Oct. 25, 1966 O. C. HOLLSTEIN 3,281,598

OVERHEAD SUPPORT FOR A VERTICALLY AND ROTATABLY MOVABLE X-RAY TUBE SUPPORT ARM AND COOPERATING TILTABLE X-RAY TABLE

Original Filed Oct. 21, 1963 7 Sheets-Sheet 1

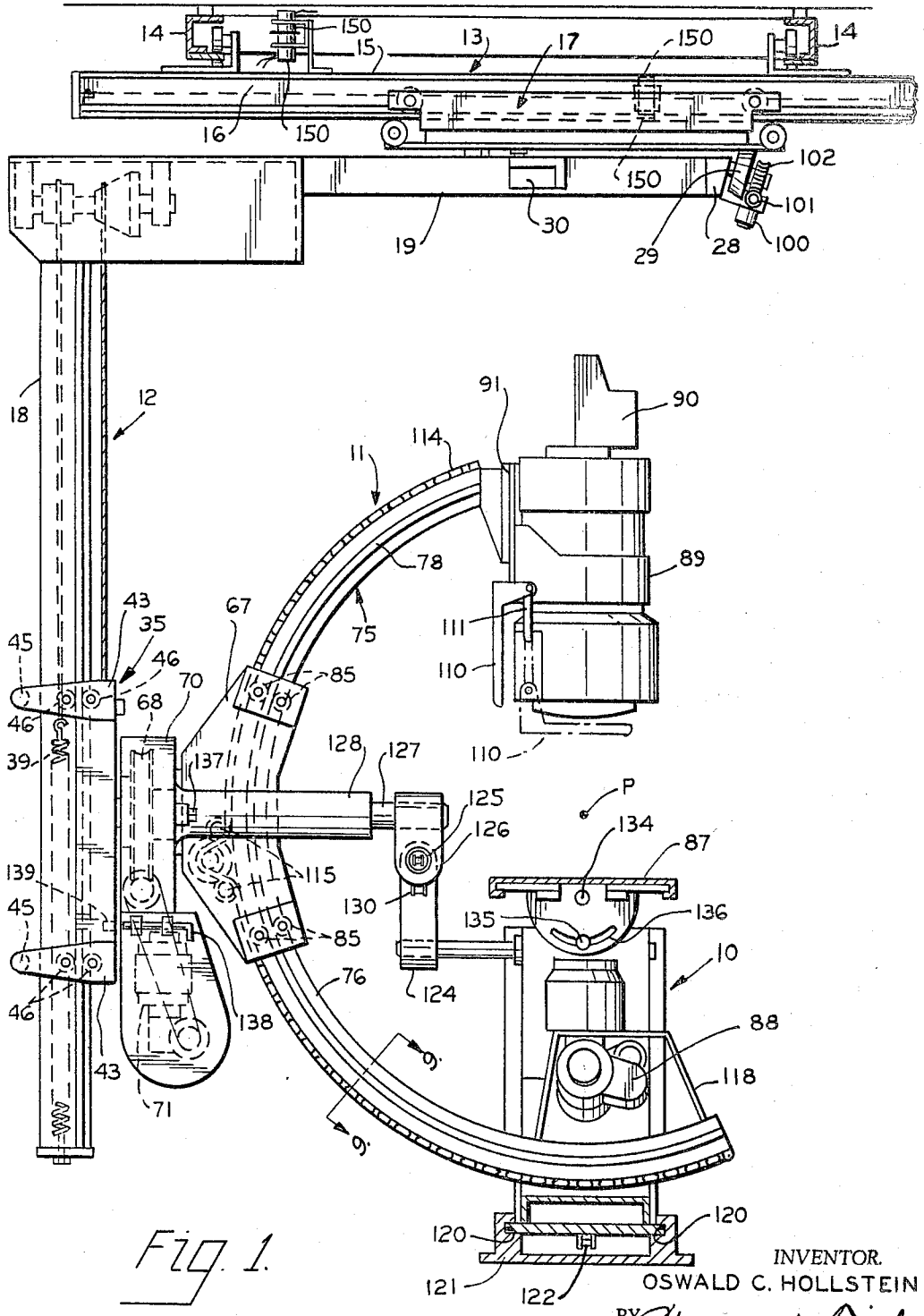


Fig. 1.

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Fig. 2.

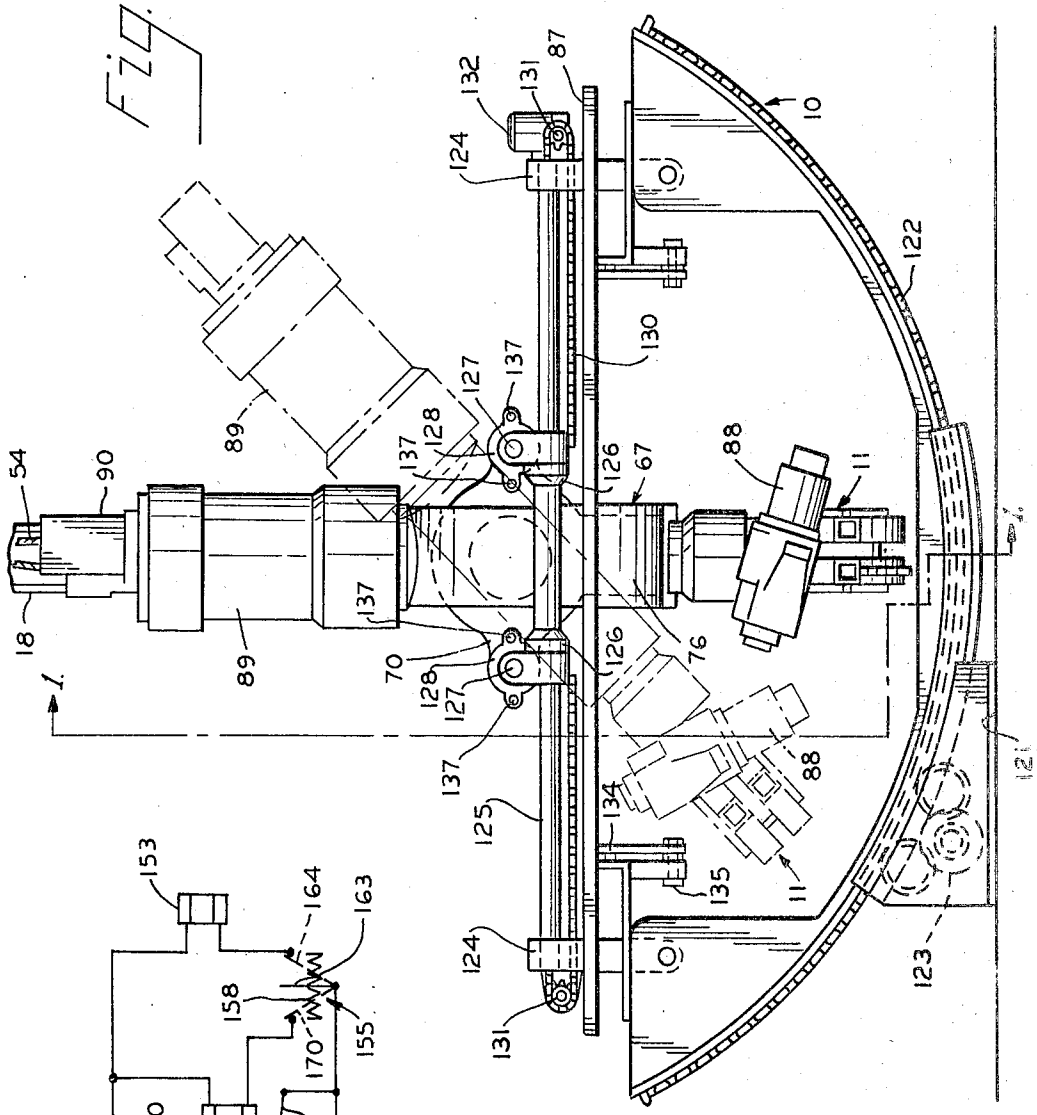
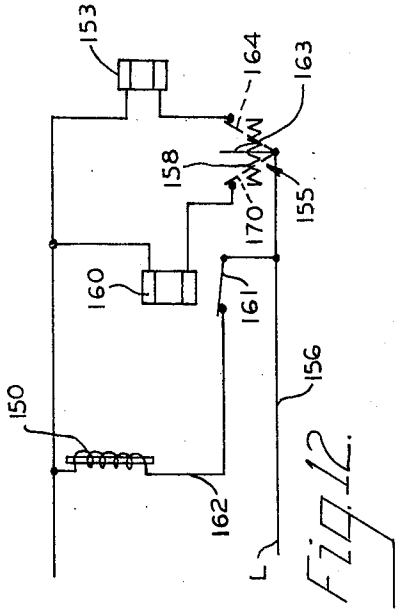


Fig. 12.



