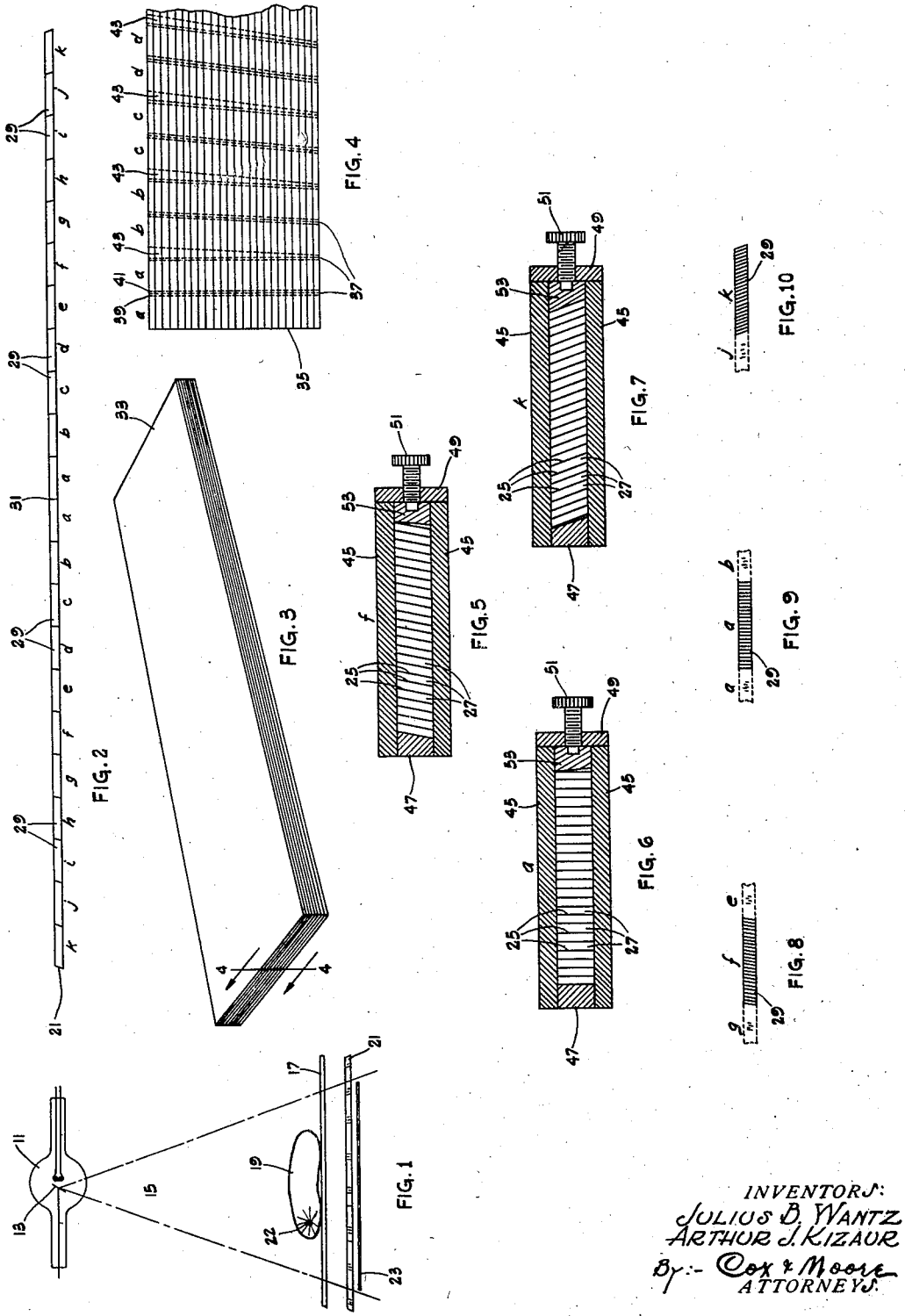
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METHOD OF MAKING A RADIOGRAPHIC DIAPHRAGM

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METHOD OF MAKING A RADIOGRAPHIC DIAPHRAGM

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Our invention relates in general to the radiographic art and has more particular reference to photography by means of X-light.

