two-arm, and Fig. 32 for the disc type.

In Fig. 30 when the right hand terminal of the transformer is –, flow of electrons is from A-B-tube-C-D. If the spindle turns 90° while the polarity of the transformer is reversed, electrons flow from E-F-tube-G-H. In both cases the current takes the same direction *through* the tube.

The disc type is shown in Fig. 32, PQ and RS are two conducting sectors fastened to an insulating disc turned by the motor.

Flow is A-B-tube-C-D in one case and a quarter turn connects D to B and C to A, meanwhile the transformer has reversed so that electrons pass from D-B-tube-C-A.

In Fig. 30 the cross-arm machine, E and A, C and F, B and G must be well insulated by barriers, or else the shaft must be unduly long. In the disc machine the diameter must be large enough to insure insulation between the shaft and the rim and also to avoid establishing an arc between the fixed sectors along the edge of the disc.

Sparking Troubles.

Dust and moisture may impair the insulation of barriers or disc. Remedy: Keep clean and wipe with a cloth *slightly* moistened with kerosene.

The cross-arm type must be well insulated where the arms pass through the shaft. If a break occurs there, it is not possible to patch it up. Get a new arm.

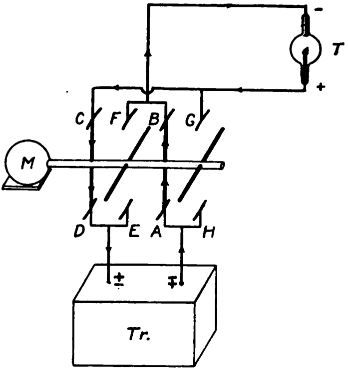


FIG. 30. Secondary circuit of Snook machine. Cross-bar type rectifier — four arms.

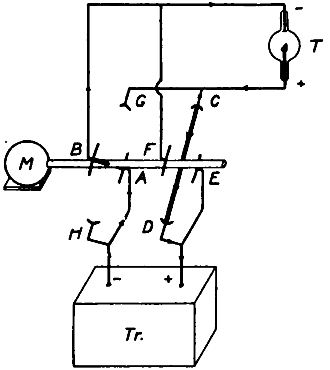


FIG. 31. Secondary circuit Waite & Bartlett machine—cross-arm type—two arms.

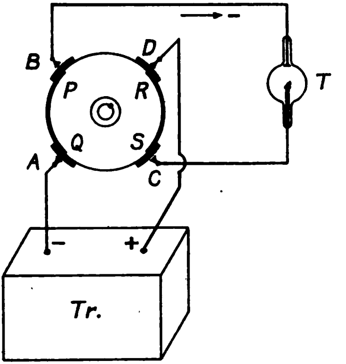


FIG. 32. Secondary circuit for disc type of rectifier.

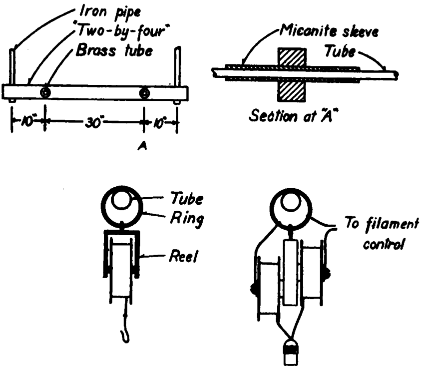


FIG. 33. Tube system of overhead high tension.

Noise.

If a disc is out of balance or if bearings are worn by lack of lubrication a machine will be noisy. Be sure to keep bearings well oiled. Do not accept a machine poorly balanced.

Inverse.

Inverse shows by fluorescent rings back of the target in a gas tube and by sparks across gap on low power setting on Coolidge tube.

Rectifier out of position. It is assumed that the maker will *mark* the shaft of the cross-arm type or the disc in the other class with reference to the motor shaft so that one can see if slip has taken place and adjust to the proper position. If this has not been done, re-adjust so that the current is a maximum on a low power setting and with the tube kept constant. This is fairly easy with a Coolidge tube. One accustomed to the appearance of the arcs at the rectifier terminals can set fairly accurately by observation.

Line Wiring.

The line for X-ray installations should receive more careful attention than has usually been given to such important work.

The primary or low tension wiring should contain enough copper to insure that there will be no considerable voltage drop on the line even when the heaviest work is done. If a line from a supply transformer or a generator has a resistance of say .3 ohms, and one draws 50 amperes, a loss of .3 x 50 = 15 volts would result. If the original voltage was 100, the total available at the X-ray transformer would be 85 volts. On 220 volt operation this is not so serious, but more reliable operation will be attained if the wire is such that at the *highest* primary current the line drop does not exceed 3 per cent.

When A. C. lines are used, the transformer from which power is drawn should be of ample capacity, and on D.C. the generator should have a capacity exceeding any estimated demand. Connecting a 10 K.W. X-ray transformer to a 5 K.W. line transformer is poor business. Fuses or circuit breakers should be conveniently placed, and all care should be exercised to avoid short circuiting or grounding the lines.

The following table shows the loss in voltage of a primary line for 50 and 100 amperes low tension current, on the assumption of a run of 100 feet between an X-ray transformer and the power transformer, giving 200 feet of line. The terminal voltage to be taken by primary and control is the difference between the line voltage and the loss. Thus, a machine drawing 100 amperes for a short exposure on a 200 volt circuit, using No. 10 wire, will have 220 — 19.9, or about 200 volts available. On 110 volt operation, 110 — 19.9 = 90 volts, making a very decided percentage drop. For this reason, machines using a large primary current are unsuited for 110 volt operation if rapid work is required.

No.	Ohms per foot	Volts lost 200 feet. 50 Amp	Volts lost 200 feet. 100 Amp.
00	.0000778	.778	1.5
0	.000098	.98	1.96
1	.000124	1.24	2.4
2	.000156	1.56	3.1
3	.000197	1.97	3.9
4	.000248	2.48	4.9
5	.000313	3.13	6.2
6	.000394	3.94	7.8
7	.000497	4 97	9.9
8	.000627	6.27	12.5
9	.000791	7.91	15.8
10	.000997	9.97	19.9

To compute the size of wire needed, one must know: (a) the maximum primary current in the X-ray transformer; (b) the distance from the supply transformer (or generator) to the X-ray transformer.

The *loss* in voltage due to line resistance is given by the product of *current in amperes by resistance in ohms of line wire per foot, by length of supply wires in feet.* Thus, on a 220 volt line, *if* a drop of 6 volts is permissible, the line being 200 feet long and the maximum current 60 amperes, then

60 x 200 x Resistance per foot = 6 volts

$$\text{Resistance per foot} = \frac{6}{60 \times 200}, = .0005 \text{ ohms.}$$

The smallest permissible wire is then "No. 7." Better use a wire considerably larger to insure the best operation.

High Tension Wiring.

In the use of high power machines, much greater care should be taken in high tension construction than is generally the case. Three points should be carefully considered. These are: First, safety of the patient and operator; second, prevention of loss by leakage; third, avoidance of puncture of tubes.

While one might get a very unpleasant jolt from an induction coil, yet danger to life is slight as compared with transformers of like voltage. In general, a *maintained* voltage of 500 through vital portions of the body is dangerous if a current of 100 M.A. or more can be delivered. A static machine, an induction coil, or a condenser may give a high initial voltage with a *brief* rush of current upon contact or grounding; this is disagreeable but usually harmless. On a power transformer which *maintains* voltage, the current continues, with possible fatal results. In most if not all installations, the *middle* of the secondary coil of the transformer is connected to the iron case or to the "earth;" the earth is such a large reservoir that its electrical condition may be regarded as constant. Thus, when working at 60 K.V. between the tube terminals, the voltage between the + line and the earth is + 30 K.V., and between the — line to earth — 30 K.V.

This divides the insulation strain on the transformer and reduces danger of sparking to the stand. If one terminal of the transformer were grounded, the full voltage would tend to pass current from the other line to anything connected to the earth. Thus, there would be a ten-inch spark length to stand, floor, water, and gas pipes, etc. When treating at a ten-inch gap the strain is then double that in the other connection, but the line to the grounded side of the transformer is safe to touch. When using metal stands, tables, and protecting screens with the metal screens *between the tube* and the patient, they should be well grounded. The patient is then free from induced "static" and from any discharge that may occur between the parts of the outfit. *When the patient is between the tube and the grounded metal, there is always more danger to the patient*, and corresponding care must be used.

Aside from the difficulty of preventing spark discharges and arcs, it is of great importance to prevent leakage between all parts having a high potential difference. This leakage is due to high electric stress, rendering the air conducting and giving rise to "corona." Also, many good insulators when clean and dry become conducting when dusty and moist. High tension wires mounted on ordinary wood or on glass may be expected to leak badly.

Surface leakage is less on hard rubber and micanite than on glass. Wiping insulating surfaces with a cloth *slightly* moistened with kerosene will often greatly reduce leakage over the surface.

Corona loss is decreased by reducing the electric stress between the conductor and the surrounding air. This is accomplished by avoiding points, sharp edges, and close proximity of conductors of high potential difference. High potential overhead lines should be from 24 to 30 inches apart. All sharp points and corners should be avoided and small wires, especially if cloth insulated, should *not* be used. Gutta percha covered wire *without* braided covering is useful where a flexible conductor is needed. For rigid wiring and overhead lines, metal tubing not less than half inch external diameter should be used. This may be mounted by insulating rods attached to the ceiling, or as shown in Fig. 33.

The same design can be easily adapted to inter-connecting rooms by mounting the tubing in the center of a large micanite or porcelain tube and filling the space with a good insulating wax. The insulating tube should be extended 6 to 8 inches from the wall. The rings for tube connection may carry reels if desired.

While line leakage of moderate amount may be tolerated in fluoroscopic or radiographic work, it may be of great importance in treatment. A milliammeter measures not alone the tube current but all leakage *beyond* the instrument itself. Corona between wires, spark gap corona and surface leakage together may give an error of two or three hundred per cent. We may avoid this (1) by proper design, (2) by *always* connecting the milliammeter beyond the spark gap as shown in Fig 45. (3) where any doubt arises check by testing with a second milliammeter connected directly to the tube.

Tracing Circuits.

The modern transformer X-ray machine is rarely characterized by simplicity of wiring or accessibility of connections. In case of trouble, or where one must connect or set up the machine without expert aid, it is well to learn to trace the circuits and to test out for breaks, etc.

While to one unaccustomed to do this, it seems very difficult, a few suggestions may help. There are only two main current paths from one supply line through the apparatus to the other line—the motor circuit and the transformer circuit. In tracing either circuit, follow a complete metallic path from one supply line through the machine back to the other supply line. Where paths divide, they must come together again further on, and one must avoid simply chasing around some loop. The main circuit in outline on all resistance controlled machines is shown in Fig. 34.

Where no attempt to bring the motor contact into correct phase is made, a reversing switch is provided —Fig. 35, which changes polarity of transformer without disturbing the motor circuit. A timer connection may be added, as in Fig. 36. There may be a special switch to be operated by a small current through a magnet, Fig. 37. Several taps (inductances) may be brought out from the primary winding, Fig. 38. There may be a polarity indicator to show the way to place the reversing switch for a given tube connection.

The *main* wiring schemes of the five machines likely to be used in army hospitals are shown in Figs. 40 to 44. Different models put out by the same manufacturer may be no more alike than the different makes. Whatever machine be used, to become familiar with the wiring will help to quickly overcome difficulties when they arise.

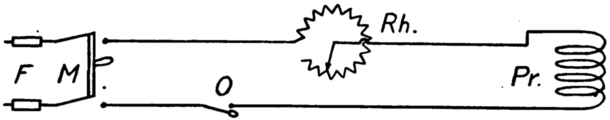


FIG. 34. Simple primary circuit, rheostat control.

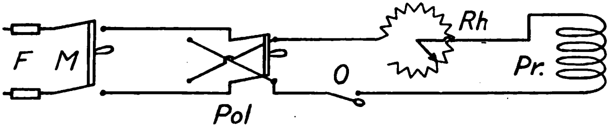


FIG. 35. Addition of reversing switch (polarity changer).

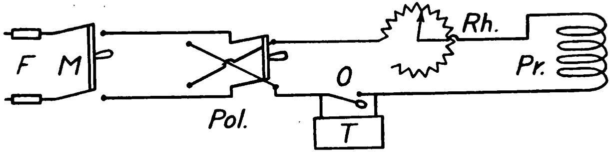


FIG. 36. Time switch added.

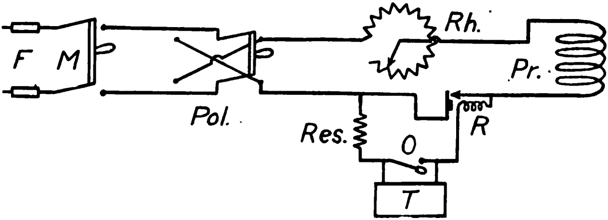


FIG. 37. Magnetic control-switch added.

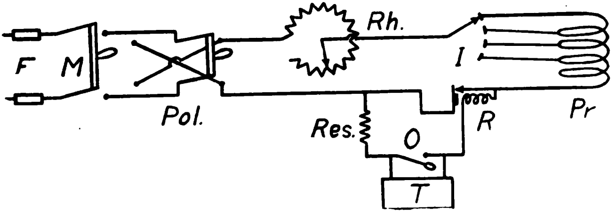


FIG. 38. Multiple primary taps added.

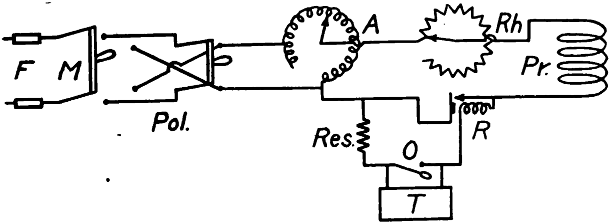


FIG. 39. Auto-transformer instead of multiple primary taps.

A.	Auto transformer.
B.	Blowout magnet.
Btr.	Booster.
C.	Coolidge filament trans-former primary.
C. B.	Circuit breaker.
F.	Fuses.
F. S.	Foot switch.
G.	Ground.
I.	Inductance taps.
K. V.	Kilovolt or gap meter.
L.	Lamp.
M.	Main switch.
Mot.	Motor.
Mot. S.	Motor switch.
M. T.	Meter transformer.
O.	Operating switch.
Pol.	Polarity changer.
Pol. I.	Polarity indicator.
Pr.	Primary of transformer.
Prot.	Protective resistance, con-denser or lamp.
R.	Remote control contactor.
Rh.	Rheostat.
Reg.	Filament regulator.
Res.	Resistance.
Rect.	Tungar rectifier (low ten-sion).
Syn.	Synchronising switch.
St.	Starting switch.
T.	Timer.
T. S.	Timer Switch.

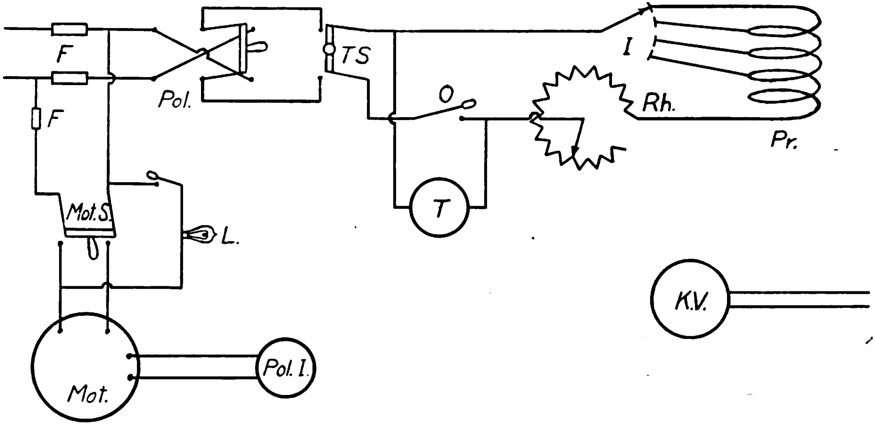


FIG. 40. Wiring of primary of Campbell machine. Rheostat—multiple "inductance" control.

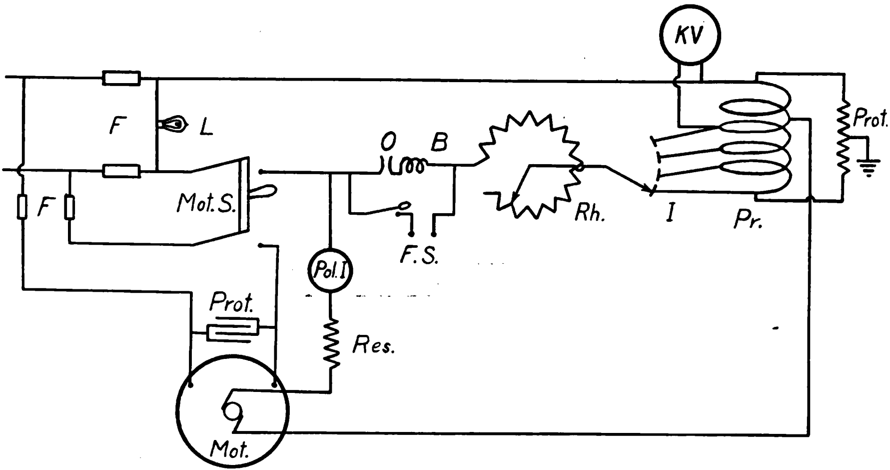


Fig. 41. Wiring of primary of Snook machine. Rheostat—multiple "inductance" control.

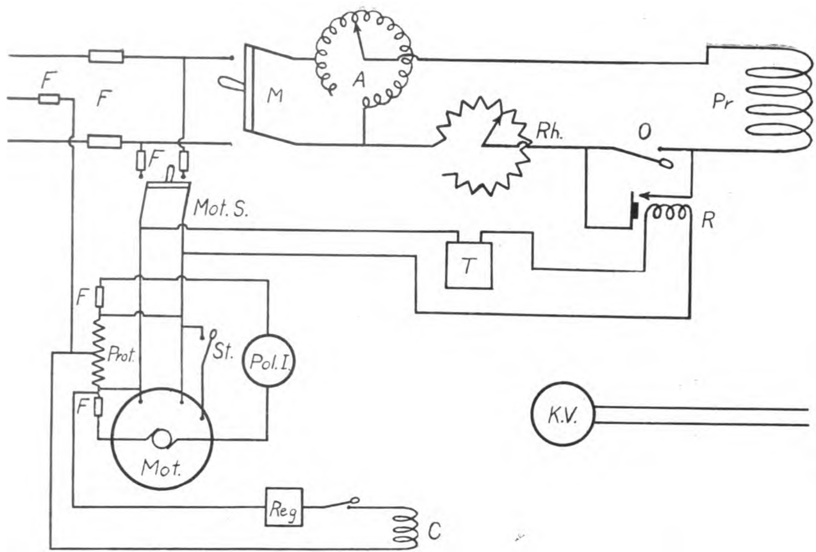


FIG. 42. Wiring of primary of Wappler machine. Auto-transformer—Rheostat control.

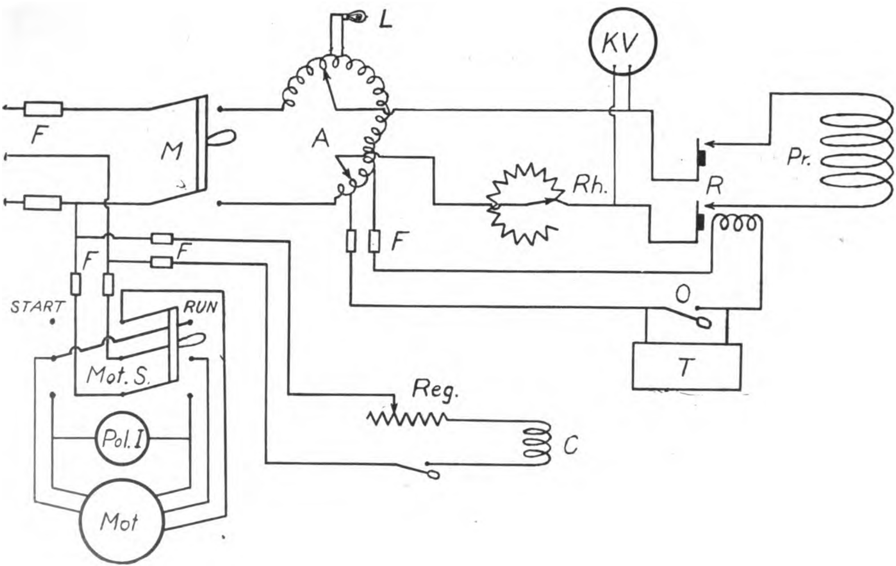


Fig. 43. Wiring of primary of Kelly-Koett machine. Auto-transformer—Rheostat control.

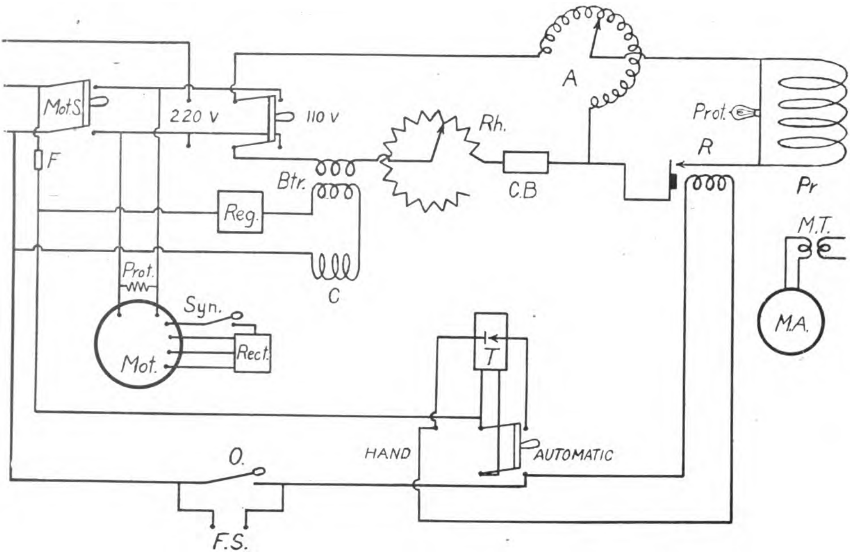


Fig. 44. Wiring of primary—Waite & Bartlett machine. Auto-transformer—rheostat control.

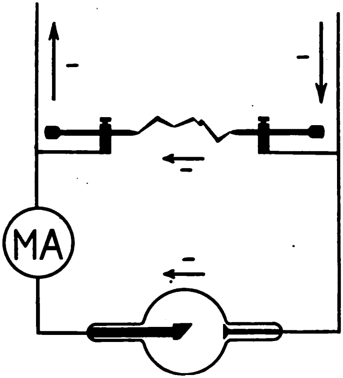


FIG. 45. The path of negative charge from line through spark gap, tube and milliammeter.

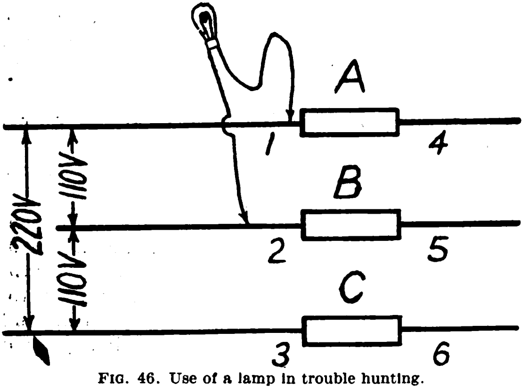


FIG. 46. Use of a lamp in trouble hunting.

Locating Trouble.

Troubles in X-ray apparatus may be divided into two groups: (a) mechanical; (b) electrical.

Under mechanical, we may have worn bearings, worn or broken brushes, slip of rectifier on shaft; warping of wood thus throwing shaft out of alignment. Care in oiling and keeping clean and dry will prevent most of these.

Under electrical troubles, we have:

(a) Improper connections.

(b) Break in conducting line.

(c) Loose connections.

(d) Failure of insulation.

To avoid (a) all wires removed from their connections should be labeled as well as the binding posts, etc., from which they were disconnected. Serious damage may be done if one attempts to operate with improper connections.

To find breaks, close switches and use test lamps, as directed in the following pages. When the lamp lights on connecting two points between which the resistance should be low, there must be a poor connection or a break.

Loose contacts are likely to cause irregular or intermittent action. Failure of insulation may cause current to pass between two wires without going through the proper path.

If the fuse in any part of the circuit blows when only moderate power is used, open all switches and look for a short circuit; and if none is found insert a new fuse and test out on low power before attempting to continue work. Beware of the high tension line and terminals when hunting trouble on the primary or motor circuit.

Primary Circuit.

When a machine which has been operating fails to work, there must be trouble in either the supply or some part of the circuit insulation or wiring. The low tension side may be easiest tested by using an ordinary incandescent lamp of suitable voltage. Start back of the fuses on the main line, having motor and transformer switches *open.* Fig. 46.

Touch lamp terminal wires (bared ends) to bare wire at 1 and 2. If the line is "alive," a 220 volt lamp will light up to half brightness. Do the same for 2 and 3. Connect 1 to 5, and if lamp fails to light, fuse B is burned out. Or if switches are closed and the lamp lights when connected to the opposite ends of a fuse, as 2 to 5, the fuse must be burned out. Try 2 to 4 and 2 to 6; if all these connections give equal brightness to the filament, the trouble must be further along.

Close motor starting switch, and if motor does not start connect lamp across motor fuses one at a time. If a fuse is intact, it has so low a resistance that current will not pass through the lamp; if broken, the full line voltage appears at the break, and the lamp will light.

Finally, connect across the motor terminals, and if the lamp lights fully the trouble is *inside* the motor.

Follow the same general procedure in testing the transformer circuit, but *use great care to keep away from the high tension terminals;* also, be sure to set rheostat at lowest power.

If the lamp lights across the low tension terminals and no spark can be driven across a short gap between the secondary terminals, the trouble is inside the transformer and the chance of its repair by an operator is slight. If a break is near the terminals, it may sometimes be located and repaired; otherwise it must be sent to a manufacturer.

Secondary Circuit.

Outside of a break in the secondary coil or an arc to the case, the most common trouble in the secondary line is a complete or partial short circuit. This may occur in various ways.

(1) In a cross arm machine, the insulation may break down between the cross conductor and the rectifier shaft.

(2) In a disc machine, the disc may be dirty or carbonized, "shorting" around the periphery or to the motor shaft.

(3) A high tension line may be in contact with the tube stand, a wall containing metal lath, the floor, etc.

The latter may, of course, be remedied at once by the operator.

In case of rectifier trouble, a Coolidge tube may be run directly on the transformer, provided low spark gap and current is used so that the target does not get hot. For fluoroscopic work there is no trouble in doing this. but for radiography time must be allowed between exposures for the target to cool.

Care of Tubes.

All tubes are fragile and may easily be damaged by fracture. A warm tube must not be placed on a cold support. Keep tubes free from dust and moisture. Do not allow either high tension wire to come within five or six inches of the glass bulb. Always heat the filament of the Coolidge tube before attempting to pass current through it. Preserve cases or frames in which tubes are received for the return of punctured tubes or those requiring repumping. Use great care in softening gas tubes. Never soften a gas-containing tube with rheostat set for heavy radiography; use low power. If a tube is too soft, the rays emitted will not pass through the flesh. Better take more time and soften stepwise, testing after each *short* passage of current through the softener.

To soften the Snook hydrogen tube, pass through the reducer about 15 M.A. five or ten seconds at a time. Repeat if necessary. Do not use more current; *use more time.* Always maintain polarity as shown in Fig. 47. To harden the tube, pass through the raiser about 25 M.A. (never more than 30 M.A.) twenty seconds at a time. If the tube is excessively soft, disconnect spiral temporarily from + terminal of raiser. Connect anode wire to + terminal of raiser and cathode to − terminal of raiser. Run three minutes with 22 to 25 M.A. Repeat if necessary. Replace spiral. Regulate tube before making exposure. It should test out at 2″ gap and about 5 M.A. The tube tends to harden a trifle during the first exposure when the tube is cold. To compensate, introduce a little more gas. Operate at 40 M.A. for a medium focus tube. It will give much more service than at 45 to 50 M.A. A sharp focus should be limited to 20 M.A. and the time of exposure doubled. Use a broad focus tube for extremely fast exposures in making stomach and intestinal plates.

When a tube is in operation, the heat developed at the target is measured by the current × voltage. If this heat is produced at such a rate that it cannot be dissipated by conduction and radiation, the metal at the focal spot may be vaporized or melted and the tube ruined very quickly.

It is rarely necessary to do so-called flash or instantaneous work, and it can only be done at high tube cost. Properly used, a tube is capable of a large amount of work.