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Original Filed Oct. 21, 1963 7 Sheets-Sheet 3

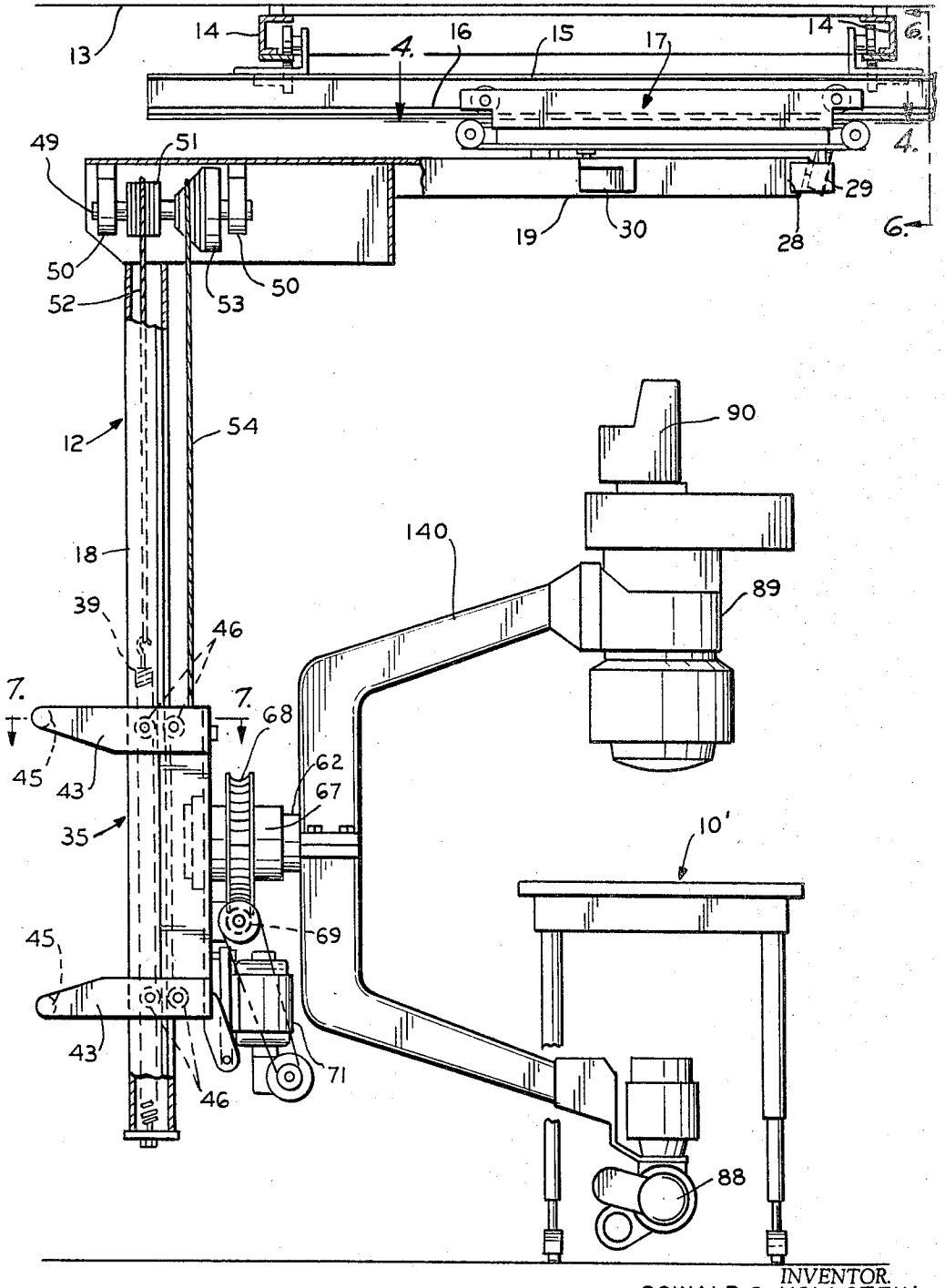


Fig. 3.

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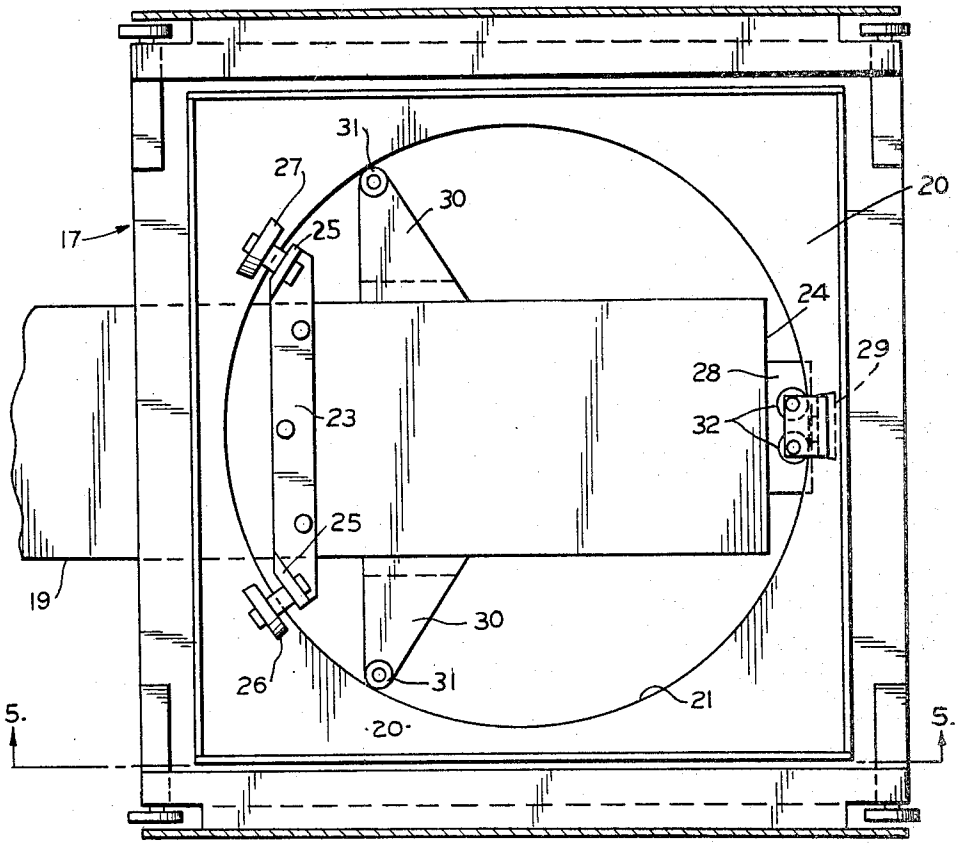


Fig. 4.

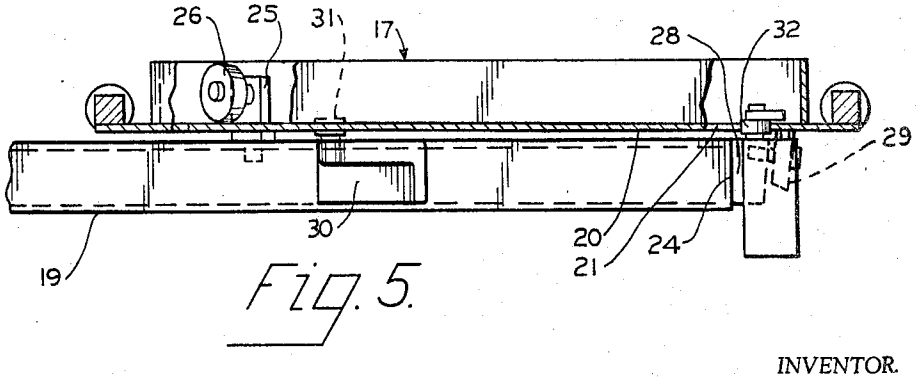


Fig. 5.