An important object of the invention is to provide for making line-free radiographs through a diaphragm or screen of the kind known commonly as a "Bucky" diaphragm, especially where the radiographic exposure is of short duration.

The use and function of the "Bucky" diaphragm in the radiographic art are well known; and it is thought unnecessary to describe the construction and operation of the same beyond stating that structurally the diaphragm comprises strips of lead or other substance opaque to X-light and strips of wood or other substance transparent to X-light, the strips being arranged alternately and angulated to form a composite plate or diaphragm adapted to permit only the direct X-light radiation from the X-ray tube or other point source to pass the diaphragm while absorbing and thus excluding from the film any indirect, secondary, reflected or incidental X-light radiation, originating from other than the point source.

"Bucky" diaphragms of the character heretofore proposed embody certain inherent defects, which prevent the making of radiographs having exposure duration of less than one second because the negative produced under such conditions with diaphragms of the character heretofore provided includes an image comprising parallel lines or zones upon the negative and representing the image of the lead strips forming the diaphragm. This phenomenon is known as "grid lines" and reduces the scope and usefulness of the "Bucky" diaphragm in radiographic work. In fact, this has prevented the production of satisfactory relatively high speed radiographs to the extent that accurate diagnosis of certain pathological conditions, by means of radiographs, has heretofore been considered impossible with any degree of certainty.

It is an important object of our invention to provide a diaphragm capable of producing substantially line-free radiographs at exposure intervals of substantially less than one second, say for example an exposure interval of the order of one-tenth second or less, and, to this end, to produce a grid or diaphragm having a predetermined fineness, that is to say, the number of lead strips per inch of grid and a predetermined grid ratio, that is to say, the depth of the lead strip as compared with the thickness of the intermediate wood strips whereby, when the grid moves at a given rate of speed through a predetermined distance, to permit the production of substantially line-free radiographs during exposure intervals, of relatively short duration, the invention being especially valuable in that it teaches how to make line-free radiographs in response to exposures of less than one second in duration.

Another important object of the invention is to improve the angulation of the individual grid strips in a "Bucky" type diaphragm.

Another important object is to correlate the fineness and the grid ratio of the diaphragm with respect to the length of excursion of the same in operation and with respect to the duration of the exposure interval.

Still another important object is to control the angulation of the individual grid strips in a novel yet relatively inexpensive and commercially feasible manner.

Another important object is to produce an unusually fine grid at reasonable cost, without sacrificing accuracy of strip spacement or angulation.

Another important object resides in fabricating the grid by assembling strip sections each having a substantially uniform strip angulation in order to facilitate the fabrication of a grid or diaphragm of unusual fineness.

Another important object is to produce grid strip sections by first fabricating a board comprising alternate laminations of wood and lead and then sawing the sections from the laminated board along planes of severance intersecting the laminae at varying angles to produce grid sections having strip angulation suitable for use in various portions of the grid whereby thus to provide a desired strip angulation varying in the various portions of the grid.

Another important object is to produce grid strip sections in the manner mentioned and then to press each section in a suitable die in order to relatively angulate the several grid strips in each section before assembling the same with other sections to form the complete diaphragm.

Among the other objects of the invention is to provide a new and improved radiographic technique involving the use of a "Bucky" diaphragm by correlating and taking cognizance of the relationship between time of exposure, time of grid travel, wave form of energizing current, distance between the source of light and the sensitive film, position of the tube with respect to the grid, the fineness of the grid, the ratio of the grid, the length of grid travel, the X-light absorption of the grid and the angulation of the grid strips in order to provide a diaphragm capable of being used in such a way that line-free radiographs can be made with exposures of less

than one second duration, the grid also having the capacity, of course, of producing acceptable radiographs where an exposure of longer than one second is involved.

Numerous other objects, advantages, and inherent functions of the invention will be apparent from the following description, which, taken in connection with the accompanying drawing, discloses preferred embodiments of the invention.