Do not use intermittent excitation during an exposure

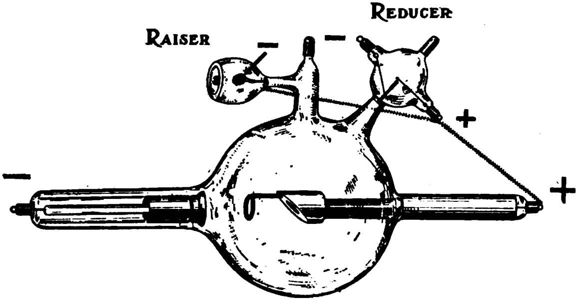


FIG. 47. Diagram showing softening and raising connections on Snook hydrogen tube.

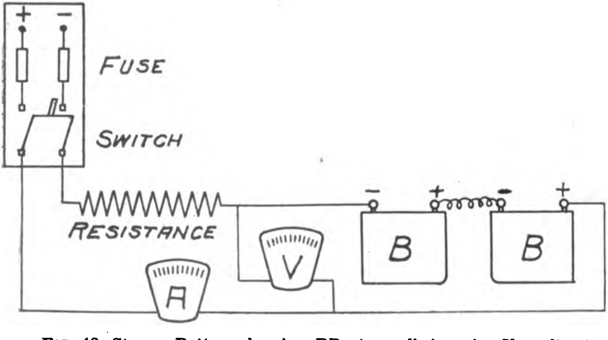


FIG. 48. Storage Battery charging. BB—two cells in series. V—voltmeter. A—ammeter.

In heavy work, if 60 M.A. for 4 seconds overheats the tube at the gap needed, many operators close the switch for four separate seconds with three *intervals* of a second or more. The patient must remain at rest for seven seconds. The same exposure may be secured with 40 M.A. continuously delivered for six seconds. In the latter case the danger of pitting or cracking the target is less and the part need be held immobile for less time. This intermittent method has been suggested to overcome the tendency for voltage drop on heating gas tubes while in operation, but the allowable interval is too short to do much good.

Care of Motors.

(1) All motors need oil at periods depending on the amount of use. Failure to oil may cause the bearings to wear enough to allow the armature to rub on the field supports and ruin the motor.

(2) Most, if not all motors used on X-ray machines have either slip rings or commutators, or both. Bearing on these are carbon or other conducting brushes. As the tension is low, these must have a good, even, contact. Springs are provided to secure this, and if these break or get out of adjustment there will be either intermittent contact or none. The motor then either fails to start or it sparks at these bad contact points and corrodes the metal rings or commutator bars. If only slightly injured, they may be smoothed down by 00 sandpaper, lubricated slightly with paraffin or *light* oil and rubbed off with a clean cloth. New brushes should then be inserted and properly adjusted.

(3) Many motors have two sets of connections, one for *starting*, the other for *running*. Usually a double throw switch is used and marked for the purpose. Don't close on the running side and wait for something to

happen. Don't throw over too quickly. Don't leave switch on starting position.

(4) Keep motor clean, dry, and in as dry a place as circumstances permit.

(5) If the motor fails to start, *open* the starting switch and test the fuse on the motor circuit; also be sure the line is "alive." If power is on and the fuse is intact, go carefully over the wiring to the motor, examine brushes, look at all external wires, and if no break is found it is fairly probable that some internal trouble has developed requiring technical motor knowledge for repair.

(6) Be very sure not to connect a motor on a line for which it was not designed,—as an A.C. motor on a D.C. line; or a 220 volt motor on a 110 volt line, or the reverse; or an A.C. motor designed for 60 cycles on a 40 cycle line, etc.

(7) If an A.C. motor fails to run at the right speed, do not try to operate tubes with it.

Care of Batteries.

The only type of battery likely to be met in X-ray practice is the storage battery. This is sometimes used for portable coil work, and quite often to light the Coolidge filament. Each separate cell of a storage battery adds about two volts to the line. For any given voltage, then, half as many cells must be used as volts are needed. This voltage is independent of the size of the cells. A storage cell does not store electricity; it uses electricity to cause a chemical change in its plates, and when it is discharged this chemical change is reversed and electric current flows from the cell. The amount of chemical change on proper charge is in proportion to the charging current and the time of flow, and is estimated in ampere-hours.

Thus, a 10 ampere-hour battery will deliver ten amperes for one hour, 1 ampere for ten hours, ½ an ampere for twenty hours, etc. Too rapid charge or discharge should be avoided because of damaging the battery.

The storage battery consists of two sets of plates, each containing a salt of lead held in some sort of small lead pockets, the whole being immersed in a solution of sulphuric acid. In a single cell, all the positive plates are joined together, likewise all the negative, and these sets must not be in contact. The negative of one cell must be joined to the positive of an adjacent one, leaving one + and one — for external connection. The ampere-hour capacity depends on the area of + and — plates per cell.

The following are the main points to be kept in mind when using storage batteries:

(1) They must be charged on *direct* current.

(2) The charging rate given by the maker should not be exceeded.

(3) The discharge rate allowable should not be exceeded.

(4) Loss of electrolyte by evaporation must be replaced by adding distilled water, or as pure water as can be had.

(5) Loss of electrolyte by accidental spilling must be replaced by adding an *acid solution* of the proper density.

(6) In making up an acid solution, never pour water into the acid, but pour acid slowly into the water.

(7) Never let the solution get so low as to leave a portion of the plates bare.

(8) Do not overcharge, nor discharge after the voltage falls below 1.8 volts per cell.

(9) Do not let the battery freeze.

(10) Do not let the battery stand idle for long periods.

If it must be laid up, charge it fully and draw off the solution. For short periods, put a high resistance across its terminals and let it slowly discharge, and charge it up again at intervals.

(11) If overheated by too high current passing in or out, the active material is likely to crumble and fall to the bottom of the cell and cause a short circuit, whereby the battery discharges internally.

(12) The discharge voltage falls quite rapidly after a battery is first charged, then more slowly until nearly discharged, then rapidly. When used on a Coolidge filament, which requires about four amperes, it is well to pass twelve or fifteen amperes through a suitable resistance for three or four minutes to bring the voltage down to the steady state the first time it is used after charging.

(13) A small voltmeter is very useful in charging a battery, and a suitable resistance to bring the line voltage down to that required in charging should always be at hand. Either a voltmeter or a test for acid density may be used to indicate full charge.

(14) Do not fail to disconnect the charging line before using on a Coolidge tube.

(15) Storage cell terminals are almost sure to corrode; scrape clean when connecting.

The charging connections are shown in Fig. 48. If the battery has any charge, it will deflect the voltmeter in the same direction when discharging as when charging. Connect the voltmeter in the right way before starting to charge, and it will tell you whether you have connected to the charging line correctly. The ammeter may be omitted if one knows that the charging current is neither too large nor too small.

Conditions For Good Diagnostic Negatives.

Consider two regions, A and B, of unequal absorbing capacity and in a mass of less dense material, C. Fig. 49.

For the target position, 1, the shadows of A and B will overlap in part, and both are super-imposed on that of C. When the target is at 2, the shadows of A and B are separated. The practical question of position is to get the most favorable relative position of A and B. The problem of exposure is to clearly outline these two shadows in the general shadow of C. If the absorbing capacity of A and B is nearly equal to that of a like volume of C, this becomes of increasing difficulty as C is made thicker. Not only is the differential absorption less, but the shadow of A or of B is more diffuse and scattered radiation tends to fog and obliterate the shadows. No exact solution is possible for the infinite variety of cases presented but attention to specific cases will be of great assistance until a fair routine practice is developed. Development is also a very important factor. The speed of plates must also be considered although good work can be done with any standard make of plate. The inexperienced operator is quite prone to attribute failures to the plate used, but it is rather unusual to find really poor plates unless they have been misused after purchase. They should be kept where it is cool and dry, and entirely protected from both heat, light and both direct and scattered X-rays.

Fast Work.

From what has gone before, it is clear that the same radiographic density can be secured in a great variety of exposure times. Certainly, for the inexperienced operator high speed is inadvisable. If 3 to 10 seconds would give the most desirable exposure, an error of one second

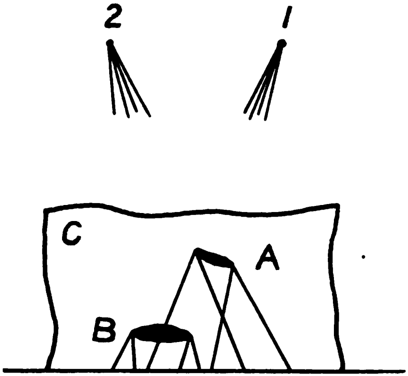


FIG. 49. Relation of target position to shadows and their overlapping.

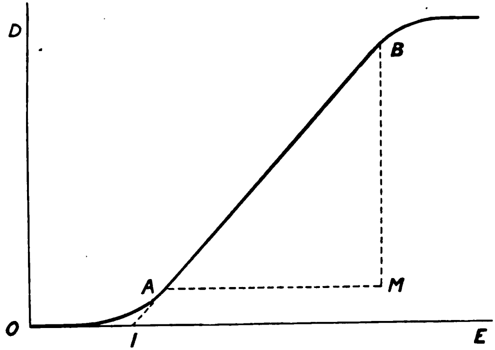


FIG. 50. The relation between exposure and density of a photographic plate.
Below A—under exposure. Beyond B—over exposure. OI—inertia of the plate.

would give a fairly good plate. On power such that ½ second is the best, an error of one second in judgment or execution would exceed the latitude of the plate.

The conditions for fast work are:

(1) Small target distance.
(2) Very large current.
(3) High voltage.
(4) Fast plates or intensifying screens.

The disadvantage of the first is distortion and haze of outline, due to size of electron focus; of the second danger of melting the target, and difficulty in setting to proper voltage. When high voltage is used, the evening up of penetration as well as the increase of scattering with high penetration rays, tends to give flat plates. Very fast plates and ordinary plates with screens allow little latitude of exposure. Screens also may register their own dust or surface defects.

Photographic Density and Character of Negative.

Considerable objection has been made to the use of photographic plates, films, or paper in the study of Roentgen radiation. Much of the adverse criticism is well founded, for the following reasons: The unaided eye is a poor judge of comparative absorption of light by a negative; only by means of comparison involving photometric apparatus can one be fairly sure of correct measurement. If an unexposed or clear portion of a negative transmits an arbitrary amount of light, Q, an area transmitting 50 per cent. or half as much would be said to have an opacity of 2; and the logarithm of this opacity would be named the density of this portion of the negative. It has been found that density determined in this way is proportional to the amount of silver reduced per unit plate area. Transmissions, opacities, and densities are related as follows:

Transmission per cent.		*Opacity.*	*Density.*	
		0	D	
(Clear glass)	100	1	0	(Log 1 = 0)
	90%	10/9 = 1.11 —	.104	
	80%	10/8 = 1.25 —	.223	
	70%	10/7 = 1.43 —	.358	
	60%	10/6 = 1.66 —	.507	
	50%	10/5 = 2.00 —	.693	
	40%	10/4 = 2.50 —	.916	
	30%	10/3 = 3.33 —	1.203	
	20%	10/2 = 5.00 —	1.609	

When the intensity and quality of light remains fixed, the exposure varies only with the time. Suppose that K t = E where K depends on the nature and intensity of the radiation. Plotting E and D, there remains a line approximately as shown in Fig. 50. A portion of this line AB is nearly straight; below A and above B it is curved somewhat, as shown. If AB is produced to cut the density axis at I, OI is named the *inertia* of the plate. The portion AB of the plot is the region of proper exposure. Above B the density fails to increase in proportion to exposure and is the region of over-exposure. In fact, if the exposure is carried too far, the density falls off and a reversal may occur.

The slope of the line AB or the ratio [BM/AM = is named the development factor: For under-development γ is small and contrast is low. For longer development, the line swings counter clockwise on I as a pivot. The point where one should stop is a matter to be governed by experience. In ordinary photography γ ranges from .8 to 1.3; probably no accurate determination can be made of the most desirable conditions until some agreement is reached as to the best quality of negative for specific purposes.

The *inertia* of the plate is not affected by time of development. A fast plate is one where O I is small. A plate of great latitude is one where exposure difference for A and B is large. The speed of a plate is determined by the inertia O I and is expressed in arbitrary sensitometer units.

The conditions during development fix, for a given plate, a time beyond which development should not be carried on account of fog. In X-ray work, the use of high penetration on thick patients tends to fog by cross scattered radiation, and this may be noticed long before developer fog becomes troublesome.

As a means of measurement, we may utilize different portions of the same plate under different physical conditions to learn whether the radiation effects on the plate are or are not alike. For example, if a *constant* voltage is used at constant distance, the exposure varies as the product of current and time,—so that 20 M.A. for 2 seconds and 40 M.A. for 1 second should give equal density with equal development, provided the rise and fall of voltage be alike in the two cases.

Certain terms are in common use when negatives are described, and should be understood.

CONTRAST refers to the amount of difference in darkening for a small difference of exposure. Thus, if rays pass through bone and flesh, there is a variation in the amount of radiation *reaching the plate*, due to difference of absorption; when this results in a marked difference in darkening, the negative is "contrasty." Contrast depends on the nature of the plate and the development, and to a great extent on the quality of the radiation used. If the beam is too penetrating, contrast is reduced, for if rays pass through bone and flesh equally well there would be no contrast. Too "soft" radiation will fail to get through the denser portion and will give high contrast but poor detail in thick parts. The amount of contrast to be desired will vary with the work to be done. A plate to show fine bone detail and contrast may show but little of the soft tissue.

DETAIL refers to the fineness of the marking of light and shade. Thus, a mastoid plate should show minute structure or lines of light and shade should show sharp gradation or density change. Detail depends on:

(a) Breadth of tube focal spot.
(b) Distance of target from plate.
(c) Distance of part to be radiographed from plate.
(d) Complete immobilization of patient.
(e) Correct exposure and development.

Exposure Table.

Many attempts have been made to work out exposure tables such that inexperienced operators can get favorable results. Without doubt the best work is done when spark gap, current, and time are chosen with reference to the individual case in hand, and any operator who cannot improve on the results secured by adhering to any single table is unfit for the work.

As a general guide in *starting* work, a uniform rather high gap may be used,—say 5 inches, and a uniform target plate distance,—say 20 inches except for chest, where 28 inches is advised. With all this understood, the average of reports from many sources gives the following table for a patient of about 150 pounds weight and a Seed X-ray plate. The author prefers a *shorter* gap for most work [A-P head work excepted], and certainly with the ordinary solid tungsten target, medium focus Coolidge tube, better negatives result from proper exposure on a four-inch gap than on a five-inch one; this will require about 50 per cent. increase in time of exposure for the same distance and current.

Part.	*Time sec.*	
Head, A-P	12	
Head, Lat.	6	
Neck	3	
Shoulder	3½	
Elbow	1½	
Wrist	1	All exposures on 5″ gap, 40 M.A. 20″ distance except chest which is at 28″.
Kidney	3—5	
Bladder	3—5	
Hip joint	5—7	
Pelvis	5—7	
Knee	2	
Ankle	1½	
Lumbar spine	5—6	
Teeth (slow film)	4	
Teeth (fast film)	1½	
Chest (at 28″)	2½—4	

NOTES: (a) For parts above average thickness, increases time considerably more than in proportion to increase of thickness.

(b) If it is *necessary* to work at other distances than 20″, use the following table of multiplying factors:

Distance	*Time factor*	*Distance*	*Time factor*
15″	.6	21″	1.1
16	.6	22	1.2
17	.7	23	1.3
18	.8	24	1.4
19	.9	25	1.6
20	1.0		

For "Diagnostic plates," reduce time by 1/4?
For Paragon plates, reduce time by 1/5?

Plates and Films.

Photographic plates and films consist of a thin layer of gelatine containing a salt of silver and spread on glass or celluloid. Light and X-rays cause a change in the silver salt such that suitable chemicals, called developers, act on the portions that have received the radiation, changing the silver compound to metallic silver and thus rendering those portions more or less opaque to light. The opacity produced will depend on the amount of radiant action, on the sensitiveness of the emulsion, and on the development. Those portions receiving much light or X-rays, when fully developed, may be quite opaque; other portions may be entirely or nearly transparent.

After development the plate is washed and placed in a "fixing" bath which removes the unused silver salt, as shown by the disappearance of the cream color of the emulsion, rendering the parts not radiated and developed transparent.

All plates sensitive to X-rays are also sensitive to ordinary light and hence they must be entirely protected from ordinary white light until finished.

The emulsion is an example of unstable chemical structure and may be injured by (1) moisture, (2) high temperature, (3) contact with other material, (4) exposure to light or X-rays. Plates should be kept in the original boxes, on edge, in a cool dry room, well protected from X-rays. No more plates should be put up in envelopes than are likely to be used in the next two or three days.

Filling Envelopes and Cassettes.

X-ray plates are used either in envelopes or in plate-holders, called cassettes. It is quite essential that in regular work the emulsion side should be toward the patient. To insure this when using envelopes, arrange the envelopes to be filled before darkening the room. Put black and yellow envelopes in alternation with the end flaps down, insert plate with emulsion side down,—i. e., so that the flap will fold over the *back* of the plate; then insert the flap end first in the yellow envelope with the emulsion down so that the flap of the outer envelope also folds over the back. Then place the smooth side of the envelope toward the target. A soft brush is useful to remove dust from plates and *cassettes*.

In using cassettes *without screens, put the emulsion side down*. This side can be determined by sighting across the surface, as it appears dull as compared with the glass side; or touch the tongue to the extreme corner of the plate,—the emulsion side will be slightly sticky. Form the habit of closing partly empty plate boxes *at once* after filling envelopes or cassettes.

Intensifying Screens.

When using intensifying screens the usual practice in this country is to allow the rays to pass *through the glass* to the emulsion and then to the screen surface. Consequently the negative, when viewed with the emulsion side toward the eye, is *reversed* as to *right* and *left* as compared with the usual plate. The screen should be firmly fixed to the back of the cassette and should be kept *scrupulously* clean, wipe off dust with a *clean* cloth, and never touch the surface with wet or greasy fingers. *Insert cleaned plate with emulsion side up*, and be sure that the springs press the screen firmly against the plate. On account of the variable X-ray opacity of the glass at present in use, screen work is rather uncertain. Be sure to keep screen clean by not letting it get wet, dirty, or dusty.

Care in Handling Plates.

In all cases, plates must be kept well protected by lead when in the X-ray room. A good lead lined box on casters is very useful for this purpose, and where much work is done, one for exposed and another for unexposed plates should be provided, or a partition plainly marked "EXPOSED" and "UNEXPOSED," dividing a single box may be used.

The following cautions may be given to those unfamiliar with plate work:

(1) Never handle plates with wet or greasy fingers, either before or after exposed. Marks and streaks are sure to result, even if the emulsion is not destroyed.

(2) Learn to handle plates without touching the emulsion side, even with dry fingers.

(3) Mix all solutions according to instructions and see that chemicals are actually *dissolved.*

(4) Keep all trays *clean,* and do not use insufficient or too old developer; stains are hard to remove, and the cost in time and money is excessive if it is attempted.

(5) In tray development, be sure that the developer covers the entire plate at once. Tilt the tray slightly on inserting the plate, and tilt the tray in several directions to ensure complete wetting of the film as soon as possible. Keep tray in motion during development.

(6) Do not examine the plate by removing it from the developer until the minimum time for full development or normal exposure has elapsed.

(7) Do not try to develop several plates in a tray at one time, if they overlap.

(8) Wash plates well on removing from the developer, before placing in the fixing bath.

(9) Leave plates in the fixer for some minutes *after* they *seem* to be fully cleared; then wash thoroughly, in running water if possible.

(10) Don't use the same trays for hypo and for development. Mark hypo trays and keep them well away from developer. A little hypo in the developer is fatal.

(11) Keep plates in a dust-free atmosphere and in one position until dry.

(12) When the developer is not in use, keep in *tightly* closed containers. Glass fruit jars with rubbers are as good as anything for small amounts. Use a close fitting float in tank.

(13) Don't try all the developing formulae you can find; take one advised for the plate you use, and learn to use it.

(14) Don't fix in plain hypo, at least in warm weather.

Tank Development.

In tank development, the plate is placed, while dry, in a special frame or holder and hung vertically in the tank containing the developer. This method is desirable when much work is done. If full strength developer is used, the developer must be stirred during development, either by a motor tilting device or by moving plates by hand.

Temperature.

The action of the developer varies greatly with changes in temperature. Between 60° F. (16°C.) and 70° F. (22°C.) is best. Hot developer works *fast* and is likely to fog the plate. Cold developer is slow and may not give anything on a normal exposure. Do *not* cool developer by *adding* ice or ice water, as this dilutes the solution. When using tanks, cold or ice water may flow or stand around the developer tank until a proper temperature is reached.

Concentration.

If more water is added to a normal developer, slower action will result. This is sometimes advised in tank development, and with screen plates, but is not necessary if the developer is stirred occasionally.

Plate Defects.

Plates are sometimes defective, due to faults or accidents in manufacture, but in most cases of complaint the trouble is due to improper treatment after leaving the factory. If one is sure of proper exposure, development, fixation and washing, and still finds streaks, spots, bubbles, or bad color, the plates may be blamed. Much trouble is traced to the materials used at present, and in all cases of doubt check plates should be made. Defects are not likely to appear on the same region in both negatives. Looking across the negative at any evenly illuminated surface will often show whether a spot is due to a defect in the glass or to something on the emulsion surface.

Examining Negatives.

When it can be avoided, plates ought not to be examined until dry. If they must be used while wet, care is needed to avoid heating the gelatine or it will melt and completely ruin the negative. A well diffused illumination is very desirable; it should be well under control so as to give a strong light for dark negatives and a much weaker one for thin ones. Ground or opalescent glass is not needed if a matte white surface is illuminated and the plates are viewed against it.

Developer Action.

The action of developer on an exposed plate is rather a complicated matter. For the present purpose we may omit discussion further than to say that with any active developing agent a suitable amount of alkali is indispensable. Do not vary the proportion shown in reliable and tested formulae, at least in routine work. Development at any given depth below the surface of the emulsion can only take place when the active development solution has reached that point in sufficient amount to cause the change required. Hence dilute or partly exhausted developer requires more time. Prolonged action of developer on the emulsion will cause a darkening, even with little or no exposure, and too strong developer will over-develop the outer layers before the deeper ones are affected. Plates exposed to X-rays are developable through the entire depth of emulsion, while light only affects the outer layer. Hence, if fog can be avoided X-ray plates will increase in density with longer development to a greater extent than will negatives exposed to light. The action of potassium bromide restrains or delays development at the surface and tends to keep the "whites" clear. All developers are absorbers of oxygen and are useless when they no longer absorb this gas. For this reason, they ought to be protected from air when not in use..

"Hypo" or Fixing.

The purpose of fixation is the removal of all unreduced silver, leaving the small specks of metallic silver suspended in the gelatine film. Any unreduced silver left in the gelatine will sooner or later discolor and ruin the negative. By using acid and alum, the clearing is improved and the film of gelatine hardened. "Hypo" must be *thoroughly* removed by washing half an hour to one hour in running water, so that hypo crystals will not form in the gelatine, ruining the negative. If the bath is too acid a rash will appear on the surface of the gelatine. The acid should be partly neutralized by the addition of sodium carbonate. If the bath appears milky, it generally lacks acid and can be cleared by the addition of acetic acid.

Developing Formulae.

Most X-ray operators had been using a hydrochinon-metol developer prior to the shortage of metol. Certain substitutes for metol have been marketed of more or less value. The following formulae have been found fairly good in practice:

Hydrochinone.

Water (warm)	1	Gal.	5	Gal.
Sodium Sulphite (dry)	8	Oz.	40	"
Hydrochinone	1½	"	7½	"
Sodium Carbonate (dry)	8	"	40	"
Pot. Bromide	1	Dr.	5	Dr.

Mix in order named.

Good for tank development.

Elon-Hydrochinone.

(Dissolve these chemicals in order named:)

Water	20 ozs.
Elon	20 grs.
Sulphite of Soda (dry)	1 oz.
Hydrochinone	80 grs.
Carbonate of Soda (dry)	1 oz.
Potassium Bromide	8 grs.

Good for tank development.

Edinol-Hydrochinone.

Solution A.

Boiling distilled water, 32 ozs.
Sodium Sulphite (dry), 6 ozs.
Edinol, 5 drams.
Hydrochinone, 1 oz.
Potassium Bromide, 6 drams.

Solution B.

Water, 32 ozs.
Potassium Carbonate, 8 ozs.

Use one ounce of Solution A, one ounce of Solution B and two ounces of water. Develop 6 to 9 minutes.

Good for tray development.

Metabisulphite-Hydrochinone.

A professional photographer doing considerable X-ray development recommends the following developer as very satisfactory for general work.

Mix in order named.

Solution A.

Water, 200 ozs.
Hydrochinone, 4 ozs.
Potassium Metabisulphite, 10 gr.
Potassium bromide, 50 gr.

Solution B.

Water, 200 ozs.
Sodium sulphite, 1¼ lbs.
Caustic soda, 2¼ ozs.

These solutions keep well in stock. For use, mix in equal parts.

Fixing Bath Formulae.

An Acid Hypo Fixing Bath may be prepared as follows:

Water, 64 ozs.
Hypo, 16 ozs.

When *fully dissolved* add the following hardening solution:

Water, 5 ozs.
Sulphite of Soda, 1 oz.
Acetic Acid (28% pure), 3 ozs.
Powdered Alum, 1 oz.

If preferred 1 ounce of Citric Acid may be substituted for Acetic.

This bath may be made up at any time in advance and may be used so long as it retains its strength, or is not sufficiently discolored by developer carried into it to stain the negatives.

Chrome Alum Fixing Bath.

This bath has good keeping qualities, fixes clean and remains clear after long continued use.

A

Pure Water, 96 ozs.
Hypo, 2 lbs.
Sulphite of Soda, 2 ozs.

B

Pure Water, 32 ozs.
Chrome Alum, 2 ozs.
Sulphuric Acid, C. P., 1/4 oz.

(Mix chemicals in order named:)

When dissolved, slowly pour B into A while stirring rapidly.

Hypo is cheaper than spoiled plates. Use plenty and renew often. Wash as usual with all plates.

Do not strengthen an old weak hypo bath. Throw it away and make a new one. It may fix but it is sure to spoil plates sooner or later.

Stained plates are usually due to one or more of the following causes:

Too warm developer.

Too long development of under-exposed plates.

Exhausted hypo bath.

Lack of acidity of the hypo bath.

Failure to wash off developer will quickly spoil a fixing bath.

Reducing Dense Negatives.

Solution No. 1.

Water, 16 ozs.

Potassium Ferricyanide, 1 oz.

Solution No. 2.

Water, 16 ozs.

Hypo, 1 oz.

Place plate in Solution No. 2 sufficient to cover it, then add a small quantity of No. 1, and watch it carefully. If it reduces too slowly, add more of No. 1. If only too dense in places, apply the solution carefully with a brush or tuft of cotton.

Wash in running water at least a half hour after reducing.

N. B.—Make negative properly and avoid reduction.

Dark Room.

The first consideration in a dark room is the complete exclusion of *ordinary* light. All windows, cracks, knot holes, key holes, etc., must be stopped by opaque material. If possible, an entrance by corridor or winding way should be used. If a door is used it should fasten on the *inside* so that no one can open it at an inopportune time.

The usual emulsion on X-ray plates is quite insensitive to red or orange-red light. A very small intensity of blue or white light will ruin a plate. The quality of light, not the amount, is what must be considered, and enough of a safe light may be used to see clearly what one is doing without danger of fogging a plate, if the operator is not too slow. The inner walls of the room should be painted red or orange, not black. A ruby, 20-watt lamp, four or five feet above the working shelf with a translucent shade below it covered with post-office paper, will give a diffuse illumination of the room very desirable for work. Test the light by placing an opaque object on a small plate. Expose on the shelf for two minutes and develop full time; if not fogged, the light is safe for that make of plate. If one desires to time development by looking *through* the plate, an arrangement as shown in Fig. 51 or one as sold by some dealers is desirable. By using a flexible cord, the lamp in Fig. 51 may be hung outside after the box is opened and serve as the source to be used when no plates are exposed to light.

Arrangement.

Dark rooms may be quite elaborate and yet be very inconvenient. A simple arrangement for a small outfit is shown in Fig. 52. No doors are needed in this case.

Fixing bath and supplies are to be kept apart from developer and developing supplies. A plain open shelf is used in filling envelopes, etc. Cassettes, intensifying screen, and envelopes may be kept in suitable compartments below. Plates in small amounts may be kept in compartments above this shelf. An inexpensive arrangement serving all needs is shown in Fig. 53 for holding developer tank, fixing tank, and also serving as a washing tank. For a permanent installation the tank may be lead-lined, but for a semi-permanent wooden tank a heavy coating of water- and chemical-proof paint will suffice. In warm weather, use ice to cool bath, and do not dilute developer.