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OVERHEAD SUPPORT FOR A VERTICALLY AND ROTATABLY MOVABLE X-RAY TUBE SUPPORT ARM AND COOPERATING TILTABLE X-RAY TABLE

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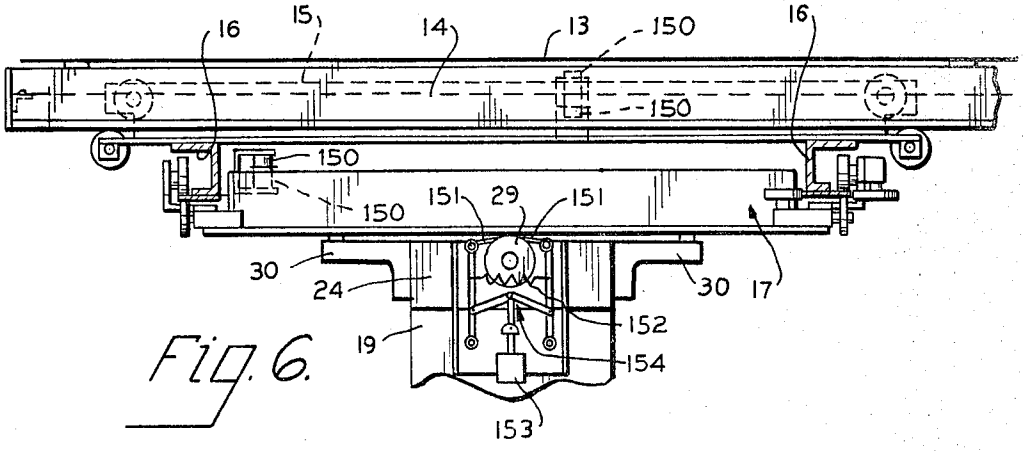


Fig. 6.

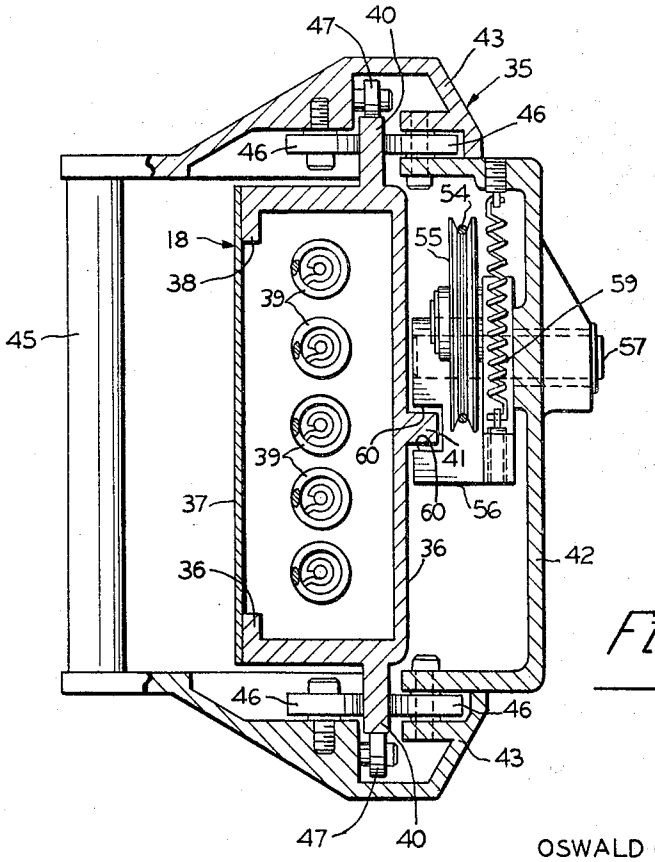


Fig. 7.

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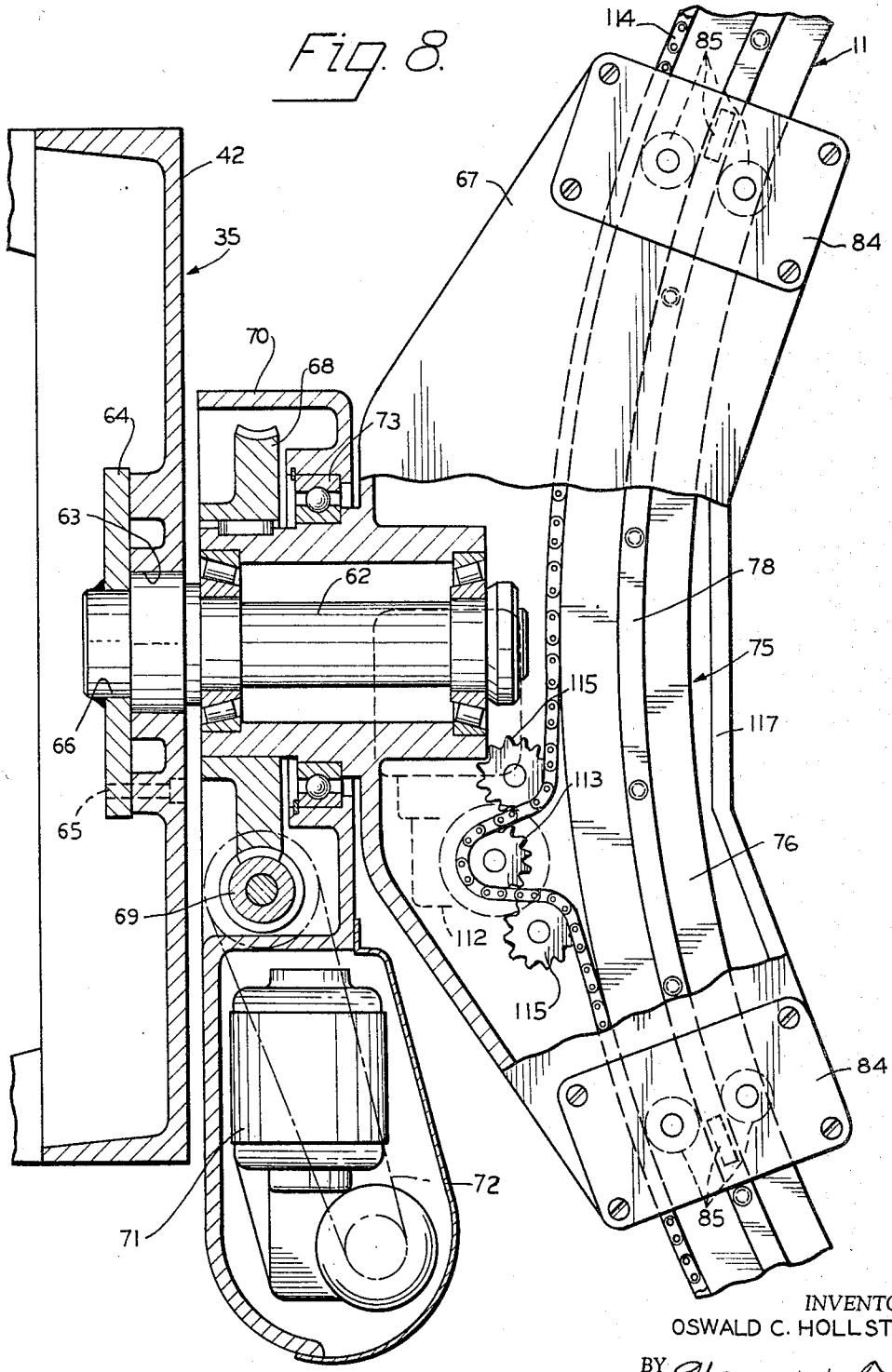
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Fig. 8.