Referring to the drawing:

Figure 1 is a diagrammatic view of radiographic equipment including a diaphragm embodying our present invention;

Figure 2 is an enlarged sectional view of the diaphragm shown in Figure 1;

Figure 3 is a perspective view of a laminated board from which grid sections used in making the diaphragm of our present invention may be cut;

Figure 4 is a sectional view taken substantially along the line 4—4 in Figure 3;

Figures 5, 6, and 7 are sectional views taken through pressing dies used in forming certain of the strip sections forming the grid shown in Figure 2; and

Figures 8, 9, and 10 are views of the strip sections as delivered from the dies shown in Figures 5, 6, and 7 respectively.

To illustrate our invention, we have shown on the drawing, in Figure 1, radiographic equipment comprising a suitable source of X-light preferably an X-ray tube 11, in which the anode 13 forms a substantially point source of X-light 15, a table 17 for supporting an object 19 to be radiographed, a diaphragm 21, and a light sensitive negative 23 positioned behind the diaphragm.

In the making of radiographic negatives, the presence of objects, such as particles or bodies 22, within the field of useful X-light 15 and capable of being excited to form secondary sources of X-light emanation, will, if no diaphragm is used, result in a fogging or diffused image in the negative, which is caused by the action of the secondary X-rays from the source 22. Fogging of the negative, as a result of excitation of secondary sources of X-light, may be eliminated by utilizing the screen 21, which is adapted to screen from the negative substantially all X-light rays except those proceeding in a direction radially of the point source 13.

To this end, the screen or diaphragm 21 comprises a plurality of alternately arranged laminations or strips 25 and 27, the strips 25 being of material, such as lead, which is relatively opaque to X-light, and being separated by strips 27, preferably of wood, which is relatively transparent to X-light. The strips 25 and 27 are assembled alternately to form a preferably, though not necessarily, flat plate comprising the grid or diaphragm 21. The strips 25 and 27 also, if the plate is flat, are necessarily angulated so that each lies in a plane passing substantially through the point source 13 provided by the anode of the lamp 11.

It will be seen also that, if the diaphragm 21 and the negative 23 are held stationarily, the negative will receive a striped image corresponding to the density differential of X-light passing the strips 25 and 27 and, since this lined or striated image is undesirable in the negative for diagnostic purposes, we provide for relatively moving the diaphragm with respect to the negative. The negative is preferably held stationary since shifting of the same with respect to the body 19 will, of course, prevent the making of a satisfactory radiograph. By moving the diaphragm 21, however, at a predetermined rate of speed with respect to the exposure interval and through a predetermined length of travel, the striated image of the diaphragm may be substantially eliminated in the resulting negative. To this end, the diaphragm is preferably moved in a direction intersecting the laminae or strips 25 and 27 preferably, but not necessarily, at right angles; and this movement is preferably controlled so that the diaphragm moves at uniform speed between the negative 23 and the object 19 being radiographed.

The general laminated construction of the so-called "Bucky" diaphragm was proposed by Gustav Bucky in Letters Patent of the United States No. 1,164,987, issued December 21, 1915; and the method of eliminating the striated image by moving the diaphragm relatively with respect to the sensitive film during the exposure interval was proposed, in 1920, by Dr. Holles E. Potter. This is the underlying principle behind the successful application of the "Bucky" diaphragm since that time. The laminated diaphragm structure, disclosed by Bucky, when used in accordance with the technique developed by Dr. Potter, has been found satisfactory where the exposure interval is in excess of five seconds. However, when it is desired to make radiographic negatives in exposure intervals shorter than five seconds, the resulting negative exhibits various kinds of undesirable grid lining. Improvements and refinements in the original Bucky diaphragm structure and in radiographic technique, if used under favorable conditions, now permit the production of satisfactory radiographic negatives during an exposure interval as low as one second, although absolutely satisfactory and certain results are not possible, under all conditions, for exposure intervals of less than five seconds.