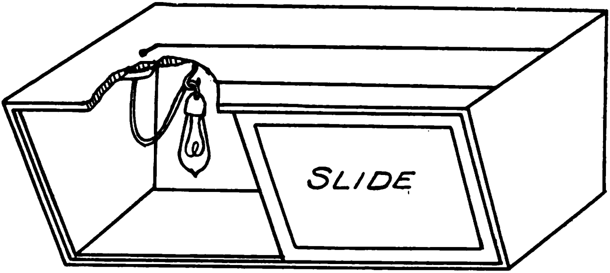


FIG. 51. Simple arrangement of light for developing. The slide contains a white and a ruby glass with yellow (P.O.) paper between. A clear lamp is used.

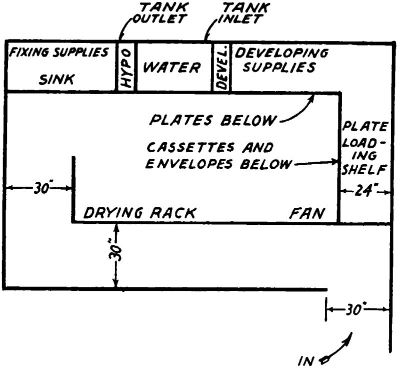


FIG. 52. A convenient dark-room arrangement.

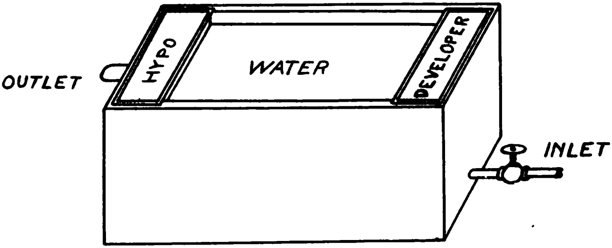


FIG. 53. Simple tank development arrangement using enamelled tanks for developer and hypo. All solutions have the same temperature.

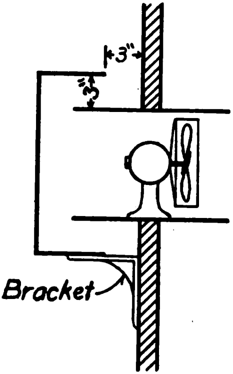


FIG. 54. Simple ventilator for dark room. All inner surfaces to be painted red or black.

Ventilation.

Good ventilation is essential in a dark room, not alone to increase the efficiency of the operator but because a close musty atmosphere is bad for the sensitive emulsion. When a new room is designed, the matter is quite simple, but when any old closet is regarded as good enough for a dark room it is quite a different matter. The important point to be kept in mind is that air must be let in and out but light must be excluded. Where an electric fan can be used, it is easy to accomplish this result. Fig 54 shows one way. The fan is placed in a box, open at each end, inserted through the wall. A second box is placed inside the room, as shown, and all surfaces are painted a flat black. Air has free passage and light is entirely excluded. A similar arrangement can be used in a window, either with or without the fan.

Humidity.

Basement dark rooms are often very damp in summer and very hot in winter. The best work cannot be expected under these conditions. If such must be used, it is best to keep unused plates elsewhere.

Care of Utensils.

Absolute cleanliness is essential in dark room work. Trays not in use are best kept filled with water. Be sure that no acid gets into the developer. Do not use developer or fixing tanks painted inside with any kind of water-proof paint.

Supplies.

Be careful to keep all containers labeled, so that no mistakes are likely to be made. Keep hypo and acids away from developer material. Keep chemicals protected from moisture. Remember that twice the weight of crystals must be used as in case of "dry" materials.

Marking Plates.

Where a large amount of radiographic work is done, a well organized record system is indispensable. In all cases the record should show in some way on the plate, and that record must be put on *before* the plate is developed. Lead numbers may be used, and if this is done the number used and the name of the patient must *be entered on a suitable card or book at the time the exposure is made.*

If numbers are not used, a slip showing the name of the patient must be attached to the cassette or envelope, and the dark room operator should always write the name with a soft pencil on one corner of the emulsion *before* development.

Records.

The importance of the correct *recording* of all information obtained by means of the X-ray cannot be overestimated. Of equal or greater importance is the establishment of the identity of the patient examined with the X-ray findings. Furthermore, the identity of the *side* examined should be verified in every case.

That the X-ray findings are brought to the attention of the attending surgeon is essential. An actual conference between the surgeon and the roentgenologist is very desirable in order that each may have the advantage of the other's personal opinion.

Each plate should, therefore, be marked for identification by means of opaque markers and the corresponding information immediately recorded on the blanks provided for this purpose.

Form 55, Medical Department, U. S. Army (Revised July 19, 1917), will be used for this purpose. A carbon copy of the record on this form may be retained. In all cases a duplicate of this report should be entered

Form 55

MEDICAL DEPARTMENT, U. S. ARMY

(Revised July 19, 1917.)

CLINICAL RECORD

RADIOGRAPHIC REPORT

Station.................................

Date..............................,191

From.................................

To.....................................

....

Information requested:...................

....

....

Clinical diagnosis:.........................

....

....

....

..............., *U.S. Army.*

Laboratory...............................

......................, 191

X-ray findings:

PLATE

Number	Size	Part	Disposition

....

..............., *U.S. Army.*

Surname of patient Christian name

....

Rank	Company	Regiment or staff corps

FIG. 55. Record and report form for X-ray examination.
(Actual size, 3½ ins. x 8 ins.)

on a card record as that in Figs. 56 and 57. A card or book in which consecutive examinations are recorded will also be found useful (see Fig. 58).

Marking Dental Films.

Dental films must be marked as to the teeth shown, and those of one patient should be kept distinct from all others. This can be accomplished by using the Eastman clip holder and attaching a tag bearing the patient's name, to be kept on the holder until the films are filed. One of the simplest means of marking the individual films is by means of a small prick point, like a conductor's punch.

Starting with the upper right molar, mark as in Fig. 59, always punching the end of the film which was away from the roots.

A glance at the film will then show what region it represents.

Dangers in X-ray Work.

The danger to the skin of operator and patient requires careful consideration in order to avoid serious injury. It is customary to speak of a dose that will cause a slight temporary redness of the skin as an erythema does. This dose undoubtedly varies considerably according to the age of the patient and to the judgment of the observer, as to the extent of redness which may be called "slight."

The skin dose will depend on the following factors:

(1) Target skin distance.
(2) Spark gap (voltage).
(3) Current through the tube.
(4) Time or duration of exposure.
(5) Nature and thickness of filter used.

NAME

SURNAME CHRISTIAN NAME RANK ORGANIZATION

X-RAY EXAMINATION

MADE AT DATE

REQUESTED BY

RANK NAME CORPS

REPORTED BY

RANK NAME CORPS

EXAMINATION OF

SPECIFY "RIGHT" OR "LEFT"

X-RAY FINDINGS:

SPECIFY "RIGHT" OR "LEFT"

(FILING RECORD ON REVERSE)

SIGNATURE OF MEDICAL OFFICER REPORTING

CLINICAL DATA

OR X-RAY FINDINGS—CONTINUED

DATE	PLATE NUMBER	SIZE	PART	DISPOSITION AND REMARKS

FIG. 57. Record card for X-Ray laboratory (Back).
(Actual size 8 ins. x 5 ins.)

Plate Number	Date	Size	Part	Name and Organization

Fig. 58. Consecutive record of examinations.

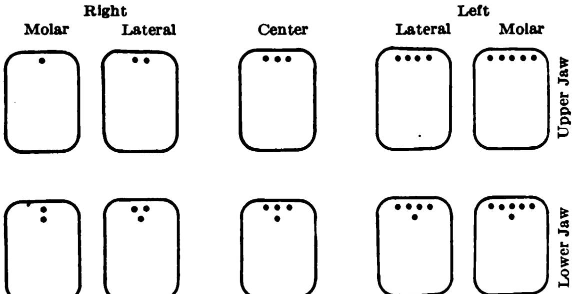


Fig. 59. Method of marking dental films. Upper row for upper jaw—lower row for lower jaw. The right upper molar is marked with one prick, etc.

While complete agreement as to what will give an erythema dose can hardly be expected, all will agree that the dose will increase with the time, with the current, with the spark gap; and will decrease as distance between target and skin is increased and as thicker filters are used.

It is convenient in this connection to combine the tube current in M.A. and the time in minutes, and speak of milli-ampere minutes, but it *must be clearly understood that the number of milli-ampere minutes allowable varies with the spark gap.*

Working at a target-skin distance of 20 inches and a 5 inch gap, 45 milli-ampere minutes may be allowed if no filter is used. For general safety, a filter of 1 mm. of aluminum is advised, and then an increase of about 40 per cent. may be allowed,—or about 60 M.A. minutes may be taken as a safe total to be received by the skin at this gap and target skin distance. Thus, at 5 M.A.—5″ gap - 20 inches - 1 mm. al., a total of twelve minutes may be used on one skin area for fluoroscopic examination, *if no radiograph is to be taken.* If 40 M.A. minutes are used in fluoroscopy at 5 M.A., and 10 M.A. are used for radiographic work before or after the fluoroscopy, then only a two-minute exposure can be made; if 15 seconds are needed at this current, a maximum of 8 plates could be made.

A very important point to remember is that when using a smaller gap although the amount of radiation reaching the skin is less, the exposure required in radiographic work is very much longer. To get the same plate density at lower gaps, the skin risk is greater. Many cases of dermatitis are due to prolonged or repeated exposure with too small a back-up gap for the work in hand.

When an erythema dose is reached or approached, an interval of three weeks should elapse before again exposing.

Be sure that unfiltered rays along the axis of the tube, which do not have to pass through the lead glass bowl, do not reach the patient.

Exposure beyond an erythema dose may be justified when circumstances arise of an unusual nature. But the surgeon or attending physician should decide *when* such a risk is to be taken.

Protection of the Operator.

The element of increase in the work time makes care in the protection of the operator of extreme importance. Two things are clear in this matter: First, that effects are cumulative; second, that evidence of injury may develop late. Since the demands of the art fix the amount of radiation for specific purposes, the operator can do only three things for self-protection.

(1) Increase the distance from the target to any part of his body.

(2) Interpose absorbing material between himself and the tube.

(3) Reduce the time devoted to the work.

The first of these is applicable in radiographic work only, as in fluoroscopy he must work at close range. The third can have only a limited application, so that the second is the practical method.

The following suggestions are offered in the hope that they may be applied:

(1) That in all radiographic and treatment work no direct rays be allowed to reach the operator's body without passing through at least 1/16 inch of lead where lead can be used.

(2) That in addition to this lead protection, the operator keep at least ten feet from the tube in treatment and heavy radiography.

(3) That in using either a vertical or a horizontal fluoroscope, a careful test be made to ensure that no direct rays come through bad joints, holes in lead, or other unprotected openings.

(4) That the fluoroscopic screen be protected with lead glass at least equivalent to 1/32 inch of lead.

(5) That the lead glass and sheet lead on the frame overlap at least ¼ inch.

(6) That the diaphragm should never be opened or moved so as to send part of the beam past the screen, and 1mm. of aluminum be used as a filter in all cases.

(7) That in horizontal fluoroscopy some protection be given for rays scattered at right angles to the patient's body.

(8) That the operator study his working conditions so as to secure the results required in the minimum time.

Under no circumstances should an operator use any part of his body for fluoroscopic demonstration, nor should he hold any plate or dental film in position during exposure.

Electrical Shock.

In the use of high-power X-ray apparatus, care must be taken to avoid discharge from high tension lines to earth through the body of either patient or operator. Fatal results may follow, and in any event the nervous shock to the patient may be serious. Danger arises from sparks followed by an arc discharge from the high voltage line to the body, thence to earth.

To get such a discharge, we must have:

(1) Grounding of patient or contact with badly insulated grounding material.

(2) So short an air distance from some part of the high tension system as will allow a break over spark.

A single spark, while disconcerting, is not dangerous to life, but it serves to pave the way for a heavy *discharge from the line* if the supply is maintained. On static machines and most induction coils, body connection so reduces the line voltage as to preclude any fatal amount of current; but with the modern high power transformer it is a different matter.

The danger of an initial spark-over to the body is solely a matter of line to skin distance and voltage from line to earth. When a tube is taking current, the voltage from either line to earth is less than it would be on the same control setting if no current were passing. Hence, failure of the tube to take current at any time tends to cause discharge to the patient. The following are the common ways in which this may happen:

a. Failure to complete high tension connection.

b. "Cranky" gas-tube.

c. Failure to pass current through Coolidge filament before turning on high tension.

d. Break or disconnection of Coolidge filament circuit while running.

e. Attempting to pass current through Coolidge tube in wrong direction.

Another cause for spark-over is the high tension surge often caused on closing the primary switch of the transformer.

Keep all high tension lines at least twice as far from any portion of the patient as the working spark gap. Thus, if using an equivalent gap of 6″, allow no wire closer than 12″. A grounded metal or conducting screen *between* the high tension lines and the patient is complete protection for the patient; thus, a horizontal fluoroscope with a grounded frame is safe with the tube below; but when the patient is between the high tension line and a grounded metal or conducting table, danger is greatly increased.

Type of Control.

Much has been said of the relative danger with various controls. Simply stated it amounts to this: the rise in voltage when the tube fails to take current is very much greater on a resistance control (See Fig. 15), so that the chance of an initial spark is greater; but after such a spark, the chance of a following arc is reduced by reason of resistance in the primary circuit.

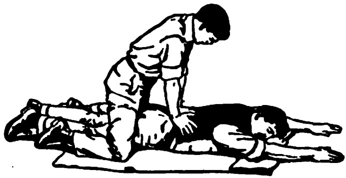
With auto-transformer control, or operation without resistance,—i.e., with rheostat all out,—the rise in voltage on open circuit is less; but if an arc *is* started, it is very dangerous. A quick-acting, over-load primary break is very desirable.

Resuscitation from Electric Shock, Asphyxiation, Etc.

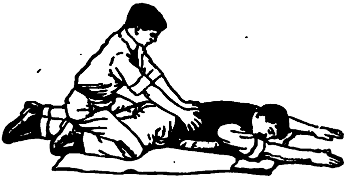
The prone pressure method of artificial respiration, devised by Prof. Schaefer, of Edinburgh, has been advocated as the most effective method by the United States Bureau of Mines' Committee. This method can be used with oxygen inhalator. It should always be used immediately to resuscitate asphyxiated persons and kept up continuously until approved mechanical resuscitating devices are brought to the scene and adjusted on the patient. Doctor should be called as frequently as is necessary to give heart stimulant by injection to patient.

This system can be used in cases of electric shock, after the victim has been removed from the live conductor, in cases of gas poisoning or asphyxiation from any cause. *Promptness should be made in applying artificial respiration, as life persists only a few minutes after breathing stops.*

Quickly feel with your finger in the victim's mouth and throat and remove any foreign body (tobacco, false



Expiration, pressure on.



Inspiration, pressure off.

FIG. 60. Resuscitation from electric shock.

teeth, etc), then begin artificial respiration at once. Do not stop to loosen patient's clothing; every moment is precious.

Lay the subject on his belly, with arms extended as straight forwards as possible, and with face to one side, so that the nose and mouth are free for breathing. Draw forward the subject's tongue.

Do not permit bystanders to crowd around and shut off the air.

Kneel, straddling the subject's thighs and facing his head; rest the palms of your hands on the loins with thumbs nearly touching and with fingers spread over the lower ribs. Fig. 60.

With arms held straight, swing forward slowly, so that the weight of your body is gradually brought to bear upon the subject. This operation, which should take two or three seconds, must not be violent, lest internal organs be injured. The air is thus forced out of the lungs.

Now immediately swing backward so as to remove the pressure, but leave your hands in place. The air thus enters the lungs.

After two seconds swing forward again, repeating this operation twelve to fifteen times to a minute, a complete respiration every four or five seconds. While this is being done, an assistant should loosen any tight clothing about subject's neck, chest or waist.

Continue artificial respiration (if necessary) two hours or longer, without interruption, until natural breathing is restored or until a physician arrives. Even when natural breathing begins, carefully watch that it continues. If it stops, begin artificial respiration again.

Keep subject warm by applying a proper covering or artificial heat, hot water bags, etc.

Do not give stimulants or liquids by mouth until subject is fully conscious.

FLUOROSCOPY.

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Definition.

Fluoroscopy is the method of making studies of opaque objects by means of the X-rays and the fluorescent screen. It depends upon the fact that under the influence of the X-rays certain substances become highly fluorescent. The fluorescent screen consists primarily of a thin layer of this fluorescent substance spread upon cardboard. This cardboard or fluorescent screen in turn should be covered by lead glass and mounted in a frame. To this frame there should be attached convenient handles and these handles should be so arranged that the hand will be protected from stray rays during the examination. Or, the screen may be covered by a hood so as to shut out other light. This hood is usually arranged in a pyramidal form. The depth of this pyramid must be at least the average focal distance for the eyes. This fluoroscope may have attached a handle by which it can be supported, or if of small size such as 5″ x 7″ the entire fluoroscope may be attached by means of a head band to the head. This arrangement is considered useful for the localization and extraction of foreign bodies.

Such a fluoroscope has been described by Dr. Dessane (Gallot et Cie)[1] Figs. 1, 2, 3. A spring attached across the hinge line will hold the fluoroscope down in its working position or when tilted over it will be held by the same spring in position on top of the head. Such a fluoroscope should be fitted near the eyes

[1] Described by L. Ombredanne et R. Iedoux-Lebard, "Localisation et Extraction des Projectiles," Libraires de L'Academie de Medicine, Paris.

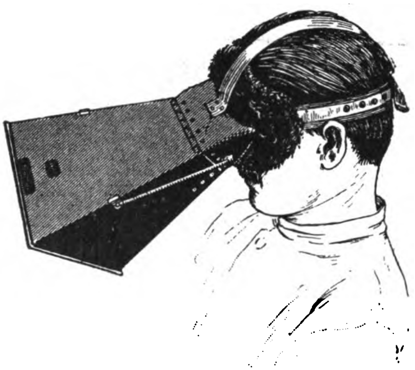

Fig. 1. Dessane's fluoroscope attached to the head ready for examination.

Fig. 2. Dessane's fluoroscope elevated to the top of the head after the fluoroscopic examination has been made, permitting the operator to see by ordinary light without losing the sensibility of the retina because of a ruby glass which automatically drops in front of the eyes as the fluoroscope is elevated.

FIG. 3. Double fluoroscope, also designed by Dessane, for the combined use of the Roentgenologist and the surgeon during the operation.

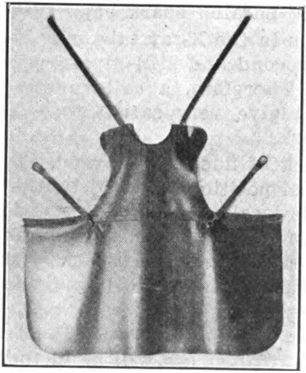

FIG. 4. Protective apron. Shoulder straps cross on back. Apron completely encircles hips.

with lead glass having an absorbing quantity equal to about 1/64 of an inch of lead. Or the fluorescent screen itself should be covered by lead glass having a similar absorbing capacity. If the lead glass is placed near the eyes and no lead glass over the screen, the walls of the fluoroscope or hood should be covered with a layer of lead approximately 1/64 of an inch thick.

The hinge fluoroscope described by Dr. Dessanne (see footnote on previous page) contains an excellent arrangement by which a layer of ruby glass drops in front of the eyes automatically as the hood and fluoroscope are raised to the top of the head.

Apparatus.

If the apparatus is to be used solely for fluoroscopic work the exciting outfit needs to be capable of producing no more than 5 to 10 milliamperes with a voltage equal to from 3″ to 6″ parallel spark gap.

The pulsations in the X-ray tube may be reduced to as low as 20 per second and still give a permanent fluoroscopic image. Therefore, a coil run by a mechanical interrupter will give very satisfactory X-ray light for fluoroscopic work.

The great bulk of fluoroscopic work can be best done in the horizontal position. It will be the position most desirable for the localization of foreign bodies, the study and manipulation of fractures, and of the stomach and intestines. With such a table the tube should be movable and the diaphragm should be adjustable under the table.

An outfit for *vertical fluoroscopy* is desirable in military work. Its greatest use will be in the study of cavities containing fluid, such as cavities in the lungs, accumulations of fluid in the pleura or the study of opaque fluids placed in the stomach and intestines to render them opaque and visible. In this vertical position one can often obtain the upper level of fluid and make an absolute diagnosis of a condition that when studied in the horizontal position would only give suggestive evidence of the correct diagnosis.

The Foot Switch.

The foot switch is absolutely essential and probably will do more for the convenience of the operator and the protection of all concerned than any other single agent. This foot switch should be adjusted: (1) so that the operator need not continuously stand on one leg; (2) so that it will control accurately and quickly the current in the tube; (3) turn on and off the current controlling the ruby light which is used for general lighting of the fluoroscopic room.

The Dark Room, Importance of Absolute Darkness.

Too much emphasis cannot be laid upon this phase of the subject, especially if an open screen is to be used by several operators which is essential when more than one operator is to view the object under study. The success in attaining absolute darkness will depend in great part upon the ingenuity of the operator. Black cloth or black paper is a cheap way of rendering cracks and light fissures dark. To cover windows and other openings, double black curtains running in grooves will be found the most satisfactory. Unless the room be absolutely dark the object under study will be dim in outline and in many instances not even visible. Lack of attention, therefore, to this detail will result in a prolongation of the fluoroscopic study, waste of time, damage to the patient, damage to the operator, nervous annoyance and very often absolute failure in the ultimate object of the work. If the room cannot be darkened, one must use the hooded screen or work at night.

Ventilation of the Fluoroscopic Room.

(See ventilation of developing room, page 113.)

Time Required for Sensitizing the Retina.

This will vary with the individual, and particularly with regard to the age of the individual, for younger people can respond to this test more quickly than older people. In general, one should be in the dark for 15 minutes before beginning fluoroscopic study. If one begins in less time than this, there is likely to be unnecessary exposure of patient and the operator, and inefficient and unsatisfactory results obtained.

The Light for the Dark Room.

In general a ruby light is recommended on the theory that the retina becomes fatigued by the ruby light and, therefore, more easily capable of appreciating the bluish white light of the fluorescent screen. It is most important, however, that so far as possible the dim lighting of the room should be arranged on the indirect plan or at least be diffused.

Protection of the Operator.

Protection of the roentgenologist or operator must be considered first, because the amount of exposure which he receives from day to day is many times that obtained by any patient or any assistant. At best and with all precautions there is some danger of damage to the skin, but the following precaution should be taken: 1st. The active tube should be surrounded by opaque or absorbing material equivalent to at least 1/16″ of lead with at least double this thickness opposite the active hemisphere. 2nd. The operator should be covered with an apron supported from the shoulders either by mechanical support or by shoulder straps, and this apron should have an absorbing value of approximately 1/64 of an inch of lead. In addition to this there should be provided leggings covering the anterior surface of the foot and leg up to and beyond the lower border of the apron because of the damage from the tube being so near the legs under the table.

A frame covered with lead set upon rollers on the floor as suggested by Caldwell will eliminate the necessity of the operator bearing this weight for hours at a time.

Opaque gloves should be provided for the hands, and these gloves should be tested in advance to be quite sure that they have some absorbing value both anteriorly and posteriorly. It is sometimes essential to place the hands under the fluorescent screen. This temptation should be resisted so far as possible, but in one's anxiety to obtain results, personal danger, especially when it does not produce immediate symptoms, is very commonly ignored. Therefore, the ingenuity and caution of the operator must be called into play continually to avoid unnecessary exposure of his hands.

Protection of the Patient.

This is provided for primarily by the opaque covering about the active tube previously described. The opening from which the source of rays are obtained should be easily adjusted and should always be worked at the smallest possible size. This will at once give protection to everything excepting the operative field. This operative field can and should be further protected by the use of at least one millimeter of aluminum as a filter. This should cover the entire diaphragm even when it is opened at its widest angle. The time of the illumination should be made as short as possible, not only the total time but the individual exposures or flashes. Therefore, active use of the foot switch for turning the current on and off will eliminate such damage. The current should be turned on just when all is ready for observation, and turned off immediately when the object is seen, sufficiently observed, or localized. In other words intermittent exposure is most important.

The exposures should not be prolonged to satisfy the curiosity of on-lookers and those not directly concerned with the welfare of the patient. The assistant or the surgeon who may be exposed similarly to the operator should be provided with similar protection.

Indications for Fluoroscopy, Foreign Bodies.

The exact methods of localization of foreign bodies will be dealt with in a separate chapter by Dr. Bowen. In this chapter only general consideration with reference to foreign bodies will be discussed. (1) Only foreign bodies which are more opaque to the X-rays than the surrounding tissues will be visualized upon the fluorescent screen. (2) The opacity of a foreign body depends not only upon its composition and its relative density, but also upon its relative size and thickness. For example: a needle, which is composed of steel and is very opaque to the X-rays, if placed at the under surface of the thigh and a screen is placed at the upper surface, the needle will often cast no shadow upon the screen. In searching for foreign bodies, the point of entrance and the symptoms will usually give one the general location, and having obtained the general location the part of the body to be examined should be then rotated if possible, so that all surfaces are brought at one time nearest the screen. In this way one can bring the foreign bodies nearest to the screen and from this point make the localization. This is important in order to see clearly the more minute shadows under movement of the tube. Unless this is done smaller fragments of foreign bodies will be overlooked in the interest of the larger ones.

Fluoroscopic Examination of Fractures.

A complete fracture giving rise to definite symptoms can usually be recognized by fluoroscopy and in such instances the rays are useful in determining the extent of the fractures and the relation of the fragments. The negative diagnosis is, I believe, never reliable. The setting of fractures under fluoroscopic observation is a most valuable procedure. It is essential to remember that the part must be rotated from time to time, or the tube must be displaced in order that the fragments may be viewed from different angles and not only in a single plane. Special care must be exercised not to expose unduly the hands of the operator or the surgeon.

Movable Organs.

Aside from the use of fluoroscopy in the recognition and localization of foreign bodies the greatest field of usefulness, is in the study of the movable organs. 1st—*The Heart.* The heart can always be seen definitely and clearly by fluoroscopy because it is a solid organ surrounded by an air containing tissue, the lungs. In the study of the heart one notes the size, the position, the shape, and the motion. The *size* of the heart will vary with the individual just as every other organ in the body varies with the size and type of the individual. The heart, however, bears some general relation to the general organism and when this general size is departed from to a considerable degree its recognition by fluoroscopy will be of considerable value. The *shape* of the heart is of very much more importance, for the shape of the heart will vary with the pathological lesions.

The *position* of the heart will vary with the position of the diaphragm, being higher and more transverse when the diaphragm is high, and more near the median line and low when the diaphragm is low. The position of the diaphragm is influenced by the respiratory movements, by adhesions, and by the degree of abdominal distention. The position of the heart is also influenced by the condition of the lungs, and mediastinal lesions. *The movements of the heart* when studied fluoroscopically are of more value than any of the other observations to which I have just referred, and a trained eye can recognize the difference between the strong steady contraction as compared with the weak, wavy and indistinct contraction spreading over the heart. The first indicates a normal heart or a heart that is at least competent. On the other hand the weak and wavy pulsation is associated with a dilated heart or a heart in which compensation and muscular weakness has developed. Between these two extremes many variations can be recognized.

The Aorta and Mediastinum.

The mediastinal organs and tissues are studied both in the antero-posterior direction and in the oblique. *Aneurism* of the aorta is recognized by a bulging mass in the course of the aorta which is generally smooth in outline, and does not infiltrate the surrounding tissues which gives rise to expansile pulsation. The normal aorta is not recognized fluoroscopically in its descending portion. *Mediastinal tumors* are recognized by the increased area of density occupying the mediastinum. They are usually irregular in outline, are not confined to the course of the aorta and commonly infiltrate the surrounding tissues.

The Lungs.

Tuberculosis. The early recognization of tuberculosis can only be accomplished by means of plates and this subject will be dealt with in detail in another chapter by Dr. Dunham. The fluoroscope is a valuable adjunct in examination and need not replace or in any way interfere with the other methods of diagnosis of pulmonary conditions. Consolidations due to tuberculosis give increased opacity to the lung tissue, generally distributed in a more or less mottled arrangement, and these mottled opacities occupy the regions that have long been known to be more frequently affected. The disease by preference occupies the apices of the lungs or the apices of the individual lobes. Opacity of one apex as compared with the other must always be looked upon with suspicion.

Tumors of the lungs are nearly always secondary, therefore the history of a primary tumor elsewhere in the body followed by the development of pulmonary symptoms should always suggest the possibility of metastasis. Carcinoma distributes itself through the lungs in a character very similar to that of tuberculosis, but ordinarily this extension is outward from the mediastinum or roots of the lungs though occasionally may be diffuse. Sarcoma is usually round and sharply defined.

Abscess of the lung is characterized at first by the appearance of local consolidation and later by the appearance of a cavity or localized destruction of lung tissue, indicated by a transparent area not having smooth walls and surrounded by an area of dense shadow caused by surrounding consolidation. The abscess may contain air, but more generally it contains both air and fluid, and at times a very definite diagnosis can be made by examining the patient in the upright position and recognizing a level of fluid over which there is a clear transparent area caused by the superimposed layer of air. The *introduction of a foreign body* into the lung may be followed by the formation of an *abscess*.