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Original Filed Oct. 21, 1963 7 Sheets-Sheet 7

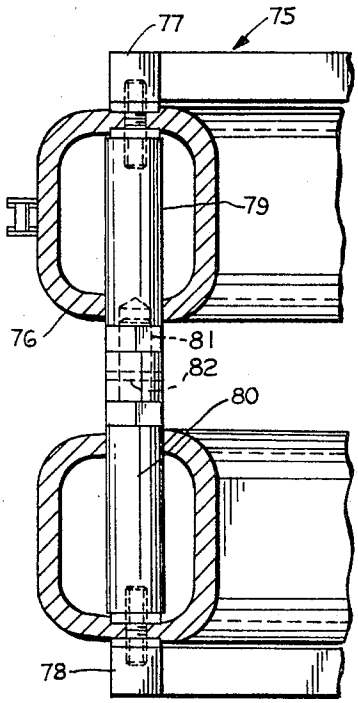


Fig. 9.

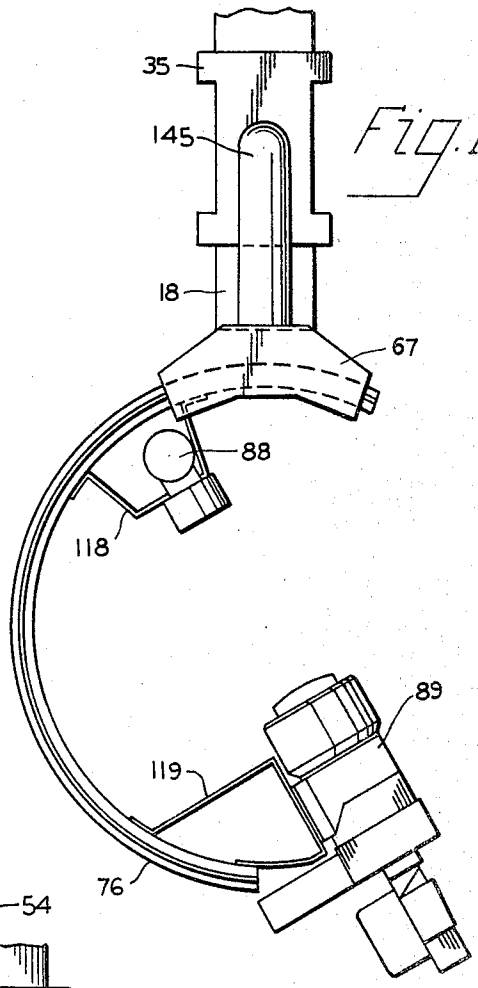


Fig. 10.

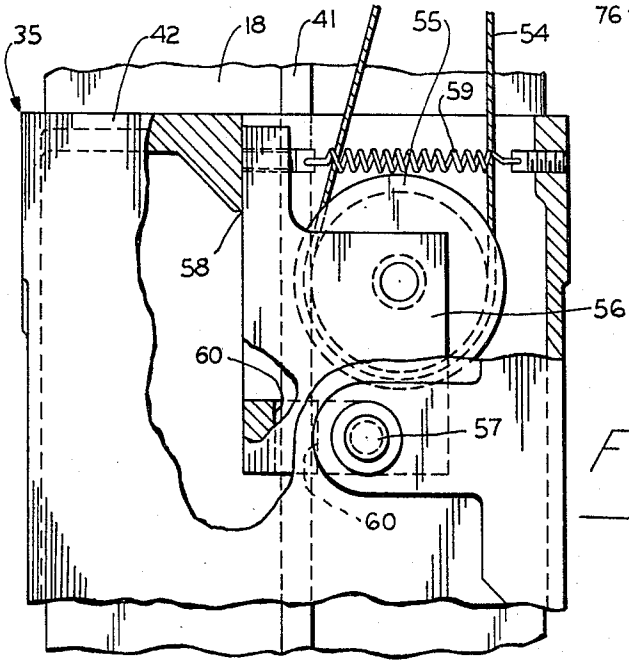


Fig. 11.

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United States Patent Office

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Patented Oct. 25, 1966

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OVERHEAD SUPPORT FOR A VERTICALLY AND ROTATABLY MOVABLE X-RAY TUBE SUPPORT ARM AND COOPERATING TILTABLE X-RAY TABLE

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Continuation of application Ser. No. 317,443, Oct. 21, 1963. This application Nov. 19, 1965, Ser. No. 511,579

29 Claims. (Cl. 250—57)

This is a continuation of United States patent application Serial No. 317,443, entitled "C-Frame" and filed October 21, 1963, now abandoned in favor of this application. This invention pertains to X-ray apparatus and more particularly to a novel and improved support for a penetrating ray energy emitting mechanism.

As the fluoroscopic and radiological arts progress, the numbers and types of studies undertaken by both scientists and physicians are constantly increasing. This results in increasing demand for versatility in mechanisms for directing penetrating ray energy against a patient or object under study. Previously available mechanisms, and prior proposals for mechanisms for supporting X-ray tubes or other sources of penetrating radiation have placed limitations on the types of studies which scientists and radiologists have been able to perform in their respective fields of endeavor.

In the past scientists and radiologists have had to tailor their studies within limitations imposed by standard available equipment. Some have resorted to the expensive and never fully satisfactory alternative of custom building special units to meet specialized needs.

The present invention obviates many of these prior limitations by providing greater versatility than was previously available in terms of an ability to direct penetrating rays of energy toward a given point from practically any direction. Powered movements are provided to permit many types of studies with the energy source to be moved uniformly through any one of a substantially infinite number of predetermined paths. Further versatility is obtained by providing a basic unit which easily and economically can be tailored to a given radiologist's or scientist's needs.

With the present mechanism an overhead support system is provided. This system includes a carriage which is movable in a horizontal plane. This carriage is known in the art as a horizontal travel carriage or more commonly, simply as a horizontal carriage. The horizontal carriage is movable in a horizontal plane to any point within a predetermined area. A vertically positioned mast is carried by the horizontal carriage for rotation about a vertical axis. The mast is horizontally offset with respect to the vertical axis of rotation permitting vertical movement of a supported mechanism substantially to the ceiling.

A bifurcated arm in the form of either a C or a U arm is mounted in an arm cradle which in turn is rotatably mounted on a vertically movable vertical travel carriage. The vertical carriage is mounted on the mast for vertical reciprocation. The cradle rotation is about an axis known as the horizontal axis which axis intersects the vertical axis of rotation. The source of penetrating ray energy is mounted on one end of the arm and positioned to emit a beam of rays through this point of intersection. A coacting mechanism is mounted on the other end of the arm in the path of the emitted beam. In the preferred and disclosed arrangement, this source of energy is an X-ray tube emitting a beam of rays toward an image intensifying tube mounted on the other end of the arm. A

pivotally mounted cassette tray is mounted on the tube for selective positioning in the path of the X-rays to permit a radiographic exposure if desired.

One feature of the invention, and one of the principal contributing factors to the great versatility obtained with the various applications of the principles of this invention, is that the beam of X-rays is positioned to pass through this point of intersection of the horizontal and vertical axes of rotation. With the patient or object being studied, positioned so that this point lies within him or it, the arm can be rotated about either of these axes while maintaining the beam focused on the object or patient under study and emitting energy towards the coacting device carried at the other end of the arm.

One of the outstanding features of the invention resides in the mast assembly which is in the shape of an inverted L. The horizontal leg of the L is pivotal about a vertical axis while the vertical leg is the mast. The mast, as noted above, is horizontally offset from the axis of rotation. This not only provides greater space for vertical movement than prior mechanisms but also permits the amount of vertical movement to be tailored for a given application by simply providing a mast of appropriate length.

When a C-arm is utilized the C-arm is mounted on the cradle for rotation about a third axis which intersects this same point providing still further versatility. This third axis is known as the orbital axis. This orbital axis is at right angle to the horizontal axis.