After extensive study and experiment, including the production of several thousand radiographs under rigidly controlled conditions, we have discovered how to improve not only the diaphragm itself but also the manner of manipulating the same in making radiographs, so that satisfactory radiographs may be produced during an exposure interval of approximately 1/20 of a second.

As a result of our studies, we have noted that the following factors not connected with the grid structure have a considerable bearing upon the condition of the resulting negative:

The time of exposure;

The time of grid travel;

The wave form of current energizing the tube 11;

The focal distance between light source 13 and the film 23;

The position of the tube with respect to the center of the grid 21.

In addition to the foregoing factors, we have discovered that the quality of the resulting negative depends to a considerable extent upon the following characteristics of the diaphragm structure itself:

Fineness, i. e., the number of strips 25 and 27 per linear inch in the grid;

Grid ratio, i. e., the ratio of the depth of the lead strip 25 as compared with the thickness of the wood strip 27;

The length of grid travel or excursion;

Absorption factor of the grid, i. e., the ratio of the amount of light striking the grid as compared

with that striking the film 23, through the grid;

Accuracy of angulation of the individual grid strips.

As a result of our investigation, we have found that the foregoing factors may be varied to produce different grid structures having individual advantages as to length of exposure and quality of the resulting negative; and each grid structure so developed has its own particular operating characteristics for best results. With this in mind, we have made two forms of grid to perform all radiographic work to be done during exposure intervals shorter than one second.

We have found that grids, having a ratio of not more than six, that is to say grids in which the depth of the opaque lead strips are not more than six times the thickness of the transparent wood separating strips, and having a fineness of forty-five strips per inch, if accurately made, are capable of producing line-free radiographs at exposure speeds of approximately one-twentieth of a second. If this extreme exposure speed is not required, satisfactory radiographs may be produced at exposure speeds of approximately one-fifth of a second, using a grid having a ratio of not more than six and having approximately thirty-three strips per inch. The forty-five strip per inch grid is, of course, capable of performing all of the work accomplished by the coarser thirty-three strip per inch grid, but it is considerably more expensive to build due to the fact that it is more difficult to construct with appropriate accuracy.

We have found, however, that by increasing the fineness of the grid to permit high speed, line-free radiographs to be made, the line-forming effect of the other factors mentioned heretofore is substantially reduced. For example, in order to obtain satisfactory results, using grids made in accordance with previous disclosures, it is necessary to maintain the exposure time approximately equal to the time of grid excursions. This, however, is no longer necessary since the 33 and 45 strip grids, having the grid ratio aforesaid and made in accordance with our present invention, permit an excursion interval considerably longer than the exposure interval without producing undesirable effects in the resulting negative. This possibility is of importance since the length of diaphragm excursion is usually fixed and with ordinary diaphragms it is therefore necessary to accurately adjust the speed of diaphragm travel in order to maintain the necessary equality between excursion and exposure time. Where diaphragms embodying our present invention are used, it is no longer necessary to accurately adjust the rate of travel of the diaphragm. Likewise, many forms of tube excitation previously considered unfavorable can be successfully employed with fine grids.

Furthermore, with prior grid constructions, it is necessary to accurately position the tube not only from the standpoint of focal film distance but also with respect to the center of the grid or diaphragm and consequently the grid travel or excursion must be kept within definite limits of the order of less than two inches. Our new fine grids are not particularly critical with respect to focal distance and a grid, made in accordance with our present invention and nominally having thirty-inch focal film distance, has been used successfully within a focal film distance range of from eighteen to forty-eight inches, and with as much as six inches off-center displacement with respect to the center of the diaphragm.

Our exhaustive tests show that accuracy of angulation is a most important factor in the performance of our new fine grids. A grid having carelessly or improperly angulated strips will not give the same desirable results but will produce a somewhat clouded appearance in the resulting radiograph due to the variation in grid opacity caused by irregularities in angulation. In fact, the performance of the best grids that could be built in accordance with previous teachings led us, initially, to believe that merely increasing the fineness of the grid would not produce much better results than could be obtained with coarser grids. However, by increasing the fineness of the grids and by applying our mode of accurately determining and controlling the angulation of each individual strip, we can produce diaphragms of unexpectedly superior operating characteristics.