THE PLEURAL CAVITY. *Effusions*. If the pleural effusin is large in amount, there may be total opacity of the affected side of the chest. If less extensive there may be an area of transparency in the neighborhood of the root of the lung and the upper portion of the lung. If the effusion is small in amount, the patient must be examined in the upright position in order to see anything at all. There is no appreciable difference fluoroscopically between the simple serous pleural effusion and one composed of pus or blood, and for that differentiation the history will be of great value, but finally the aspirating needle will make the differential diagnosis.

Encapsulated Pleural Effusions are more easily differentiated, and they will be found usually on the outer side of the chest or developing between the lobes. The opacity caused by this encapsulated fluid in contrast to the surrounding clear lung tissue is usually sufficiently striking to make a definite diagnosis.

Pneumothorax. This is often associated with fluid, and the picture, as observed fluoroscopically, is striking, but must always be studied in the upright posture. One is struck by the appearance of the level of fluid which can be made to move and splash, and above this there is a marked contrast due to the gas or air contained in the pleural cavity; and associated with this, one has the dense compressed lung in the region of the root or possibly at the apices if the lung is diseased and adherent.

The Gastro Intestinal Tract.

The alimentary canal may be visualized by rendering it either more transparent by means of gas or less transparent by either bismuth subcarbonate or barium sulphate, and barium sulphate is more commonly used. Two to four ounces of barium sulphate may be mixed with any suitable fluid—preferably buttermilk or one of the prepared fermented milks. When this is not at hand, it may be taken with a glass of water on top of a regular meal, or mixed with bread and milk or porridge. This opaque mixture may be watched as it passes through the esophagus, for which the patient, in the erect posture, should be turned in the oblique position. If it passes easily and the walls are smooth, the study is continued to the stomach. When there is any obstruction, one can estimate its size and character. Strictures of the esophagus may be caused by ciccatricial contraction, carcinoma, or by pressure of tumors upon the outside of the esophagus.

The Stomach. One watches the opaque material pass into the stomach, gradually distending the normal stomach, but falling rapidly to the bottom in a dilated stomach. If the walls are smooth and no spasmodic contractions occur, one can eliminate gastric carcinoma and gastric ulcer.

Gastric carcinoma is recognized by the filling defect which it causes. Generally this filling defect is sharply defined, but irregular in outline, and the remainder of the stomach walls are smooth and flexible. One watches the peristaltic waves, and in carcinoma they will be interrupted at the point of the carcinoma.

Gastric ulcer is recognized by the spasmodic contractions which occur if it is acute. These contractions are persistent incisura or deep narrow contractions on the greater curvature. This latter lesion is likely to occur at the level of the ulcer. Chronic ulcer is most often found at the pylorus where it produces constriction and obstruction and secondarily dilation of the stomach.

Perforating gastric ulcer is recognized by a projection outside of the stomach wall which can be made to fill with the opaque material, and at times may show a gas bubble at the highest point of perforation.

Gastric adhesions will sometimes cause a deformity of the stomach especially about the pylorus, which strongly resembles carcinoma.

Since 90 to 95% of duodenal ulcers occur in the first portion of the duodenum or "cap" this percentage can probably be recognized by a careful fluoroscopic examination, especially if it is confirmed by a series of plates. The ulcer will cause a deformity of the outline of the first portion of the duodenum either due to the ciccatrices or due to spasmodic contractions. The old ulcers will give rise to cicatricial contraction. The acute ulcer may only give rise to spasmodic contraction, but when the walls are perfectly smooth on all sides, duodenal ulcer may be eliminated.

The opaque meal can be followed through the small and large intestine and any constriction, fixation or filling defect or abnormal delay recognized. Normally the opaque meal should reach the beginning of the colon at the end of four hours; at the end of six hours the ascending colon is usually filled; at the end of nine hours the transverse colon; at the end of twenty-four hours it normally reaches the rectum and at times has passed out.

Filling defects and constriction, such as are produced by carcinoma, are best recognized by a colonic injection. For this one should use two to four ounces of barium sulphate in two pints of starch water, which suspends the barium sulphate sufficiently for injection. This can be given after the meal has been followed through from the stomach.

Appendicitis. The appendix may or may not be visualized. If the appendix is patulous, it may be recognized and found directed downwards as normal, or may be directed upwards and hidden behind the caecum and ascending colon, which is common in chronic appendicitis. Localized constrictions may at times be recognized in the appendix. Retention in the appendix over a period of forty-eight hours must, in itself, be regarded with suspicion. The tenderness, the adhesions and the abnormal position of the appendix however, make up the most valuable evidence of chronic appendicitis.

LOCALIZATION OF FOREIGN BODIES.

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In no aspect of X-ray practice has individuality been so pronounced as in the localization of foreign bodies, and the very multiplicity of methods advanced is, of itself, proof of the limitation of all of them. As each operator advances in experience, he will, doubtless, find himself favoring a practice depending much upon the principles here given but differing, perhaps even more, in detail.

Accurate Determination of the Vertical Ray.

The essence of localization is accuracy. Before any attempt is made at the use of localizing devices the location of the focus point must be determined. Upon this location and the ability to determine it rest most of the methods to be described. For this the device shown in Fig. 1 is recommended.

This may be adapted to any standard tubestand with cone attachments, using the cone fitting of that particular stand as a base. In the diagram (Fig. 1) let (A) be such cone base; (B) a brass or other metal tube with ¼ in. bore except at the extreme upper end where it is reduced to ⅛ in.; (C) is a pointer rod, and (D) a set screw to hold it in place. It is, therefore, not only a device to accurately center the focus but it serves as well, by means of the pointer to indicate the point which the central ray will strike. Substituting the attachment (P) for the pointer rod we have a plumb line with which to discover the course of the vertical ray. (Fig. 2.)

THE VERTICAL RAY, hereafter often referred to, is that ray proceeding from the focus which is perpendicular to the plate or screen. For casual examination, it may

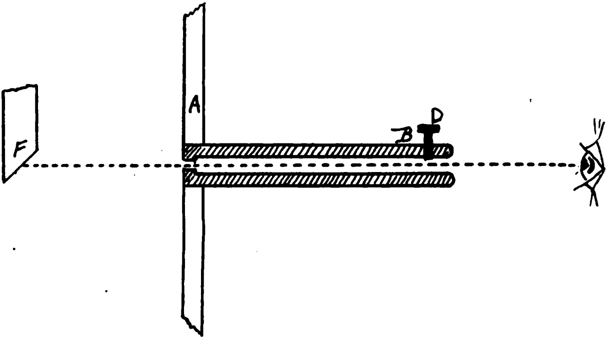

FIG. 1. Diagram of the author's tube centering device, pointer omitted.

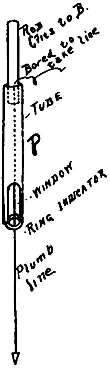

FIG. 2. Plumb-line attachment for centering device.

be permissible to think of a "central" ray proceeding from the focus to the centre of the plate, but for localization this will not do. Even should the focus be so badly centered that no ray from it is perpendicular to the plate, the vertical ray is still the ray perpendicular to the *plane* of the plate. In any of the following methods which consider the vertical ray as centered upon the center of the plate, it is at once manifest that any degree of failure to meet that requirement must detract just that degree from the accuracy of the result. In fluoroscopy where the tube is confined in a leaded box with a movable diaphragm no less care is needed. A convenient device for this purpose is (Fig. 4) made from a piece of brass pipe, 2″ or 3″ in length, set in the center of a wood block 3″ square and 1″ thick. The under side is cut away or rabbeted ½ in. on all sides leaving a shelf by which the device rests on the shutter which is opened to fit it (2 in. square). If the focus is accurately centered the tube will cast a circular shadow on the screen, otherwise the shadow will be oval.

In all Stereoscopic localization the vertical ray is as of the focus in the median position, the two exposures being made with rays equally oblique to this perpendicular.

Localization by Means of Plates.

Cross-thread Method.

It may be said that all plate methods of localization and many of the fluoroscopic methods depend upon a simple problem of triangulation, which for our purpose, may be visualized by means of cross threads, or determined by pre-arranged scales of measurement or measured by rule.

One of the earliest of the graphic methods was that described by Mackenzie-Davidson[1] and since known by his name or as the cross-thread method. It consists primarily of a frame by which the two separate positions of the focus and the focus plate distance can be accurately relocated. There are provided also small pointed weights ("mice") to the points of which are fastened threads. In practice two exposures are made upon the same plate from separate positions of the focus, both of which are carefully recorded. The resulting plate bears a double image of all shadows cast by the subject, including a double image of the shadow of the foreign body. The plate is dried and, by the aid of shadows cast upon its margin by an indicator, is placed in the frame in a position exactly corresponding to its position relative to the focus during the exposures. The threaded points are now placed upon the two shadows of the foreign body and the threads are carried to points accurately replacing the two focus positions. If the work has been accurately done the threads will be found to barely touch at a point of crossing and this point shows the distance of the foreign body from the plate.

Slight modifications of the original model are said to be in active service in British military hospitals today. The original and all American derivatives are, however, open to one serious objection for military use. This is, that a localization having been made, the whole apparatus is tied up until that particular foreign body has been removed. This has been quite overcome by Marion[2] in his localizer which is now popular with several operators in French bases. This consists of (Fig. 3) a table (b) upon which is a photographic plate (p) on which the region of the wound is laid: a graduated column (t) vertically fixed on one side of the table: a horizontal semi-circular support (s) adjustable up and down the column (t) and supporting adjustable scales and indicators another and similar support (s') adjustable in the same way upon column (t) but below (s), and carrying scales (r-r′), vertical indicators (CC), and a pointing rod (g) adjustable in any direction. The latest models have two of these pointers and a caliper (h) for measurements.

Use: The region to be examined is placed upon the table in the operating position. The foreign body, approximated by previous examination is placed so nearly as possible in the line of the direct ray. At a few centimeters distance to one side is placed a lead indicator, as a square with an opening at its center. The location of this marker is permanently marked upon the skin. Vertically above this marker and at a measured distance from the plate the focus is centered and the first exposure is made. The lead marker is then placed an equal distance to the other side. The focus is again centered above it and the second exposure is made. The distance of each position of the skin marker above the plate is then ascertained with the caliper and recorded.

The negative having been developed and dried we have a plate showing two shadows of the foreign body and one shadow of the lead skin marker in each position. Remember also that in each position this marker was vertically beneath the focus during the exposure, but that the column (t) with its attachments was removed.

Reassembing the apparatus for operation. The negative is replaced upon the base in exactly its position during the exposures. Column (t) is replaced and the two indicators d and d′ made to occupy exactly the positions of the two focal centers during the exposures. The pointed weights m and m are placed upon the centers of the foreign body shadows and the threads run to d and d′. The point of contact marks the altitude of the foreign body. The support s′ is now adjusted and the indicating rods C and C′ are made to coincide with the

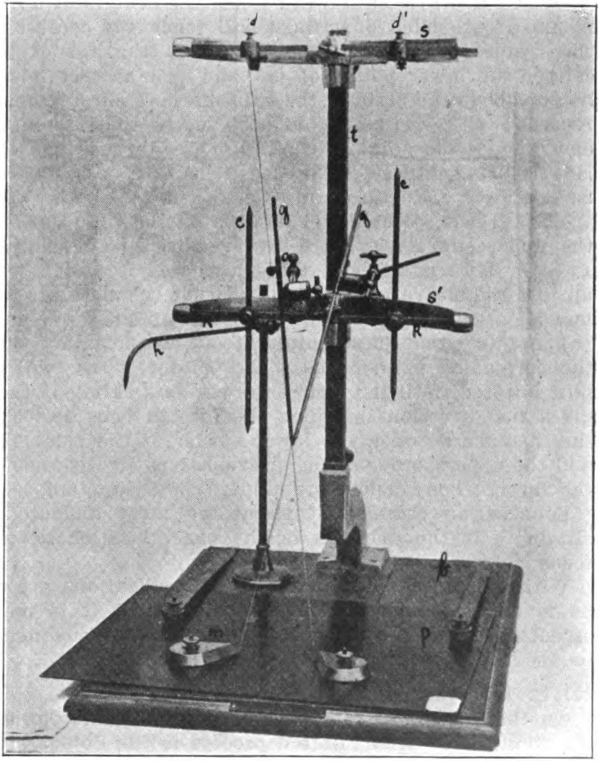

Fig. 3. Late model Marion localizer, showing two pointers and table caliper.

path of the vertical ray for each exposure. These rods will then if projected upward touch the centers of d and d^1 and if projected downward will touch the centers of the two skin marker shadows. With the aid of the caliper the lower points of (c) and (c′) are set to the height above the plate of the skin markers as previously recorded. The pointer g is now set so that its lower end touches the point of contact of the threads and the rider (1) is set close to the sleeve (o). In later models, two pointers are both so adjusted.

The threads, pointed weights, plate, and, if so desired, the upper support (s) are now removed. The pointer (g) (or both pointers if there are two) is pulled well up into the sleeve (o) taking care that the sleeve is not moved, and the patient so adjusted under the points (c) and (c′) that these points are in exact contact with the permanent skin marks. The pointer g (or two) is now lowered until it touches the patients skin. It then gives the direction in which the foreign body lies and the distance between the lower border of the rider (1) and the upper border of the sleeve (o) is the distance of the foreign body below the skin *in that direction.*

Sources of Error. Of these the most difficult to eliminate is the question of the exact location of the focus points.

With this localizer, when several localizations are to be made before any of them are operated it is most essential that the various measurements and adjustments be accurately recorded.

Hirtz Compass.

Another graphic method using a widely different application of the triangulation process is the Compass of Hirtz [2b].

In (Fig. 5′) let R be the sensitized plate. Upon its envelope is placed a lead marker V′ and upon this is

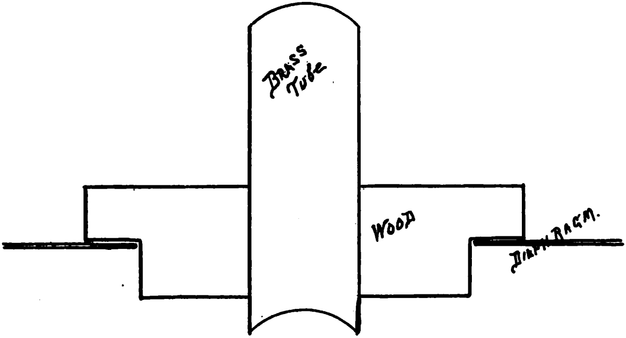

FIG. 4. Diagram of centering device applicable to rectangular opening diaphragms. (Cross section.)

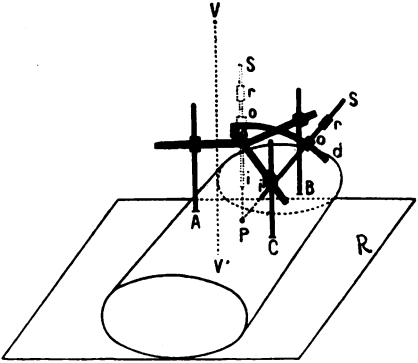

FIG. 5. Diagram of the Hirtz Compass.

accurately centered the direct ray from focus point V. The projectile is (P). A, B and C are three metal markers at conveniently chosen points on the skin. If the focus is displaced to F and to F′, Fig. 6, and an exposure made at each point, there will result upon the plate two shadows each of A, B, C and P.

Knowing the distances VV′ and FF′ we are able, by measuring the displacement in each pair of shadows, to set forth all the data needed for the primary problem.

Making the Plate.

(1) The approximate position of foreign body should first be determined by one of the fluoroscopic methods.

(2) Upon the centre of a plate of proper size place a marker, say a lead triangle (V′). Center the focus accurately above this point.

(3) Being careful not to change position of either tube or plate, place the patient so that, as well as can be judged, the shadow of the projectile will fall a little to one side of the center (V′). The position should also be one desirable for operation.

(4) Choose and mark with lead indicators three convenient skin points to form a triangle, of which the normal ray (VV′) shall be the approximate center; not too near together lest they embarrass the operative incision; not too far apart lest their shadows, one or both, be projected outside the plate. It is well to have these markers perforated in the center.

(5) Fix the focus at a chosen altitude (uniform for all cases). Co-efficient tables for 50 cm. and for 60 cm. altitude are supplied with the instrument.

(6) Two points, F and F′, are chosen at this altitude which are equi-distant from the central line, VV′. This displacement should also be uniform and in most cases is 6 cm.

(7) Two exposures, one at F and one at F′, are now

made upon one plate. After development we find a single shadow of V′ and two shadows of each, the foreign body and the three skin markers. These latter should be indelibly marked upon the skin; tattooing, thermo cautery, etc., etc.

Graphical Construction.

(a) When the plate is dry mark by a point of ink the centers of the shadows of each of the lead markers and of the foreign body.

(b) Place a tracing paper over the plate and mark these ink points, as they are seen through, upon it.

(c) It will be found that imaginary lines between each pair of shadows will be parallel to each other. Through the point V′ draw a line parallel to these. (Fig. 6.)

(d) Upon this line fix the points FF′ by a measurement, exactly the same as the two displacements of the tube. (Another way would be to determine these points before the exposure and to fix opaque markers upon the plate vertically beneath each focus position, exactly as the point V′ was determined in step (2), above.)

(e) Mark upon the chart each separate shadow, as for instance *a* for the right hand shadow of skin mark a, and *a′* for its left hand shadow. Similarly F and F′ represent respectively right and left positions of the focus.

(f) Reciprocally, join by pencil and ruler a to F′, b to F′, c to F′ and P to F′; and likewise, a′ to F, b′ to F, c′ to F and P′ to F.

(g) At intersection of lines from a-a′ mark a point (1), from b-b′ (2) and from c-c′ (3), and at the intersection of P-P′ a dot.

(h) Measure with a rule the distances pp′, aa′, bb′ and cc′ which correspond to the spreading of the images and read on a previously calculated table, which accompanies the apparatus, the numbers corresponding to the heights of the different points P, 1, 2 and 3 above the horizontal plane of the plate. There is a table calculated for a focus height of 60 cm and one for 50 cm. There is also made, a direct reading rule or scale which answers the same purpose.

(i) Subtract successively the number expressing the height of (P) from those which correspond to the points 1, 2 and 3. These differences are noted and later used in setting the compass for depth. The compass, schematically shown, in (Fig. 5) has three arms, 1, 2 and 3, revolving around a common axis (O) through an opening in which there moves, with light friction, a rod (S) bearing an indicator (r) with set-screw. On each arm, in an adjustable rider, and moving perpendicular to the plane of the three branches, there slides a rod having millimeter graduations. A winged nut under the axis of the compass serves to set the branches in a desired position.

Setting the Compass.

(a) Place the rod (S) in the median position, set the graduation of each of the other rods at zero and loosen the winged screw.

(b) Place the transparent paper chart on a small drawing board with the point of the rod (S) on the horizontal projection of the foreign body. Place the ends of the other rods on points 1, 2 and 3.

(c) Shorten the rods or lengthen them until they stand at the number of mm. found as the difference in distance, from the plate, between each skin marker and the projectile. (Fig. 7.)

The compass is now ready for use. The patient is removed to the operating table and placed in the position in which the X-ray examination was made. This requirement is not too rigid. It is only needed that the rod points shall coincide with three skin marks

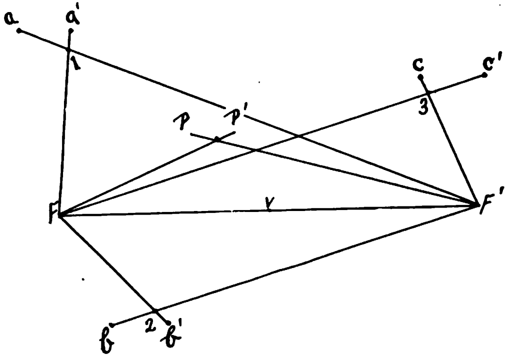

FIG. 6. Typical chart for use with the Hirtz compass.

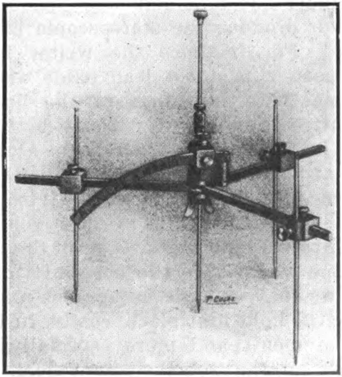

FIG. 7. Hirtz compass set ready for application to the patient.

(Fig. 8). When this condition is fulfilled, the localizing rod (S) is lowered to touch the skin. It now indicates the direction in which the foreign body lies and its depth is told by the distance between the lower border of the indicator (r) and the upper margin of the canal in which the localizing rod moves. By means of an arc almost any desired adjustment of the localizing rod may be obtained without resetting the compass. The method is interesting in that the localizing instrument plays no part in the production of the plate but is set entirely from the plate findings.

It must be kept in mind that when two exposures are made on one plate, each exposure should be just one half of the actual exposure time. If two full exposures are made the plate will be too dense for easy reading.

Localization by the Stereoscope.

This is often most satisfactory, the more so if there is real co-operation between X-ray specialist and surgeon. It is most important that sufficient opaque land marks be provided to produce the stereoscopic effect from the skin surface. For instance the writer has used, for some years past, a paste of lead oxide and vaseline to fill the normal skin markings of the hand and thus utilize the entire palm as a foreground by which needles, etc., may be localized. In larger parts a circle or cross of fuse wire at wound of entrance; a T of the same over a tender point, etc., will add materially to the efficiency. Again, if the foreign body is in close relation to some well-known surgical land mark, *e. g.*, in the glenoid fossa, the stereoscope would give the best information.

Whatever we may concede as against plates for localization they still hold first place, easily, in the *discovery* of smaller fragments and more especially when larger fragments are present in the same field. And, when infection is present and removal is sought for that

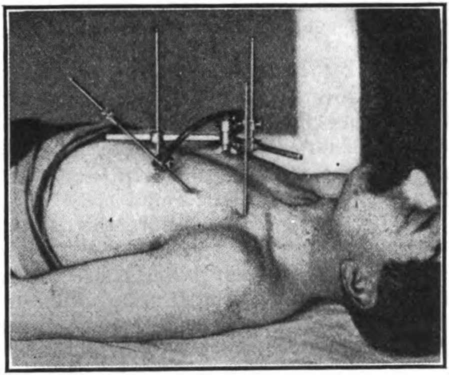

FIG. 8. Hirtz compass applied to the patient.

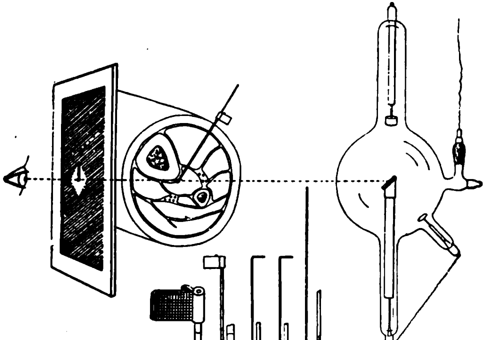

FIG. 9. Diagram showing the Sutton canula and trocar and the harpoon, as well as the way they may be used. The milled wing at the head of the canula may be engaged with a strong forceps and thus obviate the necessity for getting the hands into the open ray.

reason the plate is a paramount necessity in order that the last, even if smallest, fragment may be discovered.

Localization by Means of the Fluoroscope.

In this procedure it is vitally important that the focus point of the tube be accurately centered, and for the same reasons as stated under the plate methods.

With the fluoroscope one can learn very promptly the approximate location of the foreign body with relation to the skin or bones, and therefore the probable point of surgical approach.

Fluoroscopic methods may be classified as immediate or mediate according as localization and removal are combined or separate; and as indirect or direct according as the localization is obtained by the displacement of the shadow in the oblique ray as compared with that in the vertical ray, or by various positions of the body in the vertical ray.

Immediate Methods.

Trochar and Cannula.

Of the immediate methods the most important is that of Sutton.[17, 18] The following description is given by Flint.[15]

It is extremely convenient in most cases to have a definite guide to facilitate the search for the projectile during the actual operation. Undoubtedly, the most useful instrument of this type is that devised by Sutton, which may also be utilized as a localizer when the projectiles are situated in the muscular portions of the body. Sutton's localizer consists in a trochar and cannula which is introduced under the skin previously anesthetized by novocain. After disinfection, the operator puts on sterile rubber gloves or manipulates the cannula by means of sterile artery forceps. It is plunged beneath the skin and the sharp trochar is removed from the cannula, which is then replaced by a blunt obturator. The field is covered with sterile towel and the fluoroscope employed. Under the direct vision of the operator, the cannula with its obturator is passed down through the tissues until it touches the projectile. At this point, the light is turned on and the obturator removed. In Sutton's original method, it is replaced by a piece of very fine piano wire with a crochet end. This fine wire serves as the surgical guide to the foreign body. We found, however, that when the field of operation was stained with blood, it was difficult to see the wire, which was also too fine to be felt readily as the operation proceeded into the depths. Accordingly, we substituted a small harpoon, about the diameter of the obturator, which is passed through the cannula, where it opens and becomes fixed in the tissues immediately about the foreign body. After the cannula is withdrawn, the projecting portion of the harpoon is bent over parallel to the skin surface and is covered with a sterile dressing. Thereupon the patient is dispatched to the operating room. This larger guide can be seen with great ease and also felt during the operation, as it leads directly to the foreign body. It is quite obvious, however, that this method cannot be employed except in the extremities or in the muscular portions of the body, owing to the possible injury of important structures. Small nerves and vessels are pushed aside as the cannula and obturator are introduced. The localizer, harpoon, and the method of using them is shown schematically in Fig. 9.

In conversation with the writer, Dr. H. H. M. Lyle states that if at all possible, he undertakes to pass the Sutton localizer in the vertical ray. In this position the head of the instrument hides the point and as soon as the point can be seen it is at once known that the instrument is deviating from the direct course.

Intermittent Control.

Ledoux-Lebard[4] writes enthusiastically of a method which he calls intermittent control. In this the X-ray operator wears, during the entire operation, a modification of the familiar hand fluoroscope. This is so arranged that when not in use it can be tipped back over the head leaving the eyes protected from light by a suitable dark glass. (See Chap. on Fluoroscopy.)

Working in a light room the patient is placed in suitable position for operation, and the emergence of the vertical ray through the projectile is indicated on the skin. The incision is made and from time to time the surgeon inserts one of several forms of long handled instruments, depending upon the distance and position away from direct rays, for his protection. A fluoroscopic observation of this position of the instrument with relation to the foreign body is now made and information given the surgeon from which he proceeds in the same direction as before or in a new direction as the case may be. By this intermittent control the two work, the one operating and the other observing until the body is removed. The value of the method will depend entirely upon the skill which any pair of men may acquire for "team-work."

A serious objection to its use is the lack of protection. The author says that the surgeon is able to keep far enough away, as the tube is never excited while the surgeon is over the wound, and that the X-ray specialist has learned to take care of himself.

Indirect Methods.

In the indirect methods one plots the depth of the foreign body from the point on the skin where the vertical ray exits after passing through the foreign body. Many modifications of this principle are described in recent literature.

Simple Tube-shift.

Haret's method[12] also described by Gocht[13] is perhaps the simplest of this class. In Fig. 10 let (S) be the screen, (T) the table, and (F) the focus. The distance FT and the distance TS are measured and recorded. Practically FT is usually fixed, i. e.: the same for every case while TS is found upon a graduated upright attachable to table, or by actual measurement. The shadow of the foreign body is located in the vertical ray, the entrance and exit of which is marked, as in other methods upon the skin. It is also marked upon the screen using either the pierced screen or grease pencil. The focus is now shifted from 1 to 2, a measured distance, say 15 cm. The shadow on the screen will, of course, shift also from 1′ to 2′. This distance is measured and noted.

We now have recourse to (Fig. 11) a drawing board, or any plane surface of suitable size (the scale may be permanently laid out on one of the walls of the room) in the center of which is a scale with cm. graduations (1-1′), with a straight edge to fit a triangle (3) also graduated in cm. The triangle is now set against the vertical scale at a distance equal to (FS) (Fig. 10). A small nail is set in the drawing board at (2) to which is fastened a thread, the distance (1-2) being equal to the focus shift distance (Fig. 10). On the graduated triangle is now read the distance (1′-2′) of the shadow shift as seen on the screen (Fig. 10). The thread is now drawn straight and will cross the vertical scale at a distance, below the corner of the triangle, equal to the distance of the foreign body below the screen. The distance between the screen surface and skin must be deducted, which gives the depth of the foreign body from the skin.

Carver's Method.