In one application of this invention, the vertical carriage is coupled to a longitudinal track on an X-ray table. Since the arm, the cradle, and the vertical carriage are ceiling supported, the load imposed on the support mechanism is always vertical. This produces another of the outstanding advantages of the invention in that it is possible to couple an X-ray tube and an X-ray stimulated device to an X-ray table and utilize spring counterbalances with constant tension. Previously, the only successful counterbalancing of fluoroscopic columns and similar structures coupled to tables has been with counterweights where the inertia encountered is approximately twice that of spring counterbalances. Moreover, counterbalancing both parallel and perpendicular to a table has been required to accommodate tilting of the table. Here, because the arm is supported independent of the table, a single counterbalance replaces the two of prior structures.

The movements of (1) rotation of the C-arm cradle relative to the mast, (2) the vertical travel of the carriage relative to the mast; and (3) the horizontal travel of the horizontal carriage, all coact to permit the unit to be coupled to a table of the pivotal type. Because of these listed movements, the table is free to tilt while the tube and image producing mechanism remains stationary relative to the table top. The support mechanisms also permits the tube to be moved both longitudinally and transversely relative to the table top at all times and in all table positions. A drive means is provided to cause the device to shift longitudinally selectively relative to the table top.

As suggested above, the C-arm is rotatable about an orbital axis. When the unit is coupled to the table, the orbital axis longitudinally parallels the table top. Thus, the C-arm and X-ray tube may be rotated about an orbital axis to provide an ability to conduct X-ray studies at a variety of angles with respect to the transverse axis of the table top.

Further versatility and another feature of the invention are provided by positioning a power means between the C-arm cradle and the vertical carriage so that the C-arm may be rotated relatively to the table top about the horizontal axis which is transverse to the table top. Thus, when the C-arm is coupled to a table, the X-ray tube may

be moved at any point within a segment of a sphere and the image producing devices is maintained in an aligned position and a chosen distance from the X-ray tube.

The center of gravity of the C-arm is displaced radially from the orbital and horizontal axes. It would require a sizable counterweight to correct this off-balance condition due to the weight of the C-arm assembly. Both motions, therefore, are motor driven with remote controls always in easy reach of the operator. All linear motions are easily manipulated manually. The rotation of the mast about its off-set vertical axis also is relatively effortless, so that in its preferred design all linear motions and the rotation of the mast about its vertical axis are manually operated.

There are many applications for the arm support mechanism alone when it is either uncoupled from the table top or used in installations without a connected table. In these applications, power drives for the lineal motions and rotation about the vertical axis are provided if remote controlled operation is desired.

As an example of the use of the mechanism of this invention without a coupled table, it is possible to position the arm in a horizontal plane and then rotate the device about the vertical axis. The tube may be rotated 360° about a patient or other object to direct penetrating rays from all directions. Since the device is vertically movable, studies with rays emitted from any point within a cylindrical configuration can be obtained in this situation while maintaining the arm in a horizontal plane. Similarly, the arm can be rotated about the horizontal axis so as to emit rays from any point in a cylinder having a horizontal axis.

Another feature of the invention resides in a novel and improved C-arm cradle and C-arm construction which increases the amount of obtainable movement of the C-arm along an arcuate path around the orbital axis. Unlike prior proposals, the tube brackets do not limit the amount of obtainable rotational movement of the C-arm relative to its cradle.

This aspect of the invention is accomplished by providing a C-arm cradle which defines an arcuate slot open along its concave face and at its ends. The C-arm is mounted in the slot while the X-ray tube and, if desired, the coacting mechanism are mounted on narrow brackets which can project into the slot.

A more specialized feature of the invention resides in a novel and improved C-arm and C-arm cradle constructions which provide simple, light weight but dependable arm and cradle mechanisms.

Still another more specialized feature of the invention resides in a novel and improved fail safe mechanism which will prevent a damage to the C-arm and patient injury if a support cable on a balance spring breaks.

Another feature of the invention resides in a locking system. The linear motions are locked by electro-magnets such as those described in U.S. Patent No. 2,673,627, issued March 30, 1954, to R. J. Stava. Rotation of the mast about the vertical axis is selectively locked by a mechanical brake. This brake is held closed in the locked position by tension springs and is released by a solenoid. The magnetic locks must be energized in order to lock the linear motions while the solenoid must be de-energized in order to lock the rotation of the mast about its vertical axis. This design made it possible to eliminate a multiplicity of switches to operate the different locks. One single pole double throw switch locks or unlocks four motions. When the toggle switch is in the "center-off" position, "normally closed" contacts lock all linear locks. The solenoid for locking the rotation of the mast is de-energized so that the springs hold the rotation lock closed. Therefore, all locks are "on" when the toggle switch is in the "center-off" position.

All linear locks can be disengaged by throwing the toggle switch from the center-off position in one direction, which leaves the rotation of the mast locked, throwing the toggle switch in the other direction will open the mast rotation and will lock the linear motions. This split selectivity of locking and unlocking the mast rotation and the collective linear motions separately, provides easier manual control of the equipment and the simple switching arrangement needing only one toggle switch. The use of a single switch eliminates search for the proper switch to lock one particular motion.

The principal object of this invention, then is to provide a novel and improved support for an X-ray tube or other source of penetrating radiation and a coacting mechanism such as an image intensification tube.

Related objects are to provide constructions which contribute to the simplicity, flexibility, and versatility of such a support.

Other objects and a fuller understanding of the invention may be had be referring to the following description and claims taken in conjunction with the accompanying drawing in which:

In the drawings:

FIGURE 1 is a side elevational view of a C-arm and support mechanism and a diagrammatic and sectional showing of an X-ray table as seen from the planes indicated by the line **1—1** of FIGURE 2;

FIGURE 2 is a front elevational view of the table and arm of FIGURE 1 on an enlarged scale showing a fragmentary view of the mast;

FIGURE 3 is a side elevational view on the scale of FIGURE 1 of another application of the invention;

FIGURE 4 is an enlarged sectional view as seen from the plane indicated by the line **4—4** of FIGURE 3;

FIGURE 5 is a fragmentary sectional view of the mast support carriage as seen from the plane indicated by the line **5—5** of FIG. 4;

FIGURE 6 is a foreshortened end elevational view of the mast support structure as seen from the plane indicated by the line **6—6** of FIGURE 3 and on an enlarged scale with respect to FIGURES 1 and 3;

FIGURE 7 is a sectional view of the mast and vertical carriage showing a top plan view of the fail safe mechanism as seen from the plane indicated by the lines **7—7** of FIGURE 3 and on an enlarged scale with respect to FIGURES 1 and 3;

FIGURE 8 is an enlarged fragmentary side elevational view of the C-arm support mechanism with parts broken away and removed;

FIGURE 9 is an enlarged sectional view of the C-arm construction as seen from the plane indicated by the line **9—9** of FIGURE 1;

FIGURE 10 is a foreshortened front elevational view of a modified C-arm support on a reduced scale with respect to the remainder of the drawings;

FIGURE 11 is an enlarged fragmentary front elevational view of an upper portion of the arm carriage with parts broken away and removed to show a front elevational view of the fail safe mechanism with parts of each fail safe mechanism broken away and removed to reveal the internal construction; and

FIGURE 12 is a schematic wiring diagram of the motion arresting circuitry.

Referring to the drawings and FIGURE 1 in particular, an X-ray table is shown schematically at **10**. A C-arm shown generally at **11** is positioned for treating a patient on the table. The C-arm **11** is supported by a mast assembly shown generally at **12** which in turn is connected to the ceiling by a support assembly **13**.

The support assembly 13

The support assembly **13** has a pair of horizontally disposed and parallel ceiling tracks **14** fixed to the ceiling. An overhead support **15** is mounted on the tracks **14** for movement along the tracks in a path normal to the plane of FIGURE 1. The support **15** includes a pair of hori-

zontal tracks **16**, FIGURE 6, which are normal to the ceiling tracks **14**.

A horizontal carriage **17** is mounted on the support tracks **16** for movement therealong. The details of construction of the horizontal carriage **17** which permits and guide rotation of the mast assembly are described below in the section headed MAST ASSEMBLY. The horizontal carriage **17** is movable to any location in a predetermined horizontal area by movement of the overhead support **15** along the ceiling tracks **14** and movement normal to the overhead support movement of the overhead carriage **17** alonge the support tracks **16**.