To this end, we prefer to construct the grid or diaphragm 21 by preparing a plurality of grid sections 29, each section comprising a definite number of lead and wood strips arranged alternately and the sections being laid up in the diaphragm in abutting edge to edge relationship. The sections also have each its individual strip angulation, which progressively increases in the strips from the center line 31 of the grid toward the opposed edges thereof; and it will be noted that the strip sections, extending on one side of the center line 31 of the diaphragm, are similar to, though of opposite angulation with respect to the corresponding strips extending on the other side of the central line 31. The sections extending on one side of the grid are identified individually on the drawing as sections *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, *j*, and *k*, while the similar strips on the other side are identified by corresponding letters.

We prefer to fabricate the individual sections 29 by cutting the same from a laminated board 33, which is shown in Figure 3 of the drawing. This board preferably comprises alternate layers of wood and lead, each layer being of uniform thickness within precise limits throughout the extent of the board. The board has a width approximately equal to the dimension of the final diaphragm in the longitudinal direction of the strips thereof, and contains at least as many layers of wood and lead as it is desired to have in each of the sections 29. The board preferably has one more layer of wood than of lead so that the opposite faces of the board comprise a wooden layer. Obviously, other materials than lead and wood may be employed although we prefer to use these materials because of their availability and the facility with which the same may be handled and worked. The layers are secured together by means of a suitable adhesive and the board is finished flat as in any suitable pressing mechanism. The board 33 also may be made up in any desired length for stock purposes.

The strip sections 29 are formed by cutting the board along planes intersecting the layers of the board, as shown in Figure 4, at the angles required to produce the desired strip angulation in the several sections. This is preferably accomplished by first planing the end of the board 33 as at 35 to the desired angle, cutting off the end of the board as along the severance plane 37 parallel to the planed end 35 and finally finishing the cut edge of the section thus produced by finishing it smooth along the plane 39. The remaining cut end of the board thus exposed may then be finished, as by planing, along the plane 41 and the process repeated in order to produce the necessary strips. Since the strip angulation pro-

gressively increases in the several sections 29 from the center of the diaphragm toward each end, it is necessary, of course, to increase the angle at which the sections are cut from the board and this is illustrated in Figure 4, 43 representing wedge-like sections of waste material between successive pairs of strip sections cut from the board. After each section is thus produced, the wood strip may be removed from one end so that each section has a wood layer at one end and a lead layer at the other.

It will be seen that each section, as it is produced from the board, has a uniform angulation of all strips throughout the section. This angulation will be mathematically correct for only one strip and we prefer to cut the sections in such a way that the center strips only of each section will have the correct angulation.

The value and efficiency of the diaphragm, however, depends in no small degree upon correct angulation of each individual strip in the finished diaphragm so, before assembling the strips, we place the same in a suitable pressing die which serves to slightly change the angulation of all of the strips in the section except the correctly angulated center strips. By pressing the strip sections, each in its appropriate die, as indicated in Figures 5, 6, and 7 showing the pressing of the sections "*a*", "*f*", and "*k*", the end strips of each section are brought into angulation, the end strip of each section being thus pressed to a plane parallel with respect to the end strip of the adjacent section of the diaphragm. By thus pressing each section, every individual strip assumes its proper angulated position so that when, after pressing, all of the sections are assembled, each strip will be properly angulated in the diaphragm.

The sections also are preferably cut from the board 33 in pairs to minimize wastage, since the strip sections duplicate each other on opposed sides of the center line 31 of the diaphragm. It is, therefore, necessary to provide only half as many pressing dies as there are strip sections in the finished diaphragm.