The method described by Carver[10] does not require measurement of the focus-screen distance nor that of the focus shift. The screen is fitted to an upright which is graduated and provided (Fig. 12) with a glider (g). In the first position the screen is lowered to touch the patient. (If it does not touch the distance from the skin must be recorded and calculated in later.) The glider is raised until in contact with the screen holder. Manipulate until the foreign body shadow is in the vertical ray as described above and mark both its entrance and exit upon the skin. Now move pointer (A) (attached to screen) along the scale on the screen until it marks the shadow. The focus is now moved any convenient distance and pointer (B) is moved to mark the new position of the shadow. Pointer (C) is now set at the same distance from (B) that (B) is from (A). The screen is raised until the shadow is shifted to (C). At this point read on the scale of the upright the distance that the screen has been raised above the glider. This equals the distance of the foreign body below the screen in the line of the vertical ray previously marked. If the screen did not rest on the skin at this point the distance between them must be subtracted from the reading.

Equal Shadow-shift.

Jordan's Method[11] is based upon the fact that, given a surface (s) an object (o) and a distant light (L) movable in a plane parallel to (s):—then, the shadow of (o) will move proportional to its distance from (s) or inversely as its distance from (L). In the diagram (Fig. 13) let A, B, and C represent three

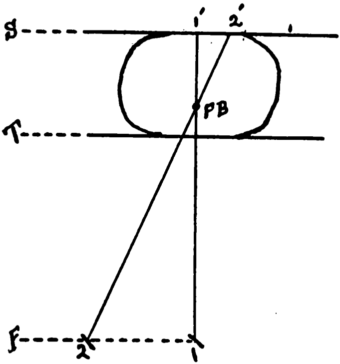

FIG. 10. Haret's method. Diagram to show movement of shadow with two positions of tube.

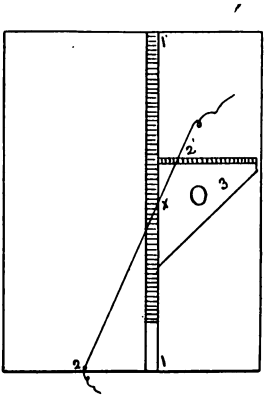

FIG. 11. Haret's method. The Interpretation board.

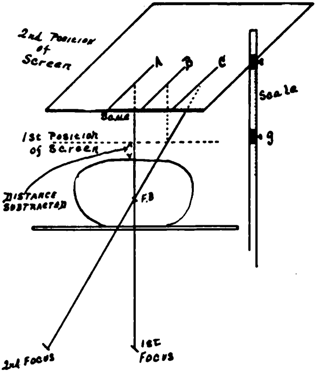

FIG. 12. Carver's method.

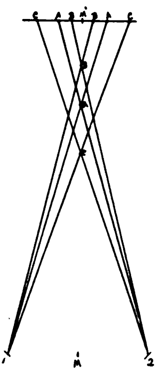

FIG. 13. To show how movement of shadows varies with distance from screen.

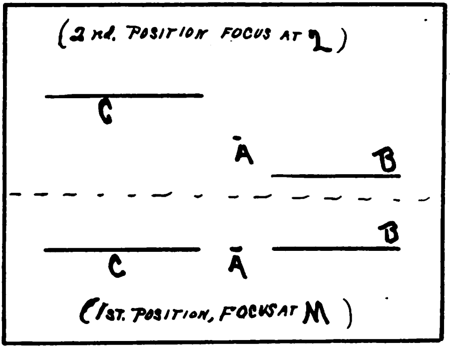

FIG. 14. Jordan's method. Appearance of image for two positions of the tube when rods and foreign body are at different levels.

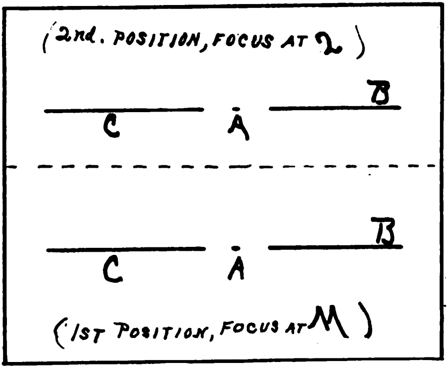

FIG. 15. Jordan's method. Appearance of image for two positions of ube when rods and foreign body are in same level.

bodies in the same vertical plane but in different horizontal planes. With a source of light at (M) the shadows C, A and B will be cast in a straight line (vertical to the plane of the diagram) at (M′). But if the source of light be shifted to 1 or to 2 the shadow of C will move more and that of B less than that of A.

Now transfer the same letters with the same significance to (Fig. 14) a diagram of a fluorescent screen. A is now the foreign body, C is a rod in the same vertical plane but at a lower level, B is a rod in the same plane vertically but at a higher level. With the light at position (M), the vertical ray, A, B and C are in line but in position 2 (the focus having shifted toward the reader the shadow of B has moved less than that of A while that of C has moved more, therefore A is farther from the screen than is B but nearer than C.

In (Fig. 15) the rods have been so maintained upon their uprights that in both position (M) and position (2) the shadows are all in line, therefore both rods and foreign body are at same distance from the screen. This method should be of value especially with patients so seriously injured that turning is undesirable. It will naturally increase in difficulty with increase in size of the part examined and consequent greater separation of the rods.

(Fig. 16) is an end view of Jordan's apparatus.

Direct Methods.

All direct methods depend upon some means which mark the point at which the vertical ray passes through the skin both at entrance and exit. The earliest, most simple, and, so the writer thinks, best of these was described by Morize[7] and many others. It may be called the ring pointer (Fig. 17). In use the foreign body shadow is first located on the screen and then the diaphragm opening shut so that a very small zone of lighted

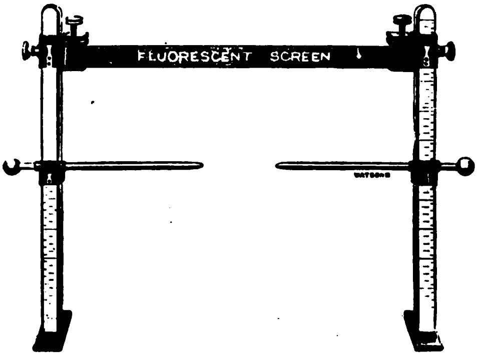

FIG. 16. Jordan's localizer, end view.

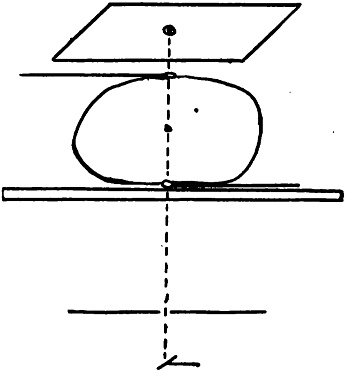

FIG. 17. Diagram to show use of ring pointer. Two successive positions in which the pointer is placed.

screen surrounds this shadow. The ring is then passed beneath the patient and so manipulated that the shadow of the ring surrounds that of the foreign body. This point is marked and the ring is removed. Without moving tube or patient the same procedure is undertaken with the ring *over* the body and again the point is marked. The patient is now turned and, with tube and diaphragm in the same position a second pair of marks is secured. Three or even four pairs tend to still greater accuracy. By marks either of distinctive color or of distinctive shape each pair should be made easily distinguishable from every other pair. The accurate marking of such points as occur on the under aspect of the patient may offer some difficulty. Following a suggestion[8] the writer has devised an instrument which may, perhaps be original to the extent that it combines the ring and the marker. This consists (Fig. 18) of a ring fitted to a tubular handle which carries a Bowden cable. (The original model made use of an ordinary shutter release such are are commonly used on amateur cameras). This cable carries at its distal end a minute bit of cotton saturated with copying ink, and is so directed that a thumb pressure will project it into the middle of the ring. The marking thus is made accurate and rapid. The writer prefers a set of four, each inked with a distinctive color. It need hardly be said that such marks are most temporary and must be replaced with others more prominent before the patient is even moved from the room. For this purpose Ledoux-Lebard uses either the thermocautery or a tattooing instrument; but unless the removal is to be long delayed it seems that solid silver nitrate should be quite sufficient. An elaboration of the ring pointer is found in the ring forceps or calipers described by Belot[9], and modified by Flint. In this instrument (Fig. 19) the upper and lower ring are combined and so manipulated over and under the patient that both ring shadows appear as one, about that of the foreign body.

Reporting to the Surgeon.

Localizing methods may be ever so clever but if we fail to transmit their information to the surgeon so that he actually extracts the foreign body from that information, then there is a fault somewhere. It is perhaps as often a failure to translate the findings into a form that the surgeon readily grasps as it is a fault of the method.

In the case of the indirect methods the information gained is, that the foreign body is at a definite depth from a spot marked on the skin. The line from the skin mark to the foreign body at the time of localization is a perpendicular but if the patient is rotated the line will become oblique. It is therefore important that the position of the patient at the time of operation should be the same as at the localization.

Cardboard Cut-outs.

The direct methods may be reported graphically as follows: We have four, six, or eight marks upon the skin grouped in pairs, each pair representing a line passing through the foreign body, and, if accurately placed, all will be in a regular line encircling the part. The separate marks should be permanently marked, as, for instance, with solid silver nitrate, and the encircling line may be less permanent, as with writing ink. We may now employ the method of Vergely[14] (Fig. 20). In a plain card of suitable size an opening is cut to fit the wounded region at the level of the skin markings. These markings are then transferred to the margin of this opening (Fig. 21) using in this instance distinctive signs, the + and the —. A better method is the use of distinctive colors. The card is now removed and laid

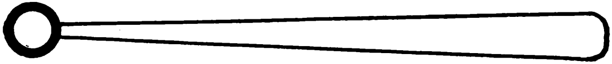

FIG. 17-a. The ring pointer.

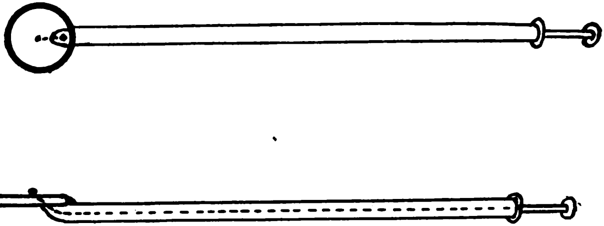

FIG. 18. Author's ring pointer and marker combined. Front and lateral views. In both the Bowden cable is shown as pushed out to its marking position. At rest it is withdrawn well below the level of the ring.

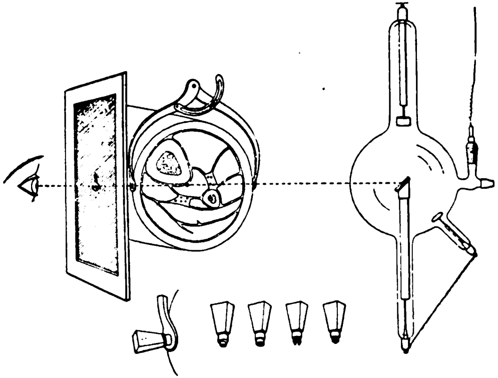

FIG. 19. Diagram showing the use of the fluoroscope and the ring compass to obtain the diagonals passing thru the projectile and the stamps to mark them on the skin.

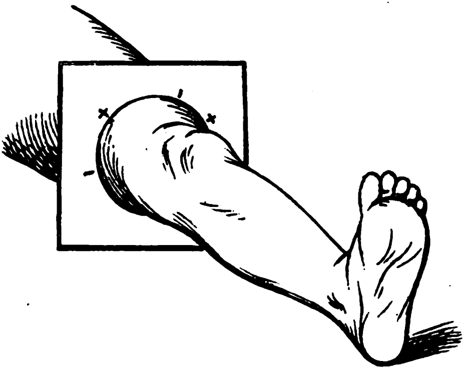

FIG. 20. Vergely's method. Formation of card.

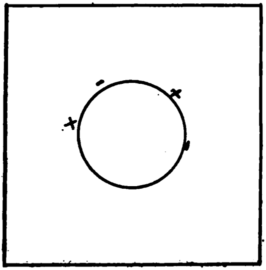

FIG. 21. Vergely's method. (Distinctive marks transferred to card.)

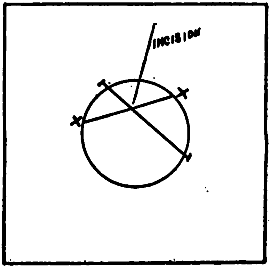

FIG. 22. Vergely's method. Completed chart.

upon a sheet of paper on which the margin of the opening is traced as are also the distinctive marks. These marks are now connected by pencil lines + to + and — to – or red to red and blue to blue, etc. (Fig. 22).

The Profondometer

Another method is by the use of flexible metal strips. During the present war this has rapidly gained in general favor but was first recorded by Flint[15] and by him credited to Irwin and by them named the profondometer. It may be made of any flexible material which has yet enough stability to retain its shape when carefully handled. The writer prefers block tin from 1/16 to 3/32 in. thick and from ½ to 1 in. in width. Two pieces are hinged end to end and are made of suitable length for the parts to be examined, somewhat more than one half the circumference of the arm, thigh, or torso as the case may be. These are now moulded about the part at the desired level, taking care to place the hinge in a favorable position that the instrument may be removed without disturbing its shape. The point of overlap is marked and the distinctive marks are transferred in exactly the same manner (Fig. 23) as described for Vergely's card, and in a like manner the paper chart is made. The further procedure is described by Flint as follows:

"The profondometer is thereupon removed from the paper and the corresponding points are converted into real diagonals by a ruler, so that we have the exact position of the projectile indicated at the point where the lines intersect. Finally, the important anatomical structures can be sketched into the cross-section, a procedure which is greatly facilitated by the aid of a good cross-section anatomy like that of Eyclesheimer, and Shoemaker, for example. It is now possible with these data to plan the operation and select the incision with reference to surgical and anatomical considerations,

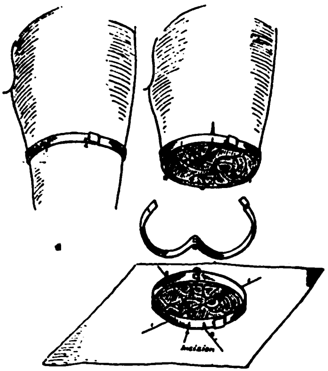

FIG. 23. Diagram showing how the profondometer is employed to make cross section charts and its use in indicating the exact position of the incisions.

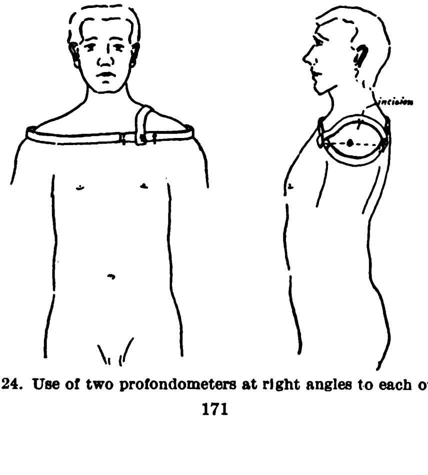

FIG. 24. Use of two profondometers at right angles to each other.

which is then marked on the tracing. By means of the profondometer, the position of the incision can be transferred to the skin surface of the body by first marking it from the tracing on the instrument and then replacing the latter on the body in its original position and making a corresponding mark on the skin. The tracing may then be used to obtain exact measurements from the incision to the projectile. The various stages of the application of the profondometer and the method of obtaining the tracing are shown in Fig. 23. It is important to remember in obtaining cross-sections of large regions of the body, like the chest or abdomen, where there may be some distortion of the profondometer from the spring in the metal which might lead to a slight error, it is well to control the anteroposterior and lateral diameters of the section under examination. This is done most easily by checking up these dimensions as the profondometer is placed on the paper. There are certain parts of the body where a simple horizontal localization sometimes does not give the data necessary for extraction, owing to the interposition of bony structures, and in these cases the method must be modified. Such an instance occurs, for example, where a shell fragment lies between the clavicle and the scapula adjacent to the brachial plexus and axillary vessels. As the only operative route lies above the shoulder, this fact necessitates the addition of a right angled or vertical localization, starting from one of the original diagonals as a base line. I solved this problem by placing a malleable band of metal similar to the profondometer and moulding it to the shoulder in a position at right angles (Fig. 24) to the ends of one of the diagonals. This diagonal is then projected out to one side of the chart (Fig. 25) and the vertical contour of the shoulder obtained by a tracing of this second piece of moulded metal. This makes it possible to obtain ac-

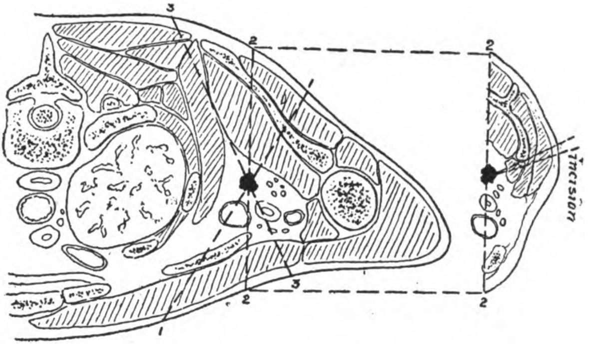

FIG. 25. Horizontal and vertical sections indicated by Fig. 24.

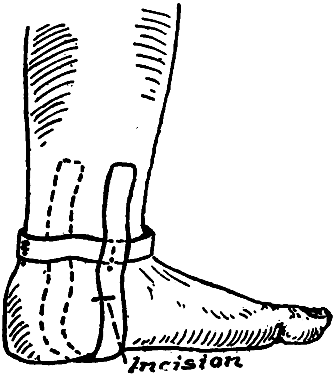

FIG. 26. Use of two profondometers on the foot.

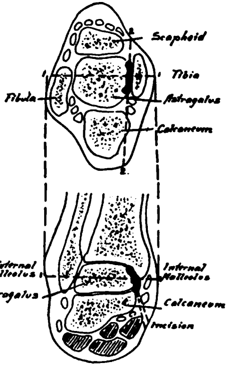

FIG. 27. Horizontal and vertical sections indicated by Fig. 26.

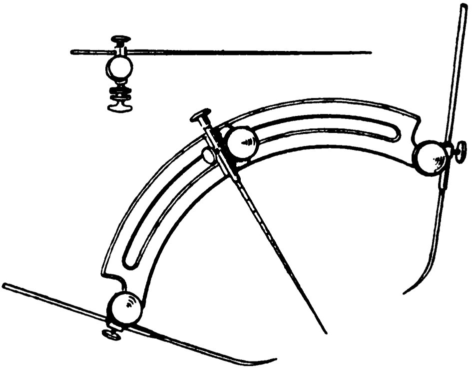

FIG. 28. Debiernie's compass.

curate measurements from above and to select the proper incision from the surgical point of view. Another similar problem is presented by the case where a shell fragment lodged between the internal malleolus and the astragalus. This patient had been operated upon unsuccessfully in another hospital. The horizontal localization shows the interference of the malleolus with the selection of a direct incision, which should of choice be from below. By the use of a secondary band extending below the sole of the foot, as is shown in Fig. 26, not only the incision, but accurate measurements from it to the shell fragment are obtained. The charts with the right angled localization are given in Fig. 27. It can readily be seen that, with similar variations of this method, there is not a part of the body which cannot be rendered accessible and for which data for the extraction of projectiles cannot be obtained."

Guiding Instruments.

Not infrequently the surgeon feels the need of some tangible guide as an added assurance that the chart is being accurately used. Such is the compass of Debiernie[16] the use of which is easily understood from (Figs. 28 and 29). The bar is an arc and the pointer may be shifted at will without resetting the compass.

A much simpler device for the same purpose is described by Flint as follows:

"To provide an operative guide for abdominal and chest cases or those with projectiles in the neck, where the Sutton localizer would be dangerous, a band guide was devised and used. This is made as follows: A small band of aluminum is bent double. It is then placed on the tracing (Fig. 30) with the bend at the position of the projectile extending in a straight line through the selected incision. At the skin level, the two arms are bent to conform to the skin contour. In this way, after the

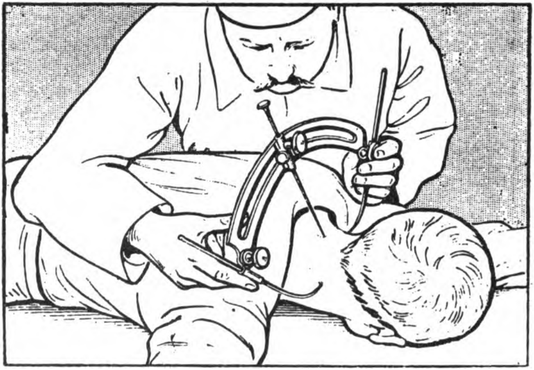

FIG. 29. Application of Debiernie's compass.

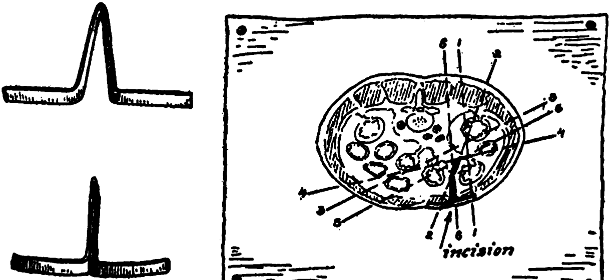

FIG. 30. A band guide and its application to the abdomen.

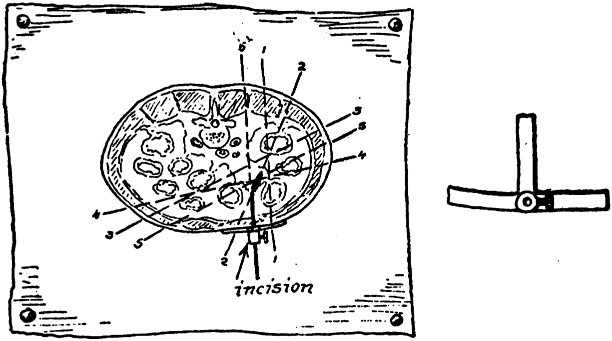

FIG. 31. Tripod band guide and chart to accompany it.

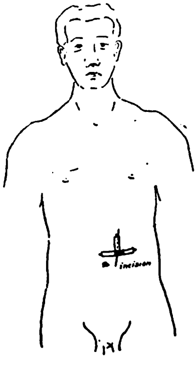

FIG. 32. Application of tripod band guide to the abdomen.

incision is made, the guide can be slipped into the wound and, when the proper depth is obtained, it should touch the projectile. As there is, however, certain possible inaccuracy in this instrument owing to the fact that the indicator can swing through the arc of a circle, a tripod guide and pointer were devised as an improvement. This is molded to the skin contour from the chart (Fig. 31) with the socket of the pointer lying in the plane of incision. It is then placed in the corresponding position upon the patient and three marks made upon the skin at the ends of the tripod (Fig. 32). The tripod is then replaced upon the chart and the pointer inserted and adjusted so that it reaches the depth of the projectile, where it is fixed in position by a thumb screw. Obviously, when this is utilized during the operation, the three marks upon the skin will always control the position of the pointer so that it leads directly to the foreign body. While these various guides are very convenient during the actual period of the operation, they are not absolutely essential. As a matter of routine, it has usually been our custom to utilize them, particularly the Sutton cannula and harpoon, in conjunction with the charts, because they facilitate and simplify the operation. Moreover, there is an additional factor of safety in utilizing one method to check the possible errors of another."

Bibliography.

1 Mackenzie-Davidson; British Med. Jour., L1, 1898.
2 Marion; Chirurgie de guerre. Paris (Maloine), 1916.
2b Hirtz; Jour. de Radiologie, 1916, p. 43.
3 Pirie, Howard; Archives of Radiology and Elect., #195, Oct. 1916, p. 137.
4 Ombredanne and Ledoux-Lebard Localization. Paris, 1917, p. 229.

5 Hallam, Rupert; Archives of Radiology and Elect. #185, Dec., 1915, p. 235.
6 Coon, C. E. Am. Roentgen Ray Society, 1910.
7 Morize, Gazette des hôpitaux, 1898, 19 Feb.
8 Ombredanne and L-Lebard, p. 87.
9 Belot Jour de Radiologie, 1916, p. 1.
10 Carver, A. E.; Archives of Radiology and Elect., #190, May, 1916, p. 423.
11 Jordan, A. C.; Archives of Radiology and Elect., #184, Nov., 1915, p. 188.
12 Haret et Schlesinger; Presse Medicale, 24 Dec., p. 746.
13 Gocht, H. Rontgen-Lehre 3d ed. 1903, p. 283.
14 Vergely Presse Medicale. 18 Feb., 1915.
15 Flint, Jos. Marshall, Annals of Surgery. Aug., 1916,
17 p. 151. Military Surgeon, Mar., 1917.
16 Debiernie; Presse Medicale. Mar. 4, 1915.
17 Sutton, W. S. Operative Surgery, Binnie (Appendix of Military Surgery, 7th ed., p. 1313)
18 Lyle, Henry H. M. Annals of Surgery, Jan., 1916. p. 114.

Especially is indebtedness acknowledged to the masterly monograph of Ombredanne and Ledoux-Lebard, and to Dr. Joseph Marshall Flint for very kind permission to make unrestricted use of recent articles.

FRACTURES AND DISLOCATIONS.

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A fracture may be defined as a break in the texture of a bone or, more briefly, as a solution of continuity.

The study of fractures with the aid of the X-ray enables us to decide; first, whether a fracture is present or absent; second, the number and relation of the broken fragments so that the best mechanical measures can be selected for replacement. After a retentive dressing has been applied it is easy to study the results of treatment without waiting for the test of healing and restoration of function.

From a radiographic standpoint fractures may be classified into: First, *simple fractures*, where the bone is broken in two pieces; second, *comminuted fractures*, where the bone is broken into many pieces. Simple fractures may be further classified according to the direction of the fracture line: First, where the line of cleavage is transverse; second, oblique; third, longitudinal; fourth, combinations of the preceding varieties. Naturally the comminuted fracture is more common in military service than in civil life. In military service there is to be seen frequently the effect of high-speed bullets upon bones. The difference between high-speed projectiles and small projectiles of low velocity is quite striking. In the former the results simulate an explosive action evidenced in the marked comminution and shattering of the osseous tissue. Small lead bullets, as a .22, usually caused only slight injury to bones, and very often the effect of the contact is seen rather in the de-forming of the bullet than in the shattering of the bone.

Fractures may be studied by the X-ray either by the fluoroscopic method or by the plate method. Each has its advantages and disadvantages.

Fluoroscopic Method.

The advantages of the fluoroscopic method are, primarily its convenience and quickness of execution, without the delay of waiting for the development of plates. It allows of a rapid survey of the entire body. It is cheap as compared with the cost of a number of plates. Its principal disadvantage lies in the fact that it does not always show clearly the texture of bones, so that fractures of slight displacement are not readily shown. This is especially true in fleshy individuals and in parts of the body where the bones are enveloped in a good deal of soft tissue. Fractures of small bones, as transverse fractures of the scaphoid or longitudinal fractures of the head of the radius, may easily escape notice. Impacted fractures also of the lower end of the radius, and of the surgical neck of the humerus may be seen so indistinctly on the screen that there may occur a reasonable doubt as to their presence.

Plate Method.

The chief advantage of the plate method is that it affords an exact study of the cancellous tissue of the bones. It also gives a permanent record of the case, so that the condition may be observed by others. As in the examination of the gastro-intestinal tract, the greatest amount of information is often best obtained by a combination of the two methods.

The determination of the part of the body to be radiographed will naturally depend, first, upon the clinical history, if one can be obtained, and second, upon the usual signs of fracture on physical examination. If a patient can be examined on the fluoroscopic table, the fluoroscope will assist in deciding on the area to be radiographed. It is evident, however, that some types of sub-periosteal fracture, for example, fractures of the lower end of the fibula, may be present without screen evidence.

In radiographic examination of fractures, the adherence to a routine and established type of technique is of considerable advantage. One of the most essential points in this technique is the choice of a suitable ray; by this is meant a ray of penetration sufficient to properly display the internal structure of the bone. Such a ray will be given off by a tube having an equivalent spark gap of four to five inches. Next to the choice of the proper penetration will be the estimation of the correct time of exposure. The next factor in the production of suitable plates is immobilization. If attention is not paid to this, the twitching of the wounded muscles and the voluntary attempt on the part of the patient to keep the part quiet will result in muscular tremor which will blur the bone detail. The immobilization can be obtained most simply by weighting the parts above and below the area to be examined, by suitable sand-bags. These sand-bags should not be completely filled. They can then be packed around the limb in order to secure the greatest quiet. If sand-bags are not obtainable, the use of strips of adhesive plaster above and below the examined area will be found useful. Wide bandages passed around the part and then tied on the under surface of the table may also be used. If one is working with a tube stand, with the tube above the table, cotton pads or an inflated rubber bag may be placed between the diaphragm of the tube-holder and the affected part for compression.