The mast assembly 12

The mast assembly **12** includes a vertically oriented mast **18** and a horizontally disposed mast support arm **19**. The horizontal carriage **17** is equipped with an apertured mast supporting plate **20**, FIGURES 4 and 5. The plate **20** has walls **21** defining a relatively large circular journaling aperture. A mast journaling bracket **23** is secured to the upper side of the arm **19** relatively near a support end **24** of the arm **19** remote from the mast **18**. The journaling bracket **23** has a pair of upstanding lugs **25** which carry mast supporting rollers **26, 27**. The supporting rollers **26, 27** engage the upper face of the apertured support plate **20**.

An arm extension bracket **28** is secured to the remote end **24** of the arm **19**. A third roller **29** is journaled on the support extension bracket **28** engaging the underface of the apertured plate **20**. The third roller **29** coacts with the rollers **26, 27**, to rotatably support the mast for rotation about the aperture in the plate **20**.

A pair of locating wings **30** project horizontally from the opposite sides of the arm **19**. The locating wings **30** carry locating rollers **31** which engage the aperture walls **21** at spaced locations. Another pair of locating rollers **32** are carried by the support extension bracket and engaged to the walls **21**. The locating rollers **31, 32** prevent relative horizontal movement of the mast support **19** and the horizontal carriage **17** while permitting rotation about the axis of the plate aperture.

When powered rotation of the mast assembly **12** about the vertical axis of the aperture in plate **20** is desired, a vertical rotation reversible electric motor **100** is mounted on the extension bracket **28**, FIGURE 1. The vertical rotation motor **100** drives a worm **101** which in turn drives a work gear **102**. The worm gear **102** is coupled to and drives the third roller **29**, FIGURE 1.

The mast **18** depends vertically from the mast arm **19** to reciprocally carry a vertical carriage shown generally at **35**. The mast **18** is horizontally offset from the axis of mast rotation depending from the end of the arm **19** remote from the mast support carriage **17**.

The construction of the mast **18** is seen most clearly in FIGURE 7 where a generally channel shaped extrusion **36** is shown in cross section. A back plate **37** is secured to vertically extending back flanges **38** on the mast extrusion **36** to provide a generally rectangular tubular construction encasing counter-balance springs **39**.

The mast extrusion **36** is equipped with a pair of laterally extending journaling tracks **40** and a forwardly extending fail safe track **41**. These tracks **40, 41** extend vertically the length of the mast to provide guiding support for the vertical carriage **35**.

The vertical carriage **35** has an arm support face casting **42** which is positioned in front of the mast **18**. Four journaling side castings **43** are secured to the face casting **42** and connected together behind the mast **18** by a pair of handle braces **45**. As a comparative examination of FIGURES 1 and 7 will show, there are a total of four side castings **43** with an upper and a lower casting on each side. Each of these four castings **43** carries a pair of carriage supporting rollers **46** which engage the front and rear faces of the supporting tracks **40**. Each of the side castings **43** also carries a lateral thrust roller **47** each of which engages an end surface of one of the journaling tracks **40** to prevent lateral movement of the vertical carriage **35** relative to the mast **18**.

The counterbalance assembly used in this mechanism is shown most completely in FIGURE 3 and incorporates the counterbalance system described in greater detail in United States Patent No. 2,901,202, issued August 22, 1959, to R. J. Stava et al., under the title Counterbalance. This counterbalance assembly includes a counterbalance shaft **49** journaled in suitable brackets **50** which are mounted in the mast arm **19**. A cylindrically contoured drum **51** is secured to the shaft **49** and connected to the counterbalance springs **39** by a cable **52**. A spirally convoluted compensating sheave **53** is also fixed to the counterbalance shaft **49**. A cable **54** depends from the sheave **53** and is connected to the carriage **35** to support it.

As is best seen in FIGURES 7 and 11, the support cable **54** is reeved around a carriage support pulley **55**. The end of the cable **54** is secured to the sheave **53** in a manner not shown in the drawings. The support pulley **55** is journaled on a fail safe plate **56**. The fail safe plate **56** is journaled on a fail safe shaft **57** mounted in the face casting **42** of the vertical carriage **35**. The fail safe plate is pivotal about the axis of the fail safe shaft **57** which is below and vertically offset with respect to the axis of the support pulley **55**.

When the support cable **54** is tensioned by the weight of the carriage, the fail safe plate **56** is caused to rotate about the axis of the fail safe shaft **57** until it strikes a stop **58** provided on the front carriage face casting **42**. A fail safe spring **59** is connected to the fail safe plate **56** and the face casting **42**. Whenever the tension of the support cable **54** is released because, for example, of a failure of either the counterbalance cable **52** or the support cable **54**, or if a balance spring breaks, the fail safe spring **59** will rotate the fail safe plate **56** about the axis of the fail safe shaft **57**.

The fail safe plate **56** has horizontally disposed rearwardly extending braking surfaces **60** which are normally spaced from and on either side of the fail safe track **41**. On a cable failure and pivoting of the fail safe plate **56** under the action of the spring **59**, these braking surfaces **60** are brought into engagement with the sides of the fail safe track **41**. A lower edge of one of the braking walls **60**, the right hand one, as seen in FIGURE 11, will dig into the fail safe track **41** arresting the descending movement of the vertical carriage **35** and preventing the free fall of the carriage which might result in either damage to the equipment or injury to a patient.

The arm assembly 11

Referring now to FIGURE 8, the vertical carriage **35** has a horizontally disposed arm supporting shaft **62** secured to it. The shaft **62** projects through an aperture **63** in a face of the carriage face casting **42**. An anchor plate **64** is welded to a reduced diameter end portion **66** of the shaft **62**. The anchor plate **64** is secured to the face casting **42** as by bolts **65** and is positioned on the inside of the face casting **42**.

The C-arm assembly **11** includes a C-arm cradle **67** which is journaled on the shaft **62**. The cradle **67** and the vertical carriage **35** are relatively freely rotatable about the axis of the support shaft **62**. A worm gear **68** is fixed to the cradle **67** and keyed against relative rotation. The worm gear **68** is coaxially disposed around the shaft **62**. A worm **69** engages the worm gear **68** and is carried by a gear housing **70**. A cradle rotating electric motor **71** is supported on the gear housing **70** and drivingly connected as by chain **72** to the worm **69**. A bearing **73** is interposed between the cradle **67** and the gear housing **70** to permit relative rotation.

The gear housing **70** is connected to the table **10** in a manner which will be described presently so that movement of the table will cause corresponding movement of the gear housing **70**. This movement is obtainable due to the previously described mast and overhead support assemblies and the journaling of the cradle **67** on the shaft **62**. At the same time horizontal rotation of the cradle **67** relative to the gear housing **70** and, therefore, relative to the table and other elements of the entire mechanism is obtainable.

This rotation of the cradle **67** relative to the table is depicted in FIGURE 2 where the phantom showing of the C-arm **11** is at 45° with the solid line showing, the other pictured mechanisms remaining stationary. With certain types of studies, this type of rotation is desirable and with the preferred arrangement rotation is provided approximately 45° in either direction from the vertical position shown in solid lines. As will be apparent, this rotation of 45°, in either direction from the vertical position, is obtained by alternately driving the cradle rotating motor **71** in opposite directions.

The C-arm assembly **11** includes a C-arm shown generally at **75**. The C-arm **75** has a pair of arcuately curved tubular, preferably aluminum, frame members **76**, FIGURE 9. A pair of arcuately curved hardened steel tracks **77**, **78**, are mounted on opposite sides of the frame members **76**. Stud assemblies including stud members **79**, **80** project through the frame members **76** and are threaded respectively into the track members **77**, **78**.

The stud member **80** has a reduced diameter end projection **81** which telescopes into a bore in the stud member **79**. A pin **82** is inserted in aligned holes in the stud members **79**, **80** to secure the stud members against relative rotation. The stud members **79**, **80** are threaded into their respective tracks with threads formed in the same spiral direction. Thus, for example, the threading of both may be right handed. With this construction and the two stud members pinned together, any tendency of one of the stud members to loosen from its connected track will cause tightening of the coupled stud member in its track. Accordingly, a simplified C-arm construction is provided in which the members are positively locked together against accidental loosening. The C-arm is fabricated from elements which are relatively easy to manufacture and the composite result is a very rigid and strong but inexpensive C-arm.