Each die comprises a box, the opposite side walls of which comprise flat plates 45 of like size and configuration. Each die, however, has its own individual bottom wall 47, the inner surface of which is disposed at the angle with respect to the inner surfaces of the side walls to which it is desired to press one of the end strips of the section to be pressed in the die. The tops of all of the dies comprise cover elements 49 carrying clamping screws 51, the inner ends of which bear upon pressing blocks 53 having surfaces facing toward the bottom walls of the dies and each angulated in a plane with respect to the side walls in accordance with the angulation desired in the end strip of the section to be pressed in the die. It will be seen that the required amount of displacement of the end strips of each section in order to properly angulate the same is minute. The pressing operation, however, is of great importance if the resulting diaphragm is to be sufficiently accurate to eliminate the defects and disabilities heretofore mentioned.

After pressing for a sufficient interval to obtain a permanently set condition, the individual sections may be removed from the dies and assembled to form the diaphragm 21 in the manner shown in Figure 2 of the drawing. In assembling the several strip sections, a suitable jig may be employed in order to obtain proper alignment of the sections and the sections are secured together by the application of a suitable adhesive between the end strips of adjacent sections and the entire assembly is or may be pressed and held in the jig until the parts adhere.

The diaphragm thus assembled may be mounted in a suitable edge frame or border comprising a suitable preferably metallic rim to provide added strength in the finished diaphragm. Finally, the opposed faces of the diaphragm may be painted with a suitable protective varnish or lacquer, or binding material such as cloth or paper.

The foregoing procedure results in the production of a laminated diaphragm, in which the laminations are angulated with extreme accuracy. At the same time, the diaphragm is of unusual fineness. The fineness of the diaphragm promotes the accuracy with which the individual strips are angulated in accordance with the process of our present invention, since it is obvious that the accuracy of angulation, by pressing the sections, could be accomplished to a much lesser degree if the individual strips were wider. At the same time, the fineness of the resulting diaphragm coupled with the extreme accuracy of strip angulation in accordance with our present invention produces a diaphragm or grid by means of which radiographs can be made at unusually high exposure speeds.

We have thus succeeded substantially in widening and enlarging the scope and utility of X-ray photography by producing means by which radiographs may be made during exposure intervals as low as 1/20 of a second.

It is thought that the invention and numerous of its attendant advantages will be understood from the foregoing description and it is obvious that numerous changes may be made in the form, construction, and arrangement of the several parts of the illustrated apparatus without departing from the spirit or scope of our invention or sacrificing any of its attendant advantages, the preferred modes and forms herein described being merely for the purpose of illustrating the invention.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is as follows:

1. The method of making a diaphragm having accurately angulated strips for radiographic purposes, which consists in fabricating a board or stock sheet comprising parallel laminations, cutting from said board progressive strip sections in which the angulation of the strip sections progressively varies, the strips of each section having a common angulation, pressing each strip section separately to progressively vary the angulation of the strips throughout each section and then assembling the sections.

2. The method of making a laminated diaphragm having accurately angulated lamination strips for radiographic purposes, which consists in fabricating a board or stock sheet comprising a plurality of laminations of X-ray pervious material alternated with laminations of X-ray impervious material, at least one of said materials being deformable, cutting from said board progressive strip sections in which the angulation of the strip sections progressively varies, the strips of each section having a common angulation throughout the section, pressing each strip section separately to deform the laminations of deformable material and thereby to progressively vary the angulation of the strips throughout each section, and then assembling the sections.

3. The method of making a diaphragm having accurately angulated strips for radiographic pur-

poses, which consists in preforming a plurality of strip sections, each comprising a plurality of laminations of X-ray pervious material alternated with laminations of X-ray impervious material, at least one of said materials being deformable, and each strip section having a common lamination angulation throughout the section, and several of the sections having a different lamination angulation, pressing each section separately to progressively vary the angulation of the laminations thereof throughout each section, and then assembling the sections.

4. The method of making a diaphragm having accurately angulated strips for radiographic purposes, which consists in preforming a plurality of strip sections, each strip section having a common strip angulation throughout the section, and several of the sections having unlike strip angulation, pressing each section separately to progressively vary the angulation of the strips thereof throughout the section, and then assembling the sections.

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