It is very important that plates should be labeled at the time of examination. In the hurry of dark room technique plates are sometimes reversed, so that it is not always possible to tell at a glance whether the plate is of the right or left leg. Accordingly, with each exposure a lead letter "R" or the lead letter "L" should be placed upon the plate to designate which limb is being radiographed. It is of further advantage in lateral plates, especially of the femur, to mark the anterior border with suitable lead letters, so that the relative position of the fragments can be told at a glance. The necessity of doing this arises from the fact that oftentimes plates are examined when the radiographer is absent, and those observing the plates may not be skilled in their interpretation. With the careful labeling of plates serious mistakes may often be avoided.

In examining fractures which we have reason to suspect are comminuted, or which may be complicated with the presence of a foreign body, the value of stereoscopic plates cannot be overestimated. These give a good idea of the true relation of the fragments, and if the foreign body is present, shows its position in three planes.

Location of Tube.

In considering the examination of special parts of the body, we must consider the technique from two separate standpoints. First, the examination may be conducted with the patient lying upon a table, the tube being placed above the part to be X-rayed and the plate underneath. Second, if the examiner is provided with an apparatus by which the tube is contained in a tube box underneath the table, the rays are then directed from below upward. Each method has certain advantages and disadvantages. The advantage of the first position is that one can see at a glance the relation of the tube to the part to be radiographed, and he is able to make use of the central rays. The advantage of using the central rays is to minimize distortion. While this distortion may have only a comparatively slight importance in plates made of simple fractures, yet in plates of comminuted fractures, especially those complicated with foreign bodies, the question of distortion assumes considerable importance. A further advantage of using the tube stand is that in certain parts of the body it is advantageous to employ oblique rays. For example, in radiographing the foot, it is often necessary to employ oblique radiation in order to properly separate the shadows of the metatarsal bones. The degree of obliquity and the angle at which the oblique rays will strike the part examined can be much easier told by the use of a tube stand than by the use of a box underneath the table containing the tube. Another great advantage of the ordinary tube stand is that the tube can be shifted so that the rays pass laterally, permitting of lateral exposures of the ankle, knee and femur, and arm without disturbance of the patient. In fractures of the femur and knee with plates made at the bedside of the patient, this will oftentimes be a point of great advantage. The disadvantages of this method are, first the necessity of raising the limb to insert the plate underneath, and second, the necessity of protecting the plate from moist dressings. This objection can be easily overcome by placing the plate in an aluminum plate-holder.

The advantages of working with the tube beneath the table are, first, the fact that the plate can be supported immediately above the injured member and, second, that no lifting of the limb while the patient is on the table is necessary. If the tube box below the table is used, it is necessary to have some mechanical pointer attached to the box so that one knows the axis of the central rays. In the making of stereoscopic roentgenograms many operators prefer the tube above the patient. Most of the types of American apparatus are made for radiographing the patient from the above downward, while many of the types of the Continental, especially the English, have the tube below the table.

Position for Exposure.

The following table shows briefly the positions in which the different parts should be radiographed. These positions may be adopted as a routine in the majority of cases, and there is an advantage in following a routine plan. The individual case may, however, demand a departure, in which case, a safe rule to follow is that the injured part should be as close to the plate as possible and the vertical ray should enter immediately over the center of this area.

The comfort of the patient must be kept constantly in mind, and if an arm cannot be completely extended, it is possible to demonstrate lateral displacement of fragments by the antero-posterior exposure even if the elbow is flexed at a right angle. The point to remember is, that it is impossible even with stereoscopic plates to tell accurately the amount of displacement that may be present in the region of a joint such as an elbow or knee if the plates have been made in one direction only.

In the case of the spine the best results are obtained by raying a comparatively small area at a time with a medium sized diaphragm. For the lateral view it is almost essential that one should use an intensifying screen and remove the tube to a considerable distance from the plate, at least thirty inches.

REFERENCE TABLE FOR STUDY OF FRACTURES AND DISLOCATIONS

Part	*a. p.*	*p. a.*	*lat.*	*obl.*	*Ster.*	*Flu.*	*Entrance of Central Ray.*
HAND		p. a.		obl.	Ster. U.	Flu. R.	Second metacarpal.
CARPAL BONES AND WRIST JOINT		p. a.	lat.		Ster. U.		Middle point.
FORE ARM		p. a.	lat.		Ster. U.	Flu. R.	Site of injury.
ELBOW	a. p.		lat.			Flu. U.	a. p. Mid-point of articulation lat. Head of radius.
HUMERUS	a. p.		lat.		Ster. U.	Flu. R.	Site of injury.
SHOULDER	a. p.			obl. U.	Ster.	Flu. U.	a. p. Through plane of articulation. Ster. Shift laterally.
CLAVICLE		p. a.			Ster.		p. a. Perpendicular to injury. Ster. Shift parallel to spine.
FOOT	a. p.		lat.	obl.	Ster. U.		a. p. Third metatarsal. lat. Astragalo-scaphoid articulation. obl. Midpoint of tarso—metatarsal articulation.

REFERENCE TABLE FOR STUDY OF FRACTURES AND DISLOCATIONS—Continued.

Part	*a. p.*	*p. a.*	*lat.*	*obl.*	*Ster.*	*Flu.*	*Entrance of Central Ray.*
ANKLE	a. p.		lat.				a.p. Tibio-fibular articulation. lat. Tibio-astragular articulation.
TIBIA AND FIBULA	a. p.		lat.			Flu. U.	Site of injury, or mid-point between knee and ankle.
KNEE	a. p.		lat.				a. p. Lower border of patella. lat. Mid-point of articulation.
FEMUR	a. p.	p. a.	lat.			Flu. R.	Site of injury.
HIP JOINT	a. p.			obl. U.	Ster.		Midway between pubic joint and antero-superior spine.
PELVIS	a. p.				Ster.		a. p. Mid-point. Ster. Shift laterally.
SPINE	a. p.		lat.				Site of injury.
RIBS	a. p.	p. a.		obl.	Ster. U.		To isolate site of injury.
HEAD	a. p.	p. a.	lat.		Ster. U.		a. p. Median line just anterior to coronal suture. Exit through foramen magnum. p. a. See Fig. on page 209. lat. Center of zygoma. Exit through center of opposite zygoma.

U—Useful. R—Reliable.
The central ray should, whenever possible, be perpendicular to the plate.

Radiographs Made Through Splints or Casts.

In radiographing parts of the body enveloped in splints or casts, there is presented, oftentimes, a difficult problem. For purposes of exact diagnosis it is always best, when possible, to remove any splints or casts. If the examination is made for determining the position after reduction, the dressing should be left on. The length of exposure is to be increased so as to compensate for the extra amount of material which has to be penetrated. Some splint material, for example yucca board, contain particles of extra density which, when superimposed on the shadows of the bone, render the detection of sub-periosteal fractures difficult. It often occurs that the radiographer has to decide whether a callus is present or absent in a limb enveloped in a plaster splint. It can be stated that this is oftentimes impossible to be decided, as the varying densities of the folds of plaster induce shadows which may simulate the appearance of callus. Sometimes when a limb has a splint on one side only, the rays can be directed so that the shadow of the bone can be wholly or partly isolated from the shadow of the splint. In elbows confined with a right angle metallic splint, the metal may cast a shadow over the part especially interesting, and here in the interest of exact diagnosis it is best to secure permission to remove the splint. Dry plaster is more easily penetrated by the ray than moist plaster, so that it is always best to X-ray a limb in a plaster cast after the cast has become thoroughly dry. The position of the fragments of long bones of course can be accurately told even when enveloped in a wet plaster cast, but it is not to be expected that fine detail and the presence or absence of callus can be made out without the removal of the cast. Where the examination is made in only one direction the plates should be stereoscopic.

The Appearance of Callus.

Changes in the periosteal surface appear very early after injury, sometimes being seen after a period of four or five days. These periosteal changes vary in proportion to the amount of displacement. If a fracture is of the sub-periosteal type, or if the fragments have been accurately coapted, periosteal changes will be small, and not extend far from the seat of fracture. If the fracture is transverse, with over-riding, or if it is comminuted with displacement, we may find periosteal changes extending a number of inches away from the seat of injury. We often find, especially in the lower leg, difficulty in telling whether there has been enough repair to allow the patient to walk upon the leg. Careful inspection of the plate may show nothing but the position of the fragments, without any periosteal change. In these cases, it is difficult to tell from the radiogram alone, as to the amount of clinical support. It is easy, of course, to determine the amount of bony repair, but fibrous tissue adhesions are often sufficient to take care of the position.

Reports.

In writing reports of X-ray plates for fractures, it is essential to describe *first* the area shown by the plate with the anatomic parts of the bone examined; *second*, to give a description of the traumatic pathology shown; *third*, a statement as to the condition of the bone or bones, and of the soft parts outside of the area described in the second heading. In the report the manner in which the plate is made should be described so that this can be taken account of in considering the interpretation. For example, if a lateral plate is made, this fact should be mentioned at the beginning of the description. A description of the traumatic pathology should embrace, first of all, the part of the bone involved; second, the type of fracture, whether transverse, oblique or longitudinal; third, whether comminution is present and the number and size of the fragments. In all cases the relative position of the fragments should be described. If the fracture is complicated by the presence of a foreign body, this should be stated, with the size, shape and position, and its relative position to the bone fragments.

Particular attention should be paid to the question as to whether the fracture line involves joint surfaces. The importance of this is based on the fact that the time necessary for absolute immobilization depends partly on this question. If it is doubtful after an examination of all the plates whether a fracture is present or absent, this doubt should be plainly stated and the reasons for it given. If the uncertainty is based on lack of penetration or blurring due to movement, a second exposure can be recommended. If splints were present at the time of examination, their appearance should be described and special note made as to whether the shadow of the splint complicates the interpretation.

Negative Reports.

If the fluoroscopic examination and the plate examination do not reveal the ordinary X-ray evidences of fracture, this should be stated with a definite description of the area shown by the plate. For example, a negative report stating that there is present no fracture of the tibia or fibula should not be made unless the plate shows the entire length of the tibia and fibula. If the limb is rayed in only one direction, note should be made of this and the conclusion should be stated that no disturbance of the outline of the bone is shown in this *one* view.

X-Ray Osteology.

To become proficient in the interpretation of plates, constant use should be made of the drawings and descriptions in standard anatomies, supplemented, if possible, by recourse to the study of the skeleton.

Epiphyses.

While in military radiography the question of the appearance of the bones during their later development will not often be raised, yet it is best to remember that during the growing period, when the bones are in formation, their appearance may be different from the fully formed adult type. The different standard anatomies give tables under which are described the development of the bones and the age at which the epiphyseal lines become ossified. In the young adult the appearance of the crest of the ileum should be borne in mind, as ossification here takes place at the age of eighteen to twenty. In cases of doubt as to whether the epiphyseal line is to be differentiated from a fracture line, a plate made of the uninjured limb for purposes of comparison is of the utmost importance.

Plate Defects.

The interpreter of X-ray plates should be constantly on his guard against confusing plate defects with fracture lines. While it is unusual for such confusion to arise, still scratches upon the plates have been mistaken for solutions of continuity; artefacts due to air bubbles have been confused with foreign bodies.

Conclusions to be Drawn from Plates Influencing Methods of Re-position.

It can be said that some clinicians do not derive from the study of the plates all the information which the plates afford. Here the conference between the experienced radiographer and the clinician is of the greatest good to the patient. A careful study of the plate with a full understanding of the problems of re-position, will oftentimes obviate the question of operative interference.

Setting of Fractures under the Fluoroscope.

In the so-called setting of fractures the aid of the fluoroscope during manipulation is of paramount value, in fact, it may be stated that every case of fracture of a long bone with displacement should, when practicable, have the attempt at replacement made under the guidance of the fluoroscope. Important precautions are, however, to be observed in this procedure. If the patient is under ether anesthesia, precautions should be taken against the ignition of the ether vapor by electric sparks from the high tension current. The danger of this is in direct proportion to the lack of ventilation in the operating room. If the high tension wires are covered with thick insulating material and loose connections are avoided so that there is no tendency for sparks to occur, the danger is minimized.

The operator and his assistant should be protected as completely as possible against radiation. This may be done by the use of X-ray proof gloves, X-ray proof aprons, suitable lead glass over the fluoroscopic screen, and the use of as small a cone of X-ray light as will enable the ends of the bones to be properly seen. Unless one has at his disposal a stereoscopic fluoroscope one should be slow about drawing inferences as to correct position from fluoroscopic examination in one plane only.

Radiographs with Patient in Bed.

It often occurs that in patients whose general condition does not warrant their removal to the radiographic table, that the X-ray examination should preferably be made with the patient in his bed. It also happens that after a re-position has been made and extension has been present for a number of hours, that it is highly desirable to find out if the fragments are in position. If the patient is moved to the X-ray room and the extension discontinued, it is obvious that the plates obtained may not represent the true condition of the fragments as afforded by the treatment in the patient's bed. To make X-ray examinations in the patient's room or ward requires a transportable apparatus with a transportable tube stand. Obviously fluoroscopic examination here can be made only under rare conditions, unless one makes use of a small hooded fluoroscope. The problems presented usually tax the operator's ingenuity and have to be studied under the conditions present. The transportable generator usually affords only a moderate amount of X-ray energy, and on this account the exposure needs to be generous. The problems of immobilization also present complications. It may be stated, however, that fractures of the extremities and fractures of the hip may be satisfactorily radiographed with the patient in bed. Fractures of the skull and fractures of the spine are not suitable for raying under these conditions. [See U. S. Army Bedside Unit, page 56.]

Dislocations.

Examinations of the body for the determination as to whether a dislocation is present or absent involve the same general applications of radiography as in the determination of the presence of fractures. The same principles of suitable penetration of the tube, immobilization as completely as possible of the part under examination, the employment of the stereoscopic method, and care in the interpretation of the plates obtained, possess equal importance. In the detection of dislocations, the fluoroscopic method is of value in dislocations of the larger joints, as the shoulder, the elbow, knee and ankle. Dislocations of the carpal bones and the metatarsal bones are not usually easily seen with the fluoroscope. The advantage of the fluoroscopic method in examination of the large joints, for example the shoulder, lies in the fact that the position of the tube is easily shifted so that the rays will strike the joint at different angles. An observation of the shoulder joint from one angle may produce a distortion which may be deceiving. In general, it may be said that the central rays should go through the joint surface under examination, and that they should strike the plate at a perpendicular. Oblique radiation, when used, should have its results interpreted very carefully.

Reduction of Dislocations with Fluoroscopic Aid.

Reduction of dislocations under fluoroscopic guidance is especially advantageous; the operator can see constantly the relation of the two articulating surfaces and better plan his attempts at reduction. It is obvious that the same precautions should be observed as in manipulation of fractures under the fluoroscope. In all dislocations of large joints it is best to have stereoscopic plates of the joint, not only to determine the relative position of the articular surfaces but also to determine their integrity. Sprain fractures are a frequent complication of dislocations, and if they can be detected this knowledge assists materially in making the prognosis.

HEAD EXAMINATIONS.

FREDERICK M. LAW,
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Foreign Bodies.

The localization of foreign bodies in the head can be divided into three groups.

1st. Those in the cranial cavity.
2nd. Those in or around the accessory sinuses including the mastoid.
3rd. Those in the orbit or eye itself.

In the case of the first group, the most essential thing is to determine the extent of the injury to the bony covering, and the approximate location of the missile. In this instance stereoscopic plates will show the extent of the injury and will give a rough estimate of the position of the foreign body. The methods of localization described in previous chapters will be found to be satisfactory.

In the second group, the localization of the foreign body with reference to the accessory sinuses will give the surgeon the necessary information in case removal is considered.

In the third group very accurate localization is necessary, as the knowledge of the exact position of the foreign body might mean the saving of an eye or the preservation of vision.

Sweet Eye-Localizer.

A simple method devised by Dr. Sweet, consists of two general parts: the base or head-rest, as illustrated (Fig. 1), and the Localizer, as shown in outline drawing (Fig. 2).

The head-rest base is composed of the following parts:

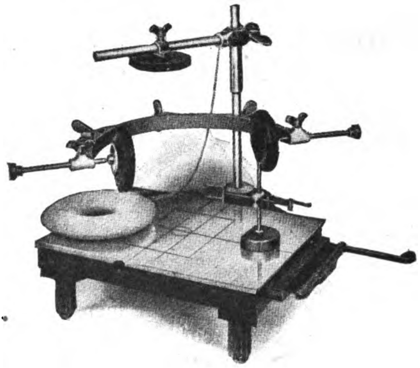

FIG. 1. Head rest for use with eye localizer.

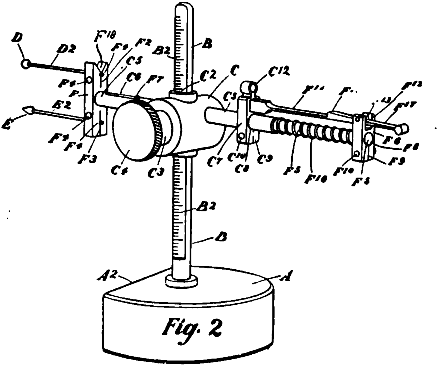

FIG. 2. Sweet eye localizer.

1. A plate-slide tunnel, so constructed as to protect one-half of a 5x7 photographic plate while the other half is being exposed, and to protect the exposed half while the second exposure is being made.

2. Four rubber-tipped legs to raise the tunnel so that it will act as a pillow to hold the patient's head level when lying on his side.

3. A plate-holder having a slide that will protect the plate from the ordinary light, but offer no resistance to the X-ray.

4. An arm or handle attached to the plate-holding slide to enable the operator to shift the plate the correct distance for each exposure, and to withdraw the same when both exposures have been made.

5. A pneumatic cushion for the comfort of the patient.

6. A double clamp to hold the patient's head and to prevent any horizontal movement.

7. A single vertical clamp to press the head downward upon the pneumatic cushion, thereby obviating any necessity for the unsanitary sand-bags.

The localizer consists of:

1. A heavy metal base (Fig. 2).

2. An upright standard B to support the localizer and permit the same to be adjusted and held firmly at any desired height.

3. The indicator-ball D, with its needle-supporting Stem D2, which, when properly adjusted to the center of an eye, will cast its shadow on the photographic plate and serve as a landmark indicating the center of the cornea.

4. The metal tip E, of stem E2, is made cone-shaped, so as to more easily differentiate its shadow from that of ball D. These indicators are permanently adjusted a known distance apart (15 millimeters), so that when an X-ray plate is made of them obliquely, when adjusted

to an eye as above stated and as indicated in "front view" on the chart, we are enabled by their shadows to definitely locate the source and course of the rays of light (in relation to the chart) that caused the shadows, and in turn the position of any foreign body that may show on the same plate can very easily be determined by the position of its shadow in relation to that of the ball and cone, because the exact position of the latter with reference to the chart is known and indicated (front view).

5. Tube C12 and notch F18 are sights similar to those used on a rifle, with which the operator can accurately align the center of the cornea of the afflicted eye with ball D and its supporting stem D2. F14 is a spring trigger which presses upwards against pin F13. F5 is the end of the rod to which the indicator-ball and cone D and E are attached by bracket F, the whole being supported by passing through tube C5. Spring F14 being attached to stationary tube C5 by means of bracket C7, rod F5, with bracket F6 can be pressed forward until pin F13 is engaged by notch F15.

6. By loosening set-screw C4 the bracket C can be raised or lowered until ball D, with its supporting stem D2, is in exact alignment with the center of the cornea of the affected eye, and the screw then tightened.

7. The patient is instructed to close his eyes and the entire instrument with its base, is slid forward until indicator-ball D presses into the eye-lid approximately its own thickness. The trigger F17 is then depressed to disengage notch F15 from pin F13, when spring F16 will cause the rod F5 and indicator-ball D and cone E to rebound exactly ten millimeters, being restricted by knob F7 in slot C6. The subject and localizer are now in correct position for making the two necessary exposures.

First Exposure.

Place patient's head, affected eye downward, on the plate-holder base, with inflated cushion in position as shown in illustration being careful that the inflated cushion does not extend over the marked lines on the cover, otherwise it might cast a shadow on the photographic plate.

Should the subject show a tendency to move about, the horizontal clamp, as shown in Fig. 1, should be adjusted to the base of the head and forehead, otherwise the vertical clamp as shown in illustrations herewith, will be sufficient. The double horizontal clamp can be adjusted for either eye by means of its two off-center holes and clamp screws.

Place the diaphragmed tube in position so that its central rays will exactly parallel the front vertical plane of the patient's eye, as shown in Fig. 3.

A fresh 5 x 7 plate having previously been placed in the plate-holder, is now placed in the tunnel with its outer flange protruding, as shown in illustration. This will expose one-half of the plate to the action of the rays, while the other half will be protected for the second exposure.

The localizer (Fig. 2) is now placed on the stand in front of the affected eye; its trigger is "set" as already described and after the indicator-ball has been adjusted to the plane of the cornea, the entire instrument is pushed forward on its base until the ball presses into the patient's closed eye-lid approximately its thickness; the trigger spring is then released and the indicator-ball and cone recede exactly 10 millimeters, thereby permitting the patient to open his eyes and wink them in a natural manner. By referring to localizer chart you will observe that due allowance of 10 millimeters has been made by placing the indicator-ball and cone just that far re-

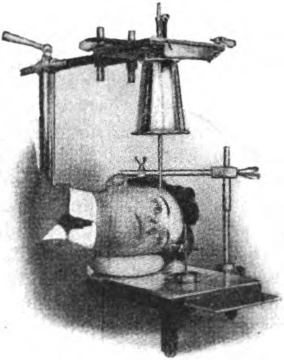

FIG. 3. Position for first exposure.

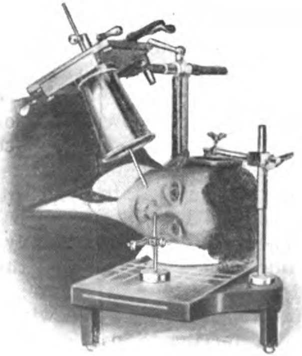

FIG. 4. Position for second exposure.

moved from the front plane of the cornea, and it should also be borne in mind that the front of the cornea is 10 millimeters in front of the shadow of the indicator-ball, as shown in your negatives. The tube is now centered over the localizing ball and cone so that the shadows of the two will coincide (Fig. 3).

Some object, such as a candle or a piece of white paper, that can be readily seen by the patient, should be placed in alignment with the sights of the indicator, but several feet removed therefrom, and the patient should be instructed to look constantly at this object while the two exposures are being made.

Second Exposure.

The first exposure having been made with the rays perpendicular to the plane of the plate and parallel to the patient's eye, thereby superimposing the shadows of the indicator ball and cone and their supporting stems, as shown in the right-hand half of illustration (Fig. 5) the X-ray tube is then shifted toward the patient's feet four or five inches and tilted so that the indicator-rod points to the ball of the localizer, thereby causing the central rays to pass obliquely through the center of the cornea of the patient's affected eye, as shown in Fig. 4. The photographic plate must now be shifted by pushing the plate-holder inward, by its handle, as far as it will go, thereby protecting that portion that was acted upon by the rays in the first exposure and bringing its unexposed half in proper position to receive the rays from the second exposure. In this position the second exposure is made with the rays falling obliquely upon the indicators, thereby separating their shadows, as shown in left half of illustration.

It should be remembered that it is not essential that the exposures be made with the tube at any specific distance from the plate or even that it be the same distance for the two exposures. Neither is it important that the tube be shifted an exact or known distance for the second exposure, as by the use of the charts and Dr. Sweet's method the course of the ray is automatically established, as is shown by the lines F^1 and P, and P^1 and P^2 of outline drawing, Fig. 6.

Charting the Plates.

In charting the plates the following method is pursued: Upon the negative (right-hand half of the illustration) which represents the first exposure, a line is drawn through the horizontal axis of the indicator-ball and cone which are here superimposed, thereby projecting their supporting stems and establishing the visual axis of the eye. Fig. 5.

A second line is drawn at right angles to the first through the center of the foreign body's shadow.

With a small pair of dividers step the distance from the edge of the indicator-ball to the intersection of the horizontal and vertical lines that you have just drawn. Then step this distance off on the diagram chart, making a dot with a pen, or very sharp, hard pencil, to represent the exact distance. Figs. 6 and 7.

On the vertical line that has been drawn through the shadow of the foreign body (right-hand half of Fig. 5) measure the distance of the foreign body above the horizontal line and indicate the same on the chart above the first dot, as is represented by dot F^1 in outline drawing "Side View."

Place another dot on the same horizontal plane at point P and draw a line through these two dots, projecting into the "Front View" as shown.

Since the position of localizer-ball B, as shown on the chart, is the same as when the first plate was made, the location of the foreign body must be at point F^1 "Side

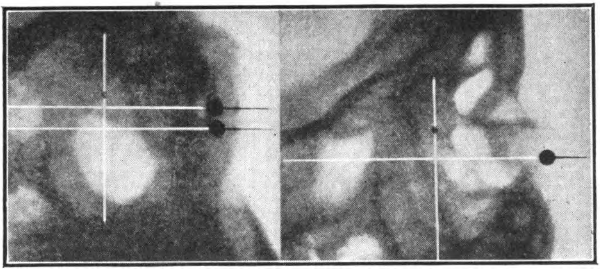

FIG. 5. Print of plate, showing construction lines.

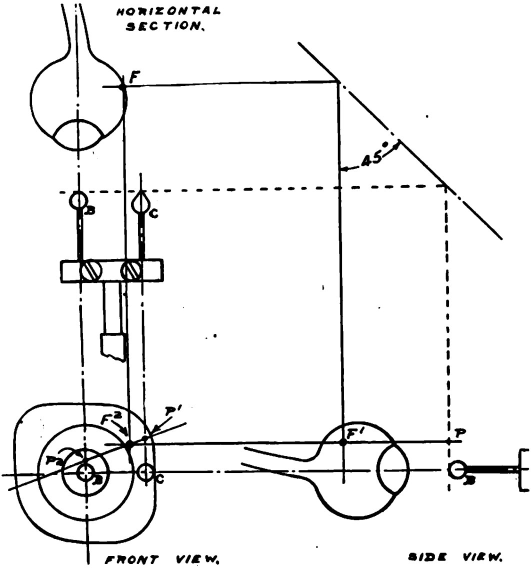

FIG. 6. Construction made on the chart.

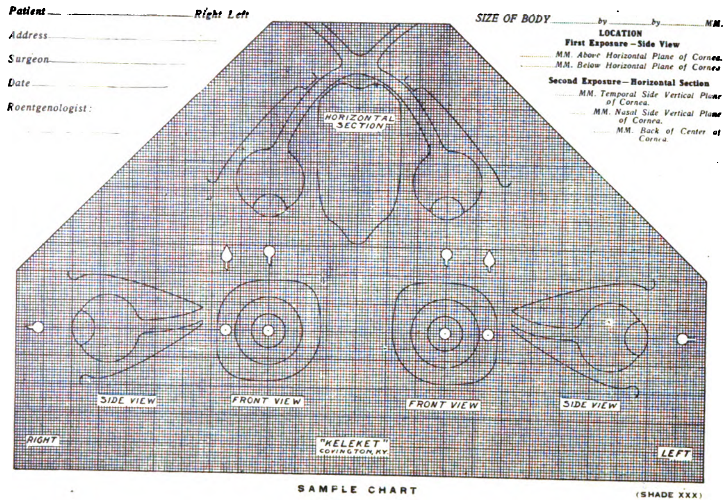

FIG. 7. Blank chart.

View," but we have yet to establish its location to the nasal or temporal side.

Project a line vertically through point F^1 to the 45 degree angle, thence horizontally through "Horizontal Section."

Upon the negative (left-hand of illustration) which represents the second or oblique exposure, a line is drawn through the horizontal axis of both the ball and the cone, thereby projecting their supporting stems and establishing the relation of their horizontal planes to that of the foreign body.

A third line is drawn at right angles to the first two through the center of the foreign body shadow.

With your dividers measure the distance of the shadow of the foreign body above the horizontal plane of the shadow of the ball and mark the same by a dot on the "Front View" of the chart just above the center B, as indicated by arrow P^1, because that was the relative position of the indicator cone when it cast the shadow.

A line drawn through dots P^1 and P^2 will represent the true course of the rays in the second exposure, and its intersection with the projected line from the "Side View," through points P and F^1, will be the position of the foreign body when viewed from the front, while a vertical projection of a line through "Horizontal Section" shows the position of the foreign body to the temporal side at point F, "Horizontal Section."

Technique for Mastoids.

It is necessary to make an examination of both ears. This may be done on one 8 by 10 plate, by covering one-half of the plate with a thick piece of lead and making one exposure on the uncovered portion then changing the lead cover to the exposed side and making the second exposure on the side which has previously been covered.

This makes comparison of both sides much easier than if separate plates are made.

The patient lies on a table with the head on a small raised platform. The affected ear next to the plate with the pinna folded forwards. There should be a clamp on the platform with adjustable pads to press on the occiput and forehead, so as not to obstruct a clear view of the mastoid cells. The head is placed so that the sagital plane will be parallel to the plate. The tube is centered over the head in such a way as to direct the central ray downwards and forwards toward the opposite ear. An angle of 15 degrees from behind forward and 15 degrees from above downward will in the majority of cases be correct. In case the shape of the head is such that it cannot be placed parallel with the plate, without raising the mastoid area above the plate, the angle of the tube must be altered to accommodate. The central ray should enter the head about 3 inches above and 3 inches behind the external auditory canal, and exit at the external auditory meatus next to the plate.