Four roller assemblies **84**, FIGURE 8, are secured to opposite sides of the cradle **67** in spaced relationship with one another. Each of these roller assemblies includes a cluster of three rollers **85**. The three rollers **85** of each cluster engage respectively the concave, convex, and side faces of the associated one of the C-arm tracks **77**, **78** to journal the C-arm in the cradle **67** for rotation about the orbital axis of the C-arm.

As the preceding description suggests, in the preferred construction the C-arm is rotatable from its vertical position as shown in FIGURE 1 and in solid lines in FIGURE 2 about the vertical axis of the vertical carriage **17**, about the horizontal axis of the shaft **62**, which axis intersects the mast, and orbitally about another axis, the axis of the C-arm. When the C-arm is in the vertical position shown in FIGURES 1 and 2, these three axes are each normal to the other two. Moreover, the structure is such that the three axes always intersect at a common point immediately above table top **87** of the table **10**. The point is indicated schematically in FIGURE 1 and identified by the letter "P."

An X-ray tube housing **88** is secured to the C-arm **75** near one end. The housing **88** and the enclosed X-ray tube are preferably of the type described and claimed in greater detail in Patent No. 3,094,616, entitled X-Ray Table, issued to E. B. Graves et al. on June 18, 1963. This housing and tube construction is preferred for the extra target to patient distance obtained with that construction as is described in greater detail in the referenced patent.

A coacting mechanism is mounted near the end of the C-arm opposite the X-ray tube. The coacting mechanism will be an X-ray stimulated device and is preferably an image intensification tube **89**. The image intensification tube **89** may be connected to a closed television circuit, used for optical viewing, and/or used in conjunction with a cine camera **90**. The tube **89** is mounted on tracks **91** for adjusting movement toward and away from the X-ray tube.

While the device is designed for use primarily with an image intensification tube **89**, there are times when a radiographic exposure may be required. To effect a radiographic exposure, a cassette tray **110** is pivotally connected to the image tube by a pivotal linkage **111**. Normally the cassette tray is parked in the storage position shown in solid lines in FIGURE 1. When one wishes to make a radiographic exposure, the tray **110** is shifted to the position shown in phantom lines in FIGURE 1 and a radiographic cassette is positioned in the tray **110**.

One of the outstanding advantages of this invention is obtained through the mounting of the C-arm in the C-arm cradle **67**. To effect orbital rotation of the C-arm about an axis passing through the point P, parallel to the table top when the device is in the solid line position of FIGURE 2, and longitudinal with respect to it, an orbital rotation drive motor **112**, FIGURE 8, is provided. The orbital motor **112** is mounted on the C-arm cradle **67**. A drive sprocket **113** is driven by the orbital motor **112**. The drive sprocket **113** engages a chain **114** which has ends secured to the C-arm near the image tube **89** and the X-ray tube **88** respectively. Between this end securement, the chain is free so that it may pass over the drive sprocket **113**. Idler sprockets **115** are mounted on the carriage housing **67** to maintain the chain **114** in driving engagement with the drive sprocket **113**.

Another advantage of this invention is obtained through the C-arm construction which permits much greater arcuate travel when the orbital motor **112** is operated than has heretofore been obtainable. This increased arcuate travel is obtained through the provision of a C-arm cradle **67** which is open at **117** along its concave face, FIGURE 8. An X-ray tube support **118** is provided which has a dimension paralleling the axis of C-arm arcuate travel which is less than the width of this concave face opening **117**. The X-ray tube support **118** is so constructed so it may pass into and through the C-arm concave face opening **117** as is demonstrated in the version of the invention shown in FIGURE 10. Moreover, the image tube **89** may, as shown in FIGURE 10, be mounted on a support **119** corresponding to the X-ray tube support **118**. With this construction the image tube support **119** can also pass into the face opening **117** to increase the amount of arcuate travel of the C-arm when the orbital motor **112** is operated.

The table and the arm connection

Referring now to FIGURES 1 and 2, an X-ray table is shown which is tiltable from its pictured horizontal position in either direction. The table shown in FIGURE 2 is one which is tiltable in one direction to a vertical position and in the other position to approximately 30° Trandelenberg. A well known, so-called "90–90 table" tiltable 90° in either direction from the horizontal may also be employed. With this table arcuate tracks **120** are provided on a pedestal **121** which supports the remainder of the table. A chain **122** is provided to cause selective rotation of the table through a mechanism quite similar to the C-arm rotation. A table tilting motor **123**, FIGURE 2, is mounted on the pedestal and in driving engagement with the chain **122** to cause this table tilting.

A pair of guide tube brackets **124** are fixed to the table near the ends of the top **87**. The guide tube brackets **124** support a C-arm guide tube **125**. Guide followers **126**

are journaled on the guide tube **125** for relative reciprocation along the axis of the guide tube **125**. A pair of C-arm guide bars **127** are respectively connected to the guide followers **126**. The guide bars **127** respectively telescope into guide sleeves **128** which are secured to the C-arm gear housing **70**. The guide bars **127** are telescoped into the guide sleeves **128** to permit relative reciprocal movement and thereby movement of the C-arm toward and away from the table top **87** along a path located by the bars and sleeves **127, 128**, while preventing rotation of the C-arm gear housing **70** relative to the table top. Conversely, when the table is tilted, the coaction of the guide bars and sleeves **127, 128** cause the C-arm to tilt with the table top maintaining the relative position of the X-ray tube, image amplifier **89**, and the table top **87**.

Longitudinal reciprocation of the C-arm relative to the table top is obtained through a chain **130** which has its ends connected to the guide followers **126**. The chain is reeved around sprockets **131** mounted on opposite sides of the guide support brackets **124**. The chain extends through the guide tube **125** and is driven by a C-arm reciprocation motor **132** mounted on the table at the right as seen in FIGURE 2. Operation of the motor **132** will cause reciprocation of the C-arm longitudinally of the table along a guided path located by the guide tube **125**.

In the arrangement shown, the table top **87** is pivotally mounted at **134** for rotation about a longitudinal axis paralleling the table top. The amount of rotation about the pivots **134** is controlled by a coacting pin **135** and arcuate slot **136**. Pivoting of the table top provides further versatility in obtaining relative angular relationship of the patient and the X-ray beam.

In the preferred and disclosed arrangement, the C-arm may be disconnected from the table. This is accomplished by disconnecting the coupling means between the C-arm and the table top. In the disclosed arrangement, bolts **137** may be removed to disconnect the C-arm guide structure from the C-arm gear housing **70**.

When the table to C-arm coupling mechanism is disconnected to permit the C-arm to be used independently at the table, a means is provided to prevent relative rotation of the C-arm and the C-arm carriage other than when the cradle rotating motor **71** is operated. In FIGURE 1 the disclosed means comprises a slidable bolt **138** mounted on the gear housing **70** and selectively projectable into an aperture **139** in the vertical carriage **35**.

In the embodiment of FIGURE 3, a U-arm **140** is provided rather than the C-arm **114**. The structure for rotating the U-arm about the axis of the arm support shaft **62** is somewhat modified from the structure of FIGURES 1 and 2 and is the structure which is preferred with either a C or U-arm designed for use normally without being coupled to a table. In this arrangement the cradle rotating motor **71** is mounted on the vertical carriage **35**. With this construction, and the construction described in greater detail above being otherwise identical, operation of the cradle rotating motor **71** will cause rotation of the U-arm **140**, or a C-arm, about the axis of the arm support shaft **62**. At the same time the cradle motor **71**, the worm **69**, and worm gear **68** will prevent rotation of the arm about the axis of the arm support shaft **62** at times when the motor **71** is not operating.

In the version of FIGURE 10, a gooseneck **145** replaces the arm support shaft **62**. This structure is preferred where ceiling height permits because the mast **18** may be terminated at a relatively high height to permit unobstructed movement under the mast. The C-arm carriage **35** may be raised vertically to move the entire C-arm assembly out of the way and permit movement under the entire described mechanism.