The tube stand should be supplied with a small cone and this brought down with firm pressure on the head. Stereoscopic plates may be made by shifting and tilting the proper distance on each side of the angle. Fig. 8.

Technique for Accessory Sinuses.

In order to obtain a satisfactory postero-anterior image of all the accessory sinuses at one exposure, it is necessary that the rays pass through the head at a certain angle. If this angle is not observed, the petrous portion of the temporal bone obstructs the view of the ethmoids or antrum or the sinuses are so distorted that the information given is not correct.

The proper angle is one which will cause the shadow of the petrous portion to cut across the lower one-third of the orbit, leaving the lower two-thirds of the antrum

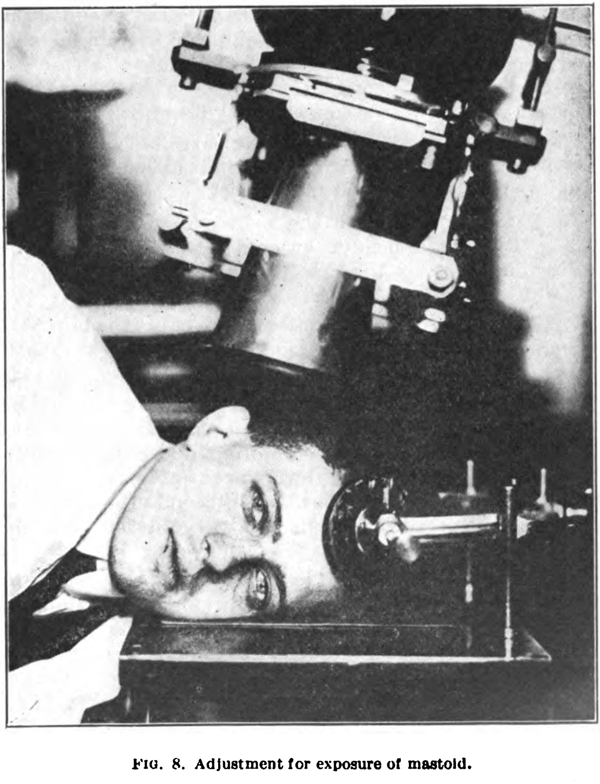

FIG. 8. Adjustment for exposure of mastoid.

free and also the upper two-thirds of the orbit clear. The superior portion of the antrum is not so important, as any condition affecting the antrum to the extent of an X-ray diagnosis will involve the inferior portion as well. The possible exception to this is in the case of a fracture involving the lower orbital margin. In this case the petrous must be thrown down into the antrum.

The position described shows clearly all that is required of the frontals, ethmoids, and antra on a single plate, and the sinuses in their proper relation and size.

To obtain this position the principal ray must be directed through the head at an angle of 23 degrees from a line extending from the external auditory meatus to the glabella.

This angle may be obtained by a pair of dividers or a permanent triangle set at an angle of 23 degrees. Fig. 9.

The patient is seated before an adjustable stand or may lie prone on a table. The head rests face downward with the nose and forehead on an inclined plane. The inclination is such as to be comfortable to the patient. The head rest shown in the illustration has an angle of 20 degrees. If the patient is sitting an adjustable rest is necessary to accommodate for the difference in the length of the neck and shape of the head.

The tip of the angle finder is placed opposite the glabella, the left arm passing across the external auditory meatus, the right arm extending upwards alongside the cone and representing the direction of the principal ray. The cone is now brought in to alignment with the arm of the finder and brought down on the head, making firm pressure. Fig. 9.

For lateral plates the patient places the side of the head on the platform holder, the head is levelled so that the sagital plane is parallel to the plate and the tube

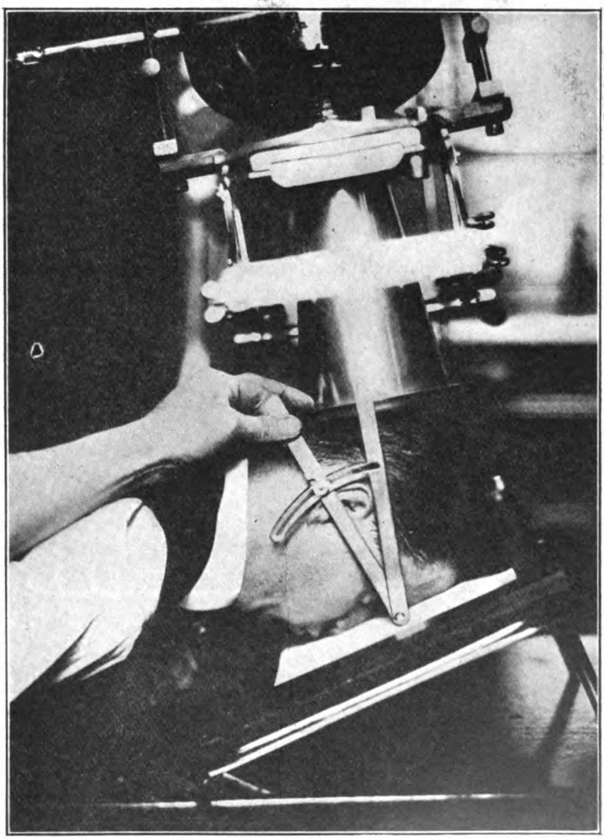

FIG. 9. Adjustment for exposure of accessory sinuses in the posterior-anterior direction.

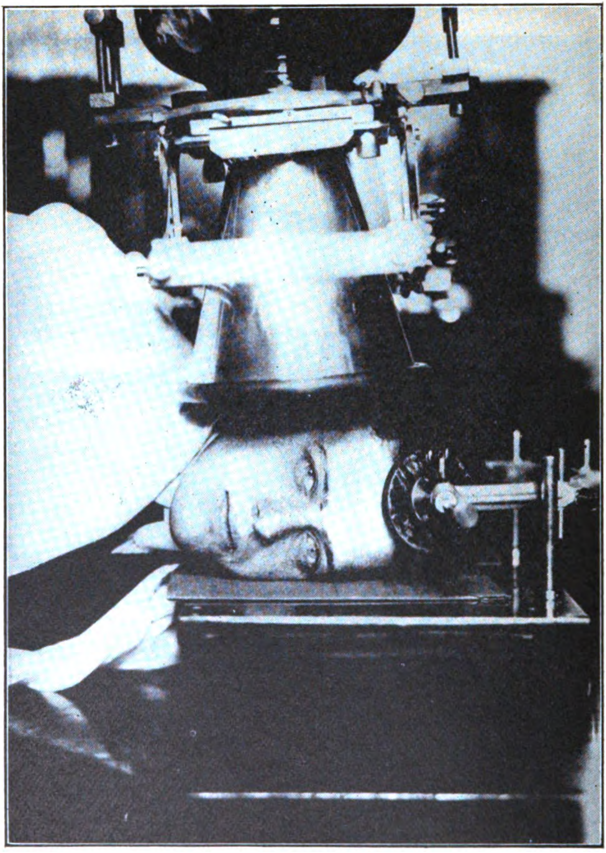

FIG. 10. Adjustment for exposure of accessory sinuses in the lateral direction.

centered so that the principal ray passes directly through the frontal sinus. This is to obtain a true representation of the depth of the sinus and the thickness of the anterior wall. The head is clamped firmly in place. Fig. 10.

Interpretation of Mastoid Plates.

In case the pinna cannot be folded forward, due allowance must be made for the increased density over the mastoid cells caused by the shadow of the pinna. Post auricular oedema will cause a haze over the cells, which must not be mistaken for inflammatory exudate. Inspection of the ear before radiographic examination will prevent this error as allowance may be made for the increased density. Farunculosis in the canal is often accompanied by a slight cloudiness of the cells, which must not be mistaken for exudate. Fig. 11.

The mastoid being a pneumatic cavity will show normally as a honey combed structure with the cell partitions clearly outlined, so that the degree of the involvement will be determined by the sharpness of these partitions. A simple congestion or thin fluid will produce a general haze over the mastoid structure but the cell walls will be clearly outlined. As the disease progresses and pus accumulates, the degree of obliteration of the cell walls will determine the extent of the disease or the amount of pus. If the condition has reached the point of bone destruction the necrotic area will show through the white blur of the cell involvement as a dark area. This usually occurs over the line of the tegman tympani representing an epidural abscess, or over and below the knee of the lateral sinus as a peri sinus abscess.

This dark area must be distinguished from a large cell in the midst of a group of small cells. This can usually be done by comparison with the opposite mastoid. As a rule the two mastoids are similar in structure.

When there is a large or small cell on one side there is usually a corresponding cell on the opposite side. Then too, a necrotic area will have hazy edges while a clear cell will be sharply outlined.

Complete obliteration of the cell area must be differentiated from sclerosis. This is a condition caused by replacement of the cell structure by dense bone and the shadow on the plate will therefore be structureless. The area resembles the bone in the rest of the skull, with a clear cut outline of the sinus showing through. This process can be so extensive as to involve the entire area including the region of the antrum, thus showing no detail at any point.

A condition may arise in which necrosis has occurred in the sclerotic area, a cholesteotoma. This will show as a dark area near the sinus or in the antrum region. Usually there is a lighter area in the dark portion which represents a mass of debris in the necrotic cavity.

In the event of a fracture or injury extending through the mastoid structure stereo plates are necessary. These cases nearly always show mastoid change due to the presence of blood or infected material.

In the event of the involvement of both mastoids dependence must be placed on the history and clinical evidence.

The size of the cells plays an important point in the prognosis. A large pneumatic mastoid with large antrum cells is more likely to clear up without operation than one of small cells, as the smaller cells are more apt to clog and stop drainage.

Many cases which have been operated and have not properly cleared up will reveal cells remaining in the mastoid process. These contain granulations which keep up the discharge and prevent healing.

Interpretation of Accessory Sinuses.

Here as in mastoids there are pneumatic cavities which in a normal condition allow the rays to penetrate readily and cast dark shadows on the plate. When pathological material is present the density of the shadows is reduced depending on the extent of the involvement. Fig. 12.

In the examination of the frontal sinuses a very important factor to be considered is the depth of the sinus and the thickness of the anterior wall, as viewed in the lateral plate. A sinus with a thick wall will naturally cast a lighter shadow than the same sinus with a thin wall. Hence a sinus with a thin wall and containing granulations or thin pus will cast the same density of shadow as the same size sinus with a thick wall but clear of pathological material. A deep sinus will normally cast a denser shadow than a shallow sinus. One must remember that one or both frontal sinuses may be absent. Figs. 13 and 14.

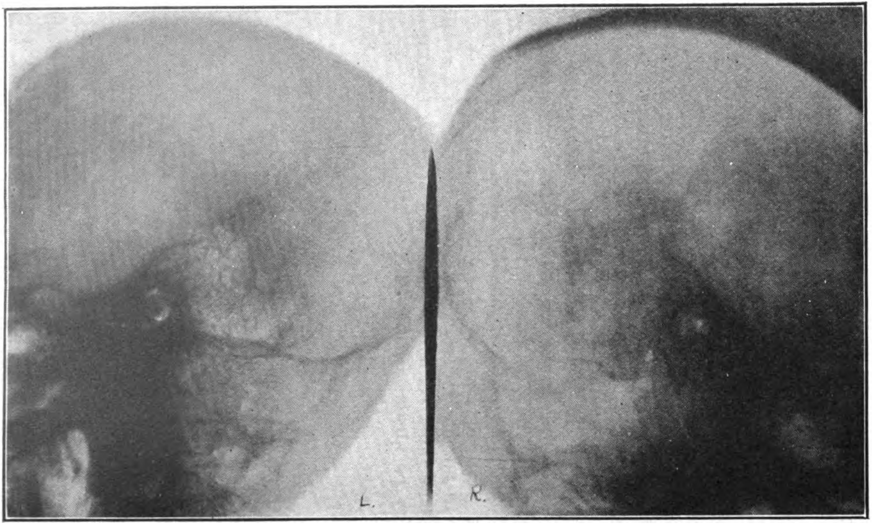

FIG. 11. Left mastoid cells show clear and normal. Right mastoid cells show occlusion with granulations or pus and the cell walls obliterated.

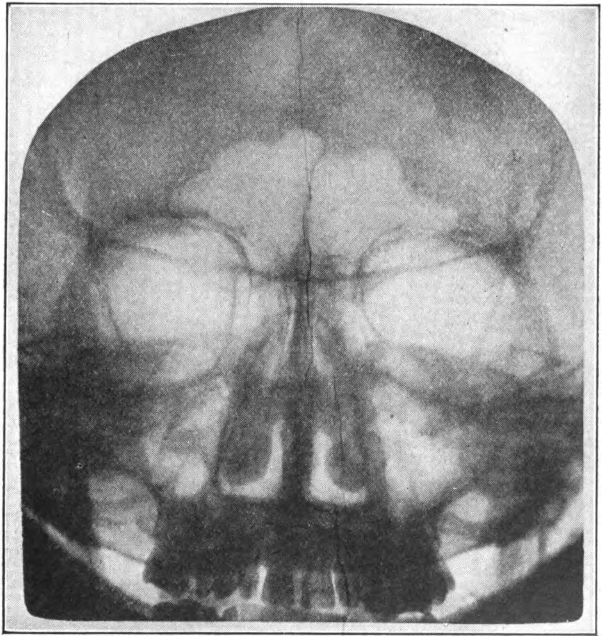

Fig. 12. Normal and symmetrical accessory sinuses.

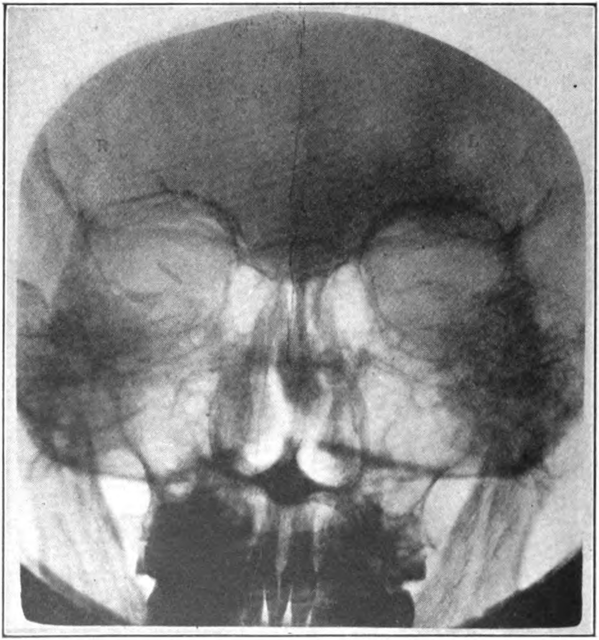

FIG. 13. Complete absence of frontal sinuses. Other sinuses normal.

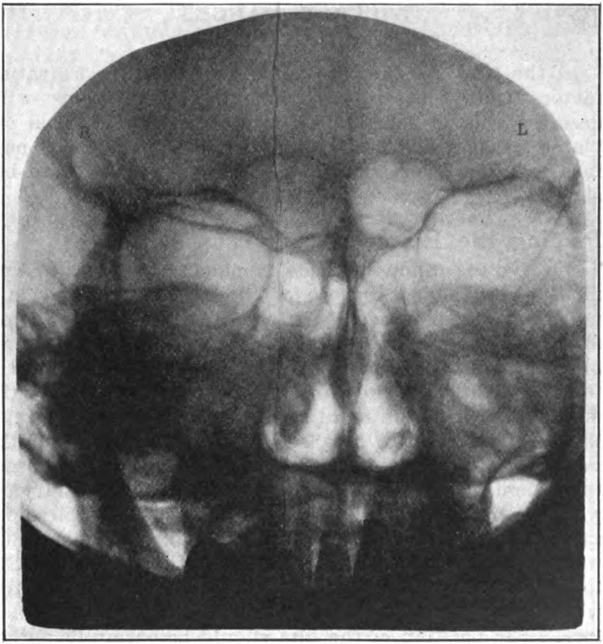

Fig. 14. The right frontal sinus and right antrum contain dense granulations or pus. The left antrum contains a thickened membrane.

TEETH AND MAXILLAE.

WILLIS F. MANGES,
Major M.R.C., U.S. Army.

In the study of the teeth dental films are more satisfactory than plates. Accompanying illustrations will describe the proper adjustments of tube and films or plates. Plates are used when the films cannot be put into the mouth, or when a large area is required to be shown.

Placing the Film.

Observe the following hints in placing the films in the mouth. All sharp corners of the wax paper covering must be folded over and softened, and the films themselves will become more soft and pliable by bending, not breaking them over the end of the finger and thumb so that they will take the curve of the palate or inner surface of the mandible more readily. To prevent gagging, the patient is told to breathe deeply through the mouth while the film is being placed in position. This causes the tongue to be carried far back into the pharynx where it need not be pressed upon. In very troublesome cases spraying the palate and pharynx with camphor water, in addition to the above precaution, adds greatly to the chance of success. Be sure that the film is far enough into the mouth to include all of the root structure. The position of the film should be carefully noted after the patient's thumb or forefinger is in place to hold the film, since the wax paper moves easily on a surface wet with mucus, and the patient's hold may relax as the operator removes his hand. For the upper teeth no additional covering over the wax paper is necessary or even desirable, and there is no better film holder than the patient's left thumb for the upper teeth on the right side, and the right thumb for those on the left side. The pressure of the thumb must be firm, and the fingers should rest on the opposite side of the face to prevent unintentional motion of the hand. In all instances the operator must mold the film to the contour of the maxillae and denote by the firmness of his own pressure how the patient shall hold it.

For the lower jaw the films should be wrapped in soft tissue paper, such as paper napkin. This prevents slipping and is also more comfortable to the patient. It is absolutely essential that the patient's tongue be completely relaxed in order that the film may be carried back far enough to reach well beyond the third molar, and deep enough to reach well below the apices of the roots. The palmar surface of the index finger of the opposite hand is preferred for holding the films against the lower teeth.

Exposure.

The patient should hold his breath during the actual exposure whether it is for one second or twenty seconds.

The proper angle of exposure must be determined by the contour of the patient's maxillae, and the tooth shadow should be approximately the same length as the tooth.

For angle of exposure see Figs. 1, 2, 3 and 4.

Interpretation.

The X-ray study of the teeth and maxillae is to be considered from the view point of dentistry without injury, and as well from the view point of wounds incident to war and, therefore, of surgery. The former has more to do with the general health and efficiency of the soldier, while the latter involves the repair and restoration of these very important parts after injury.

The reader is advised to acquaint himself with the structural and regional anatomy of the teeth and maxillae; and also to study some recognized authority on the pathology of these structures. The accompanying illustrations show practically all of the types of pathological lesions about which we are herein concerned, except injuries. Figs. 5, 6, 7, 8, 9, 10, 11 and 12.

It is difficult to anticipate the sort of injuries one has to deal with in military surgery, and therefore difficult to give definite instruction in the part taken by the radiologist. The following illustrations serve to show the proper adjustments for the different parts of the jaw bones, and they may be taken as guides in most instances. The object is to have the central rays pass in such a direction that the shadows of the teeth on the near side of the face will not fall in the area that is to be examined. Figs. 13, 14, 15 and 16.

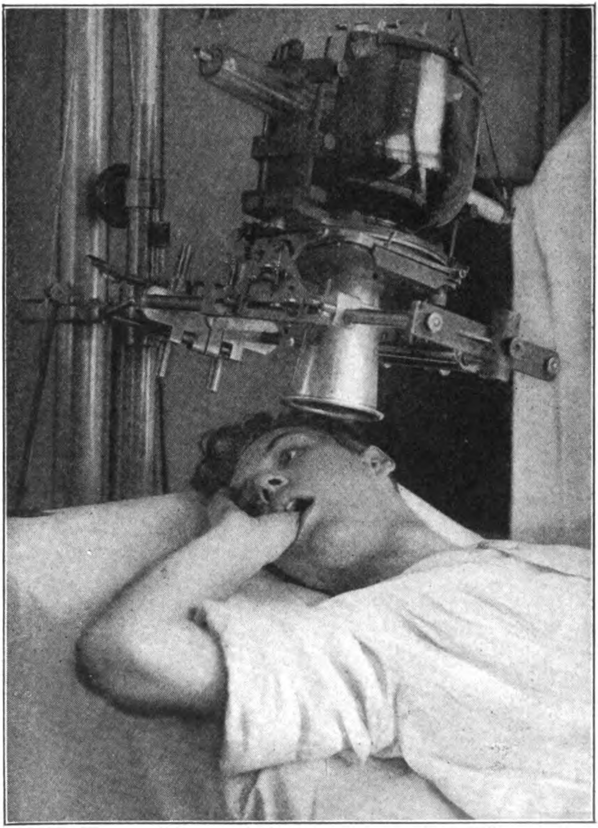

FIG. 1. Position of patient, film and tube for exposure of upper molar region. Note elevation of head and slight downward tilt of cone.

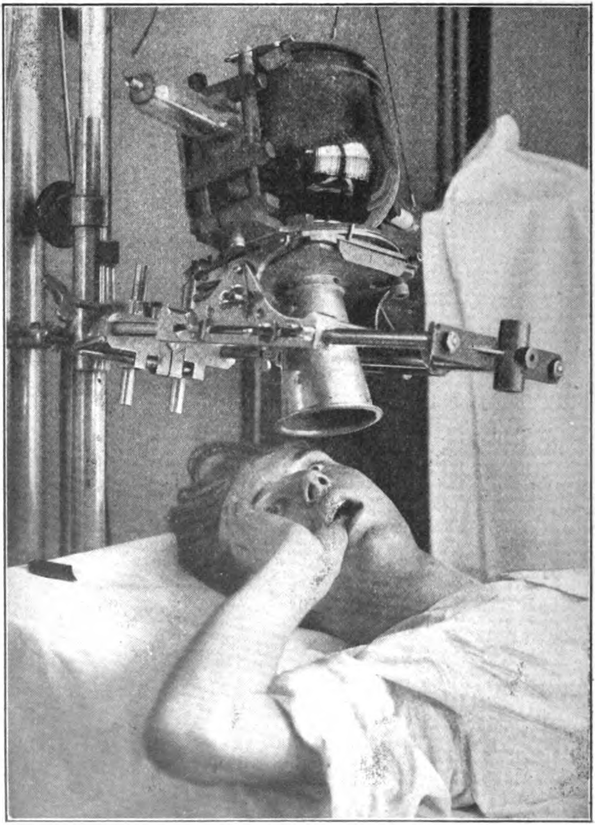

FIG. 2. Adjustment for exposure of upper bicuspids, canine, and lateral incisor. Note that cone tilts more than in Fig. 1. This same tilt of cone is used for exposing the central incisors.

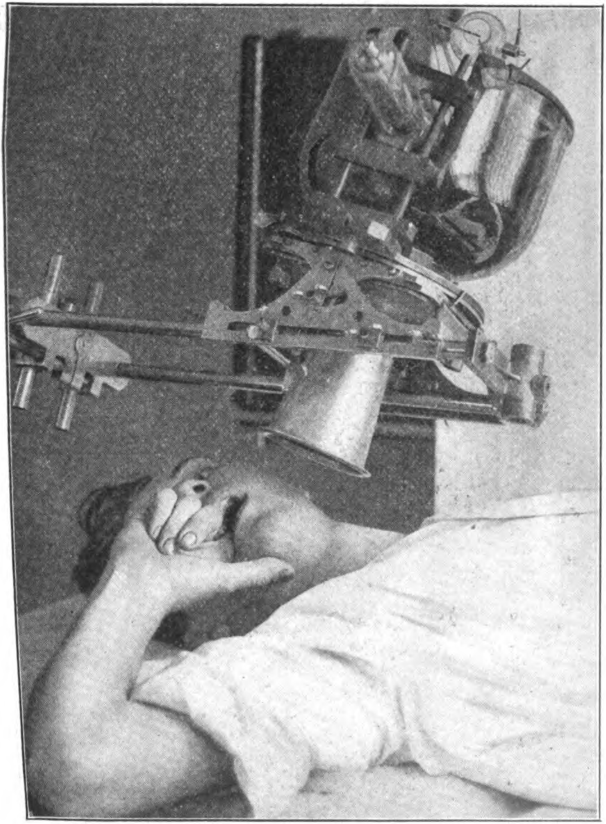

FIG. 3. Adjustment for exposure of lower molars. Head is lowered to level of body. Note position of fingers and thumb, also that cone is tilted slightly upward.

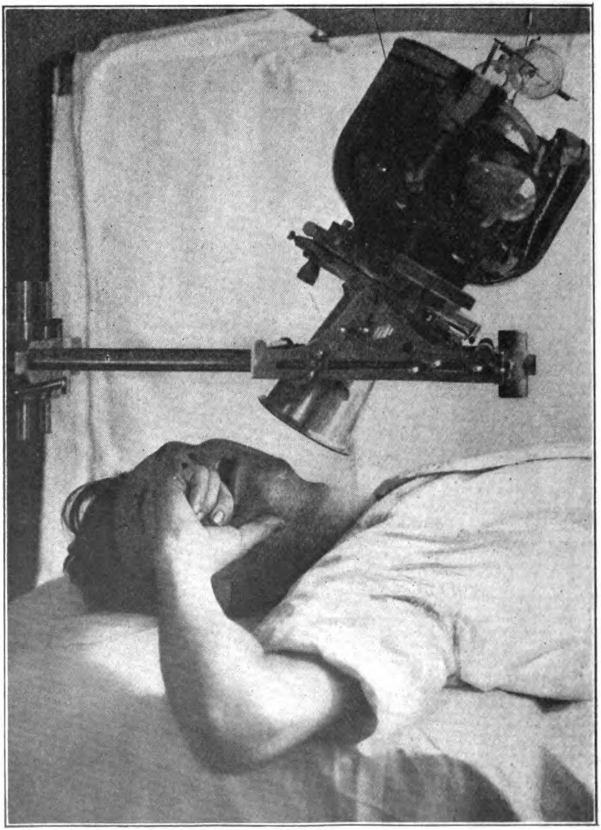

FIG. 4. Adjustment for exposing lower bicuspids, canine, and lateral incisor. Note extension of chin, also marked upward tilt of cone. This same upward tilt of cone and extension of chin apply to the lower central incisors.

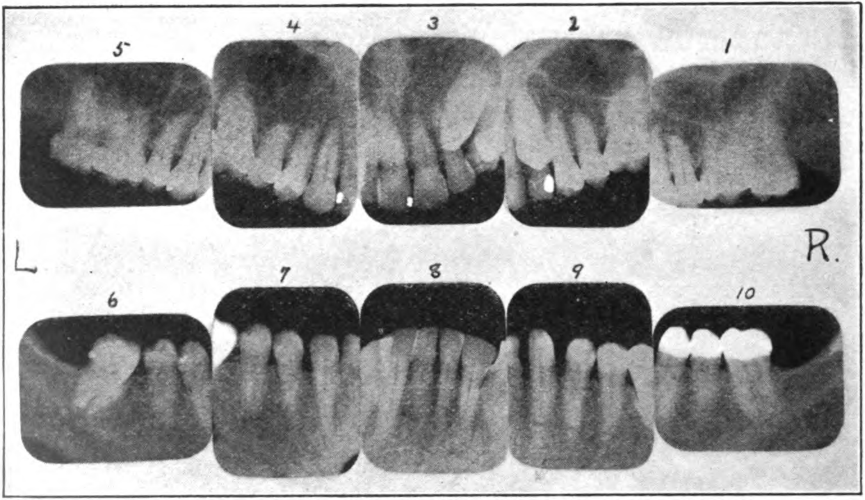

FIG. 5. Normal teeth except for unerupted canine upper. right Note the firm attachment of the teeth to the alveolar process, and also the cancellous structure of the alveolus. The numbers from 1 to 10 show the order in which the films have been exposed There is slight absorption of the alveolar margin in the lower incisor region.

FIG. 6. Localized areas of destruction of the alveolar margin, or subgingival abscess, second bicuspid upper right, first bicuspid upper left, first molar lower left, canine lower left, second bicuspid and first molar lower right. Hypercementosis of roots of first molar lower left.

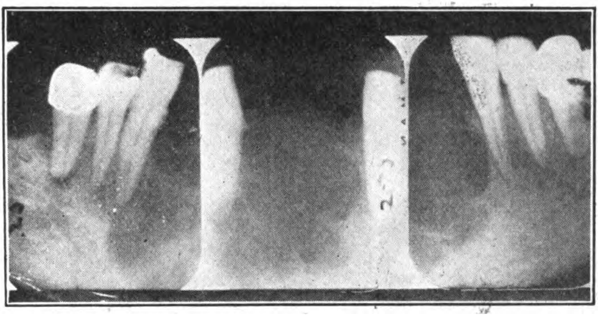

Fig. 7. Sarcoma of mandible involving median incisors and left latera incisor, probably also beginning involvement of the other teeth shown.

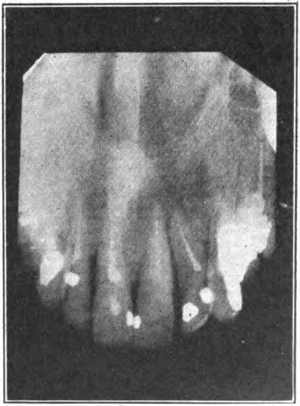

Fig. 8. Acute abscess right upper central and lateral incisors. Note that abscess is not sharply defined. Acute abscesses sometimes do not cast definite shadows.

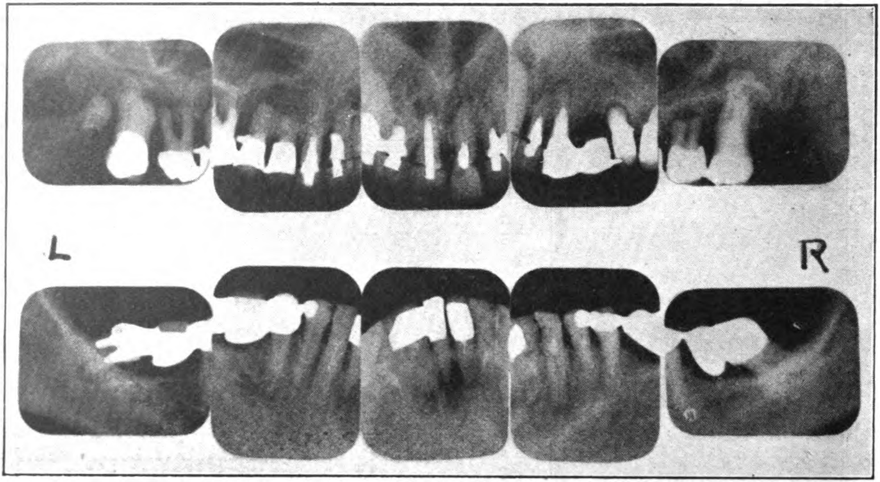

FIG. 9. Multiple chronic apical abscesses, with areas of extensive destruction of the alveolar margin. Unextracted root third molar upper left.

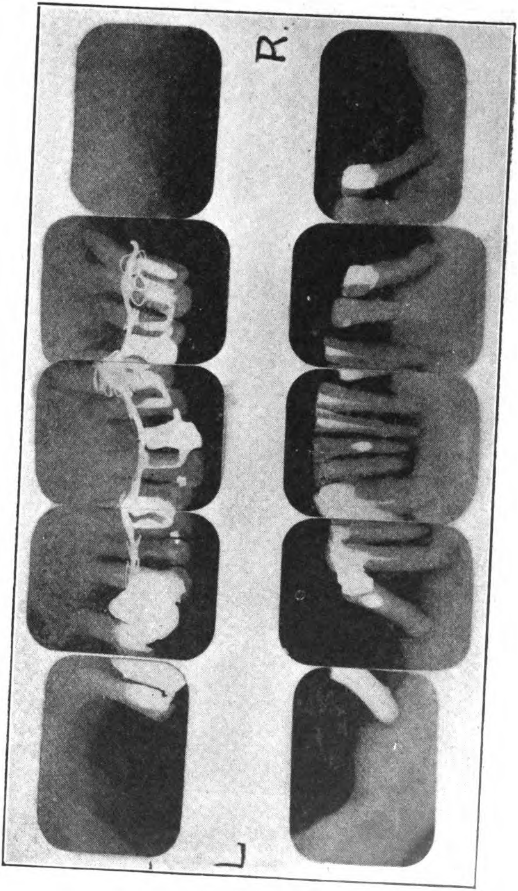

FIG. 10. Advanced pyorrhoea.

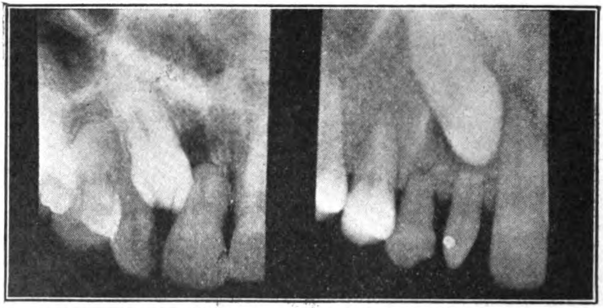

Fig. 11. Abscesses involving unerupted teeth.

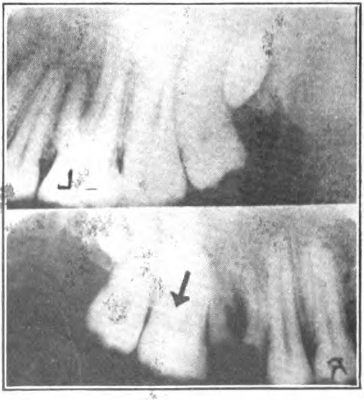

Fig. 12. Supernumerary molar teeth both sides upper jaw. Note lack of development. Complete destruction of crown of first molar upper right, also of the interradial portion of the alveolar process. Pulp stone in second molar upper right at point of arrow.

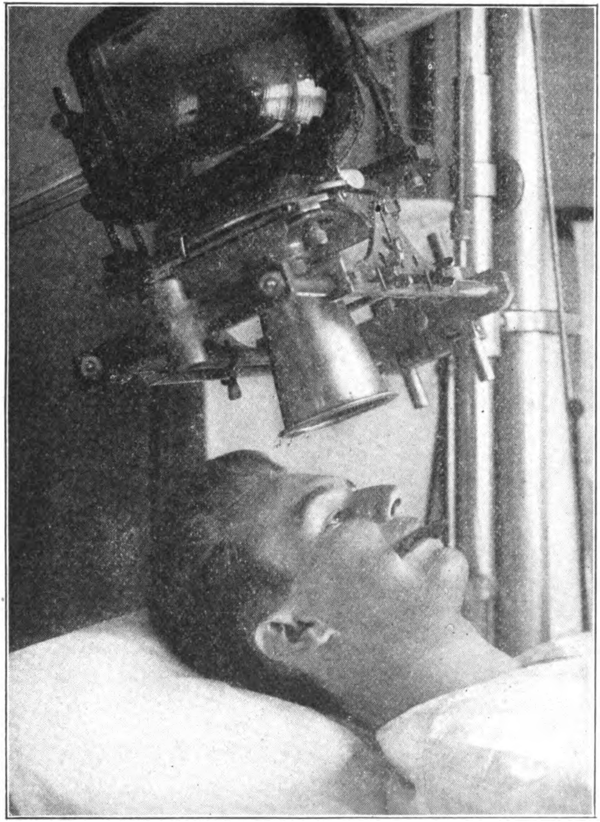

FIG. 13. Adjustment for exposure of anterior portion of upper jaw. Note large film held between the teeth. The teeth shadows will be very much foreshortened.

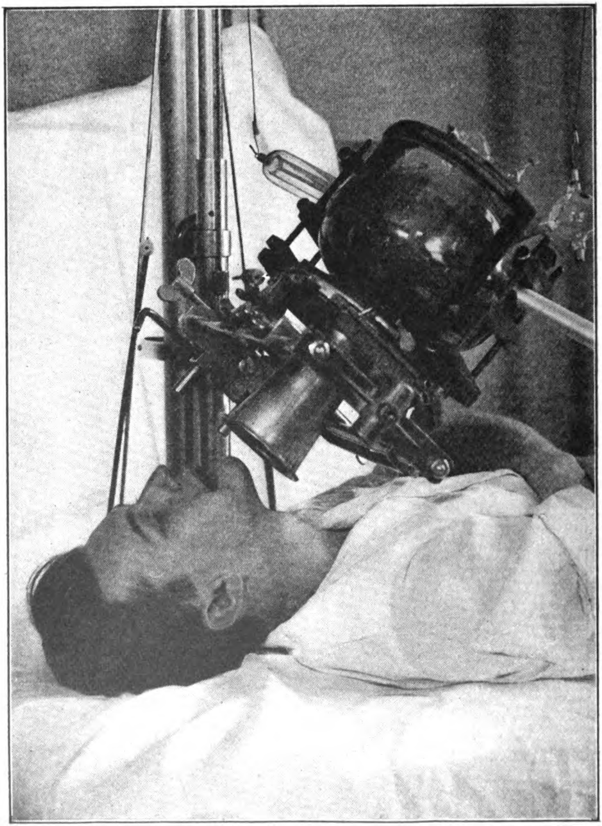

FIG. 14. Adjustment for exposure of anterior portion of mandible with large film in mouth.

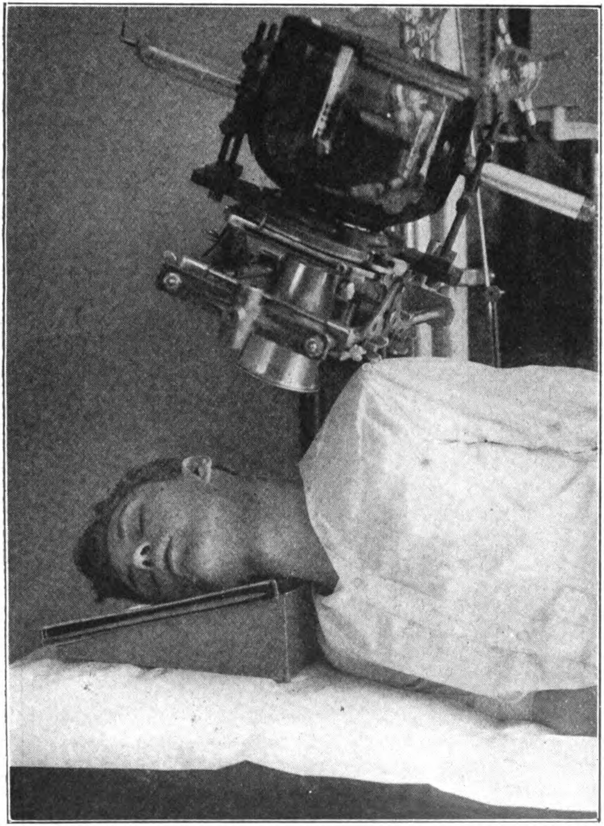

FIG. 15. Adjustment for exposure of posterior two-thirds of mandible, the articulation of the jaw, and the zygoma. Note plate holder by means of which plates may be handled for stereoscopic exposures. The tube should be shifted laterally. Chin is in extreme extension.

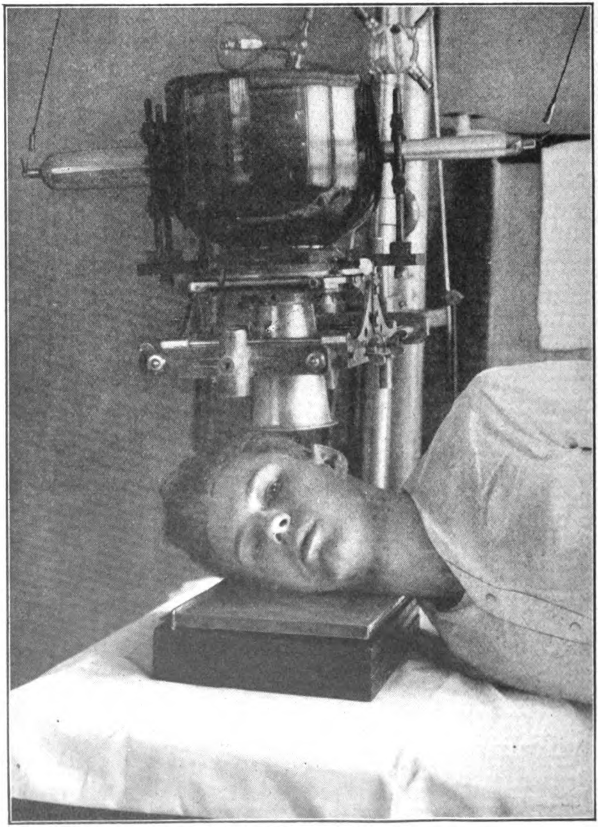

FIG. 16. Adjustment for exposure of upper jaw.

X-RAY EXAMINATION OF THE CHEST.

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The use of the fluoroscope has been dealt with in the chapter on fluoroscopy.

In the study by means of plates there is decided advantage in the use of stereoscopic plates over the single plate; but where stereoscopy is impractical there is much to be learned from the single plate, or two plates, one being taken from the front and the other from the back.

Refer to the chapter on exposure technic for the actual operation of the tube.

It is most important that the exposures should be made with the lungs containing as much air as possible, and also that there should be entire freedom from motion both on the part of the body and the breathing muscles. Comparatively rapid exposures are advisable but not essential if the patient holds his breath well and keeps his body still.

Position of the Patient.

Whether he be standing, sitting, or lying down the patient should assume the following attitude: With the plate in front, the chin should be in extreme extension, have the palms of the hands resting on the iliac crests with the fingers extending over the abdomen, have the elbows and shoulders carried forward to the plane of the plate, and be sure to have the plate high enough so that the apical shadows will not be off the plate. The tube should be centered so that the central ray will pass through the vertebrae at the level of the lower angles of the scapulae. When stereoscopic plates are made this point should be the center of the shift and the tube moved parallel with the spine.

With the plate on the back the attitude of the patient should be the same as above, and a bandage thrown from one elbow to the other tied sufficiently tight to relieve the patient of the muscular effort necessary to hold them in place. If possible the two exposures should be made and the plates shifted during the time the patient holds a single full breath, but good stereoscopic plates can be made more leisurely if the patient will keep the same position and for the separate exposure take in the same amount of air.

Reading of Stereoscopic Chest Plates.

The reading of stereoroentgenograms consists of an objective description and a subjective deduction. Describe:

(1) *Plates*, or the work of the roentgenographer. (2) *Bones*, particularly the position of the spine, the corresponding width of the interspaces and the angles of the ribs to the spine, calcification of the cartilages and all bone lesions. (3) *Muscles*, note height and dome of diaphragm, position of heart and aortic arch, pectoral muscles if seen and the breasts of a female. (4) *Trachea*, note its position in the mediastinum and relation to dorsal vertebra, in front of what vertebra it bifurcates and where each bronchus enters hilum shadows. The most important landmark on the X-ray plate is where the left bronchus passed under the branch of the aorta. (5) *Hilum*, note how right and left hilum shadows differ from each other and from normal as to size and density and the character of any calcified areas within them. Especial care must be made to detect and locate all trunks which pass from hilum toward periphery. (6) *Right thorax*, this can be divided into upper, middle and lower divisions. (a) Upper division —three trunks can be made out going to upper division. The first is called the vertebral trunk, it passes upward

more or less parallel to the vertebral column. Usually behind the clavicle it divides into radiating lines which normally should not reach the periphery. These radiating lines are called linear markings and are usually circumscribed by the circle of the first rib. Second trunk has been named, first interspace trunk, because it lies behind the first interspace and its linear markings extend out behind the first and second ribs. Third trunk in upper division is the second interspace trunk, which passes out from hilum behind second interspace and sends branches up to second interspace and down behind third interspace. This is largest trunk in upper lobe. (b) Middle Division. The trunk of this division is a branch of the main stem bronchus which goes to the lower lobe. This trunk is not always seen in normal chests. When seen it leaves main stem bronchus a considerable distance below second interspace trunk of upper lobe. A short distance from main stem bronchus it divides into a posterior and anterior branch. (c) Lower or Posterior Division. Many trunks are given off from the main stem bronchus to this division. Most of them run posteriorly or laterally, except a few which pass in front of the diaphragm and never approach the chest wall above the fifth interspace. These trunks are so matted together and so inconstant upon our plates, that it is impossible to describe them individually. But one important trunk is frequently made out, that going to the apex of the lower lobe and it is called apical trunk of the lower lobe. This passes posteriorly from the main stem bronchus apparently on a level or a little above the middle division bronchus. It has one branch which passes directly backward and upward from hilum and is seen in front of the sixth interspace and the seventh rib in back. A more lateral branch passes slightly downward and is seen on either side of the mid-scapular line in front of the seventh rib and the eighth interspace. (7) *Left Thorax* has only two divisions, the middle division being replaced by the long lingual tip trunk which passes to anterior part of chest and is usually made out in diseases of the heart. Trunks to upper division are similar to those on right side except that vertebral trunk passes to apex from a point farther within thorax. It is more likely to be curved and less likely to be parallel to spine. Trunks to lower lobe are similar to those on right side except that the basal trunks near spine are apt to be obscured by the heart. (8) Note any abnormalities or other findings which would influence a normal plate. Let us now examine a normal plate by this outline. A normal chest plate shows the ribs bounding lungs on all sides except below where we have the diaphragm. The picture is divided into right and left half by spinal column and mediastinal tissues. The heart and aorta are quite prominent. The trachea passes down median line and gradually crosses to right side of spinal density. Bifurcation occurs usually in front of the fifth dorsal vertebra, but this is higher in children and lower in old people. Left bronchus after passing under arch of aorta reaches hilum nearly in front of seventh rib and right bronchus in front of sixth interspace. By close study of favorable plates these bronchi can be followed in the right and left hilum. The trachea and bronchi are noted as areas of lesser density bordered by lines of great density.

Hilum.

This is an irregular area of greater density and frequently contains areas of calcification in healthy individuals. The trunks pass from the hilum density into the lung fields. The older the person the larger and more dense the hilum shadow. Thus we have the hilum, heavy trunks and linear markings, all of which are of greater density than is the parenchyma of the lung. When the above points have been described we find that normally the spine should be straight, the ribs regular, the corresponding interspaces of equal width and the bones free from lesions. Roentgenologically we speak of right and left diaphragm. The right should be higher than the left with both domes well rounded and smooth. Each reaches the ribs in the axillary line at a sharp angle.

Tuberculosis.

Normal variations are difficult to describe because the normal varies with age. Besides I have included with the normal many changes which are probably the result of infection but which have no clinical significance at the time of examination. Normal plates taken with the present technic do not show linear markings extending to the periphery but they do radiate more or less definitely from the trunks. Necessarily any study of the chest must deal largely with tuberculosis. If we are able to differentate the normal and the tuberculous from other chest conditions differential diagnosis in a given number of cases is comparatively easy. The characteristic tuberculosis plate marking consists of a fan-shaped density with the base of the triangle toward and near the pleura, the apex toward the hilum and connected to the hilum with a heavy trunk. The pathological lesion within the lung which causes this fan-shaped density is a cone that has its base to the pleura and its apex toward the hilum. The density within this fan-like area varies greatly. The radiating linear markings may either be interwoven and broadened, studded, obscured by a filmy cloud effect, mottled, matted together or entirely blotted out. One of the most striking characteristics of the tuberculous picture is the varying degree of change in the different trunk groups in contrast to the general homogeneous change in diseases which might simulate tuberculosis, also the lack of continuity with which the trunks may be involved. Thus we may have the vertebral and second interspace trunks on the right side involved and only the first interspace trunk on left side. Further it is very striking to note the constancy with which early or slight lesions in the adult are limited to the trunks of the lower lobes.

If the fine linear markings of a given trunk are fuzzy or are faintly obscured by a cloud effect and the fan appears to be wide open, active tuberculosis is suggested. On the other hand if the linear markings in a limited area are sharply defined and dense, show clean cut studdings beyond the trunks and the fan is partially closed a healed lesion is suggested. This condition is emphasized if it is accompanied with heavy, coarse interweavings which reach to or near the periphery. The heavy trunks between such areas and the hilum are usually broad and dense.

Pathology Other Than Tuberculosis.

The operator having familiarized himself with the normal chest markings and having learned to differentiate them from tuberculosis, he is easily able to recognize other abnormal densities. The differential diagnosis may be difficult, but the positive recognition of a lesion is easy. Thus we can say that we have a lung tumor, but the pathology of that tumor is a separate study beyond the scope of this work. The diagnosis of abscess, gangrene and cyst comes under the same category. No diagnosis of early tuberculosis should be made from the X-ray plate without ascertaining whether or not a heart lesion exists. Brown induration which is a pathological condition accompanying mitral stenosis frequently simulates tuberculosis. The density is usually more diffuse and the trunk to the lingual tip is abnormally prominent and zig-zag. Bronchiectasis also is a study in itself and while the diagnosis is difficult to make, it is easy to determine that a lesion exists. The differential diagnosis between pneumonia and infarct is almost impossible to make from the plates alone, but the symptoms and physical signs quickly determine the diagnosis. Simple catarrhal conditions of the bronchi, such as grippe and acute bronchitis, produce no abnormalities on the plate. The plate findings of pleural effusion are similar to those under fluoroscopic examination. (See chapter on fluoroscopy.)

Foreign Bodies.

The finding and localization of foreign bodies in the chest are similar to such procedure for other parts of the body and have been described elsewhere in the manual. Having found a foreign body in the chest, careful search should be made to see if a pneumothorax or a haemo-pneumothorax exists. It is well to remember that blood in the pleural cavity does not coagulate.

Gas Below the Diaphragm.

Below the diaphragm, gas anywhere in the intestinal tract stands out as brilliant bright areas normally confined. It is necessary for the operator to familiarize himself with the normal locations of these gas pockets, because gas quickly diffuses itself through the peritoneal cavity after rupture of the stomach or gut. In such case the gas may be seen between the liver and the diaphragm on the right side, while on the left side it appears only as an abnormal area of gas.

TOPOGRAPHY OF THE HEART AND ITS VALVES AS DETERMINED BY LONG DISTANCE RADIOGRAPHY.

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The radiograph, and outline drawings here reproduced represent the heart and its valvular orifices in their correct relationship to the anterior chest wall.

The information was obtained in the following manner: a frozen thorax was cut, by means of a band saw, accurately in the frontal plane so as to open both auricles from behind, without interfering with the contour of the heart. In the intact anterior portion of the thorax the mitral and tricuspid valves were readily accessible. Wires were bent to accurately fit the groove corresponding to the attachment of the valves to the heart wall. The wires were placed in position from the auricle and, in the case of the tricuspid valve, fixed by means of two sutures. The cusps of both ariculo-ventricular valves were found to be in apposition. The interior of the aorta was reached through the anterior wall of the left auricle. The region of the pulmonary valve was made accessible by removing the remainder of the left lung and cutting the artery longitudinally from the left side. Wires were shaped to fit the aortic and pulmonary orifices and placed so that they were in contact with the deepest part of each of the semilunar valve cusps, which provided excellent guides in placing the wires. After placing the pulmonary ring, the cut edges of the vessel came into position spontaneously. The accuracy of the position of the wires was verified after reproduction.

To minimize optical distortion the tube was placed six feet from the object, which was horizontal, with the anterior surface in contact with the plate holder. The tube was accurately centered on a shot, which may be distinguished in the cut a short distance above the tricuspid ring. The shot is imbedded in the skin of the median line of the thorax at the middle of the longitudinal area occupied by the wires. (Fig. 1.)

The *apex* is in the fifth intercostal space, 7.5 to 8 cm. (3 to 3¼ in.) from the median line. The *base* (above) corresponds to an imaginary line (A) drawn from a point 1 cm. (2/5 in.) below the second left chondrosternal articulation, and 3 cm. (1 1/5 in.) from the median line, to another point (the same distance from the median line) 1 cm. above the right third chondrosternal articulation. The *margo Acutus*, or lower border corresponds to a line (B) drawn from the apex through the xiphi-sternal articulation, to a point on the sixth costal cartilage 2 cm. to the right of the median line. The *right border* of the heart may be indicated approximately by an imaginary line (slightly convex to the right) joining the right ends of (A) and (B). The *left border* corresponds to a line (slightly convex to the left) joining the left end of (A) to the apex. (Fig. 2.)

If a line be drawn from the upper margin of the left third chondro-sternal articulation to the right edge of the sternum in the fifth intercostal space, the upper end of the line will lie over the center of the *pulmonary orifice*, and the lower two-thirds of it (approximately) will overlie the main axis of the *tricuspid orifice*. The *aortic orifice* is immediately to the left of the above line, with its center at the left edge of the sternum, opposite the third space. The *mitral orifice* is very largely behind the third left interspace; its upper end is behind the third cartilage, its lower behind the left margin of the sternum opposite the fourth cartilage and space.

Of the orifices of the heart, the pulmonary is nearest the anterior thoracic wall, the tricuspid is slightly in advance of the aortic, and the mitral is deepest of all. (Fig. 3.)

The pericardium follows the heart closely. The upper end (apex) in this subject, extended up, behind the sternum, to the lower margin of the first costal cartilage on the right and the upper margin of the second on the left.

To adjust the X-ray test for hypertrophy of the heart when the exposure is made at a standard distance such as twenty-eight inches, a lead silhouette was made from a tracing of the teleroentgenogram. The lead silhouette was then used as a subject, being placed at a distance of three inches from the plate and radiographed at twenty-eight inches. A second exposure was then made at a distance of six feet from the plate. The outline of the first exposure was then compared with that of the long distance one. The difference in diameter between the two amounted to one centimeter (⅜ in.). Hence, one deducts 1 cm. from the heart shadow (in the greatest transverse diameter) to obtain the true or long distance silhouette. A celluloid scale, Fig. 4, may be used for convenience in the measurement of the heart image. The zero line is placed over the median line of the heart and the apex and right border measurements made, or the zero line may be placed at the right border and the total width of the heart read. The scale is ruled in centimeters (or proportionally larger for short distance exposures) with pencil on the emulsion side of an 8x10 film, and the film is then fixed without developing.

If we measure, for example, the apex point from the median line in the long distance exposure and find it 8 cm. (3⅛ in.) we find it corresponds to our normal average. Likewise if the right border is 3 cm. (1¼ in.) from the median line it corresponds to our average sized individual.

Now if we measure the apex point from the median line in an exposure made at a distance of *twenty-eight inches* (the usual chest exposure distance) and find it 9 cm. (3½ in.) we would regard the measurement as normal for an average individual. Or if we combine the total distances from the median line to the right and left borders respectively and find it 13 to 14 cm. (5⅛ to 5½ inches) we may regard the heart as within normal average adult limits.

The variation of size of heart to size of individual is well known to anatomists and pathologists and of course a similar variation is to be expected in a series of X-ray examinations of living subjects, and must be taken into account in recording the findings in each individual case.

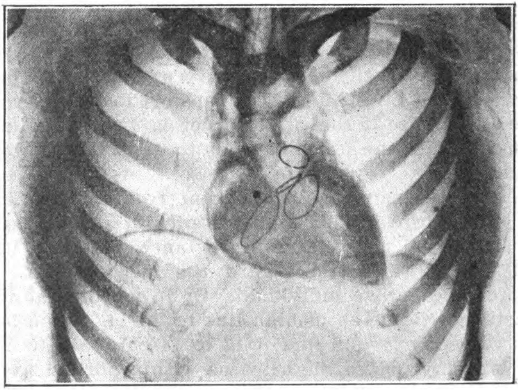

FIG. 1. Radiograph made at distance of 72 inches. Correct size of heart in relationship to the interior chest wall.

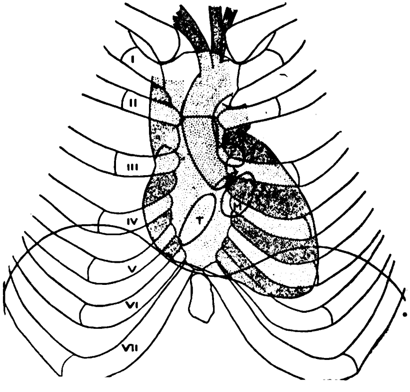

FIG. 2. Outline drawing traced from the long distance radiograph supplemented by stereoscopic examination. The position of each valve, except the aortic is indicated by its initial letter. The aortic orifice is indicated by the beginning of the aorta.

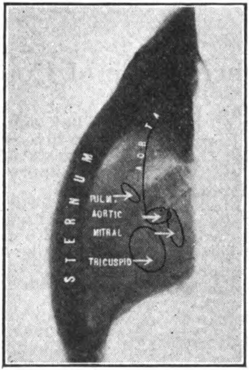

FIG. 3. Lateral projection showing relative depth of valves of heart.

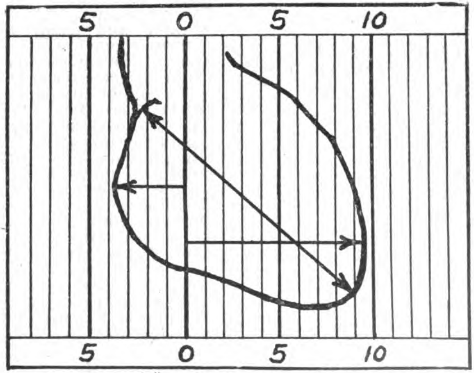

FIG. 4. Use of transparent scale for measurement of size of heart image. The heart measures 9.5 cm. from the median to the apex, and 3.75 cm. to the right border.

Reference Table of Contents

Fluoroscopy

Geo. E. Pfahler, M. D.

Localization of Foreign Bodies

David R. Bowen, M. D.