The braking system

As indicated previously, electro-magnets **150**, FIGURES 1 and 6, are used to arrest linear movements. A braking system shown in FIGURE 6 arrests mast rotation about the vertical axis. This brake system includes brake shoes **151**. A spring **152** normally holds the brake shoes **151** in an "on" condition. Energization of a solenoid **153** actuates a linkage **154** which overcomes the action of the spring **152** and releases the brake shoes **151**.

In FIGURE 12 a schematic diagram of the single switch control of the braking of the various movements is shown. Here the magnets **150** for controlling lineal motions are shown as is the solenoid **153** which actuates the linkage **154**. A single pole double throw toggle switch is shown schematically at **155**. The switch **155** is connected by a conductor **156** to one side of a line L. Pole **163** of the switch **155** is shown in solid lines in its "center off" position. A spring biases the toggle switch **155** to this "center off" condition. When the pole **163** of the switch is moved to the right to the position shown in phantom at **164**, the relay **153** is energized releasing the rotation brake.

The magnets are connected to the line L by a conductor **162**. A normally closed switch **161** is in series with the conductor **162** and controlled by a solenoid **160**. When the pole **163** is moved to the left to the position shown at **170**, the solenoid **160** is energized opening the switch **161** and de-energizing the magnets **150**.

Thus, when the switch is in the position shown in solid lines at **163**, all brakes are on. When it is moved to the right to the phantom position shown at **164**, the rotational brake is released because all magnets are energized and the solenoid **153** is also energized.

If the pole **163** is moved to the left to the position shown in phantom at **170**, the magnets and the relay **153** become de-energized and, therefore, rotational movement about the vertical axis is prevented while lineal movements are obtainable. Thus, through a single switch **155** which is normally spring biased to the position shown in solid lines, selective control of the vertical rotation and the lineal movements is obtained.

Although the invention has been described in its preferred form with a certain degree of particularity, it is understood that the present disclosure of the preferred form has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without department from the spirit and the scope of the invention as hereinafter claimed.

What is claimed is:

1. In combination:

(a) a carriage system including tracks supporting a horizontal carriage and permitting horizontal movement of the horizontal carriage to a selected location within a predetermined area;

(b) a generally vertical mast depending from and supported by the horizontal carriage;

(c) a vertical carriage mounted on the vertical mast for vertical reciprocation;

(d) an arm rotatably mounted on the vertical carriage for rotation about a horizontal axis;

(e) an X-ray tube mechanism mounted on the arm;

(f) an X-ray stimulated image producing mechanism mounted on the arm and spaced from the tube mechanism, the image mechanism being positioned to be stimulated by rays emitted from the tube mechanism;

(g) an X-ray table including a table top and means to tilt the top from a horizontal position and return; and,

(h) coupling means connecting the mechanisms to the table while permitting movement of the mechanisms longitudinally with respect to the table top.

2. The device of claim **1** wherein the C-arm is mounted for rotation selectively about the horizontal axis and an orbital axis.

3. The device of claim **1** wherein:

(a) the mast is rotatable about a vertical axis;

(b) the arm is a C-arm rotatable relative to the vertical carriage about an orbital axis; and,

(c) the three mentioned axes are substantially normal to one another intersecting at a point.

4. The device of claim 1 wherein:

(a) the mast assembly comprises an inverted L-shaped mast assembly rotatably mounted on the horizontal carriage near the end of the horizontal leg of the L assembly for rotation about a vertical axis, the L assembly having a depending vertically disposed mast horizontally spaced from said vertical axis;

(b) the vertical carriage is mounted on the mast; and,

(c) the arm is a bifurcated arm mounted on the vertical carriage for rotation about a horizontal axis intersecting the vertical axis at a point.

5. An X-ray apparatus comprising:

(a) a support assembly adapted to provide support for the remainder of the apparatus from above the remainder of the apparatus;

(b) a depending mast rotatably supported on the support assembly and rotatable about an axis horizontally offset from the mast;

(c) arm support means reciprocally mounted on the mast;

(d) a bifurcated arm rotatably mounted on the arm support means for rotation about a horizontal axis intersecting said mast;

(e) extensions of said axes intersecting at a point;

(f) a penetrating ray energy source and a coacting mechanism mounted in spaced relationship on the bifurcated arm with the source positioned to emit a beam of rays through said point; and,

(g) said mechanism being positioned in the path of the beam.

6. In the combination of claim 5 said mast including a track, the vertical carriage being a vertically movable weight mounted on the mast, and a flexible member connecting the weight to a counterbalance, the combination of:

(a) a fail safe member pivotally connected to the weight;

(b) a pulley journaled on the member and horizontally offset with respect to the weight to member connection;

(c) said member including track engageable portions adapted to engage the track and prevent downward relative movement;

(d) biasing means between the weight and the member biasing said portions toward engagement with the track; and,

(e) a flexible member reeved around the pulley to connect weight to the overhead support and pivot the member against the action of the biasing means and maintain said portions out of holding engagement with the track.

7. The device of claim 5 wherein said arm is a C-arm comprising:

(a) first and second spaced, curved, track members;

(b) first and second spaced, curved, tubular frame members between the track members; and,

(c) a plurality of spaced coupling assemblies coupling the members together, each of said assemblies comprising:

(i) first and second stud members each projecting transversely through the like numbered frame member and connected to the like numbered track member to fix like numbered members together; and,

(ii) means coupling the stud members together.

8. The device of claim 5 wherein the arm is a C-arm and the vertical carriage includes a C-arm cradle and wherein:

(a) the C-arm cradle includes four bearing clusters;

(b) the C-arm includes a pair of tracks each journaled in two of said bearing clusters;

(c) each of said clusters including three rollers engageable with said tracks, the rollers of each cluster being mounted on a different one of four supports; and,

(d) the supports being removably connected to the carriage whereby the clusters may each be removed as a unit for replacement or repair.

9. In combination with the device of claim 5 wherein the mast and horizontal carriage are relatively rotatable components and wherein the mast and vertical carriage are components which are relatively movable lineally, the improvement which comprises:

(a) lineal motion arresting means carried by certain of the components and coactable with other of the components to arrest relative lineal motion therebetween;

(b) rotary motion arresting means carried by one component and coactable with another component to arrest relative rotation therebetween;

(c) control circuitry connected to each of said motion arresting means for electrically controlling said arresting means and thereby controlling the arresting of relative movement between said components; and,

(d) said circuitry including a manually actuatable control means positionable to condition said circuitry to produce a desired motion arresting condition, said control means having:

(i) a first position wherein both lineal and rotative motion is arrested;

(ii) a second condition wherein lineal motion is arrested and rotary motion is permitted; and,

(iii) a third position wherein rotary motion is arrested and lineal motion is permitted.

10. In combination with the device of claim 5 wherein the mast and the horizontal carriage are relatively rotatable components and wherein the mast and vertical carriage are components which are relatively movable lineally, the improvement which comprises:

(a) lineal motion arresting magnets carried by certain of the components and coactable wtih other of the components to arrest relative lineal motion therebetween;

(b) a solenoid controlled rotary motion arresting brake carried by one component and coactable with another component to arrest relative rotation therebetween;

(c) control circuitry connected to said magnets and said solenoid for electrical control thereof, thereby controlling the arresting of relative movement between said components; and,

(d) said circuitry including a manually actuable switch positionable to condition said circuitry to produce a desired motion arresting condition, said switch having;

(i) a first position wherein the circuitry is conditioned to energize the magnets and de-energize the solenoid, whereby both lineal and rotative motion is arrested;

(ii) a second position wherein the circuitry is conditioned to energize the solenoid and the magnets, whereby lineal motion is arrested and rotary motion is permitted; and,

(iii) a third position wherein the circuitry is broken to de-energize the magnets and the solenoid, whereby rotary motion is arrested and lineal motion is permitted.

11. An apparatus for supporting a penetrating ray energy mechanism comprising:

(a) a carriage assembly adapted for mounting on a ceiling or the like for supporting the remainder of said apparatus and mechanism;

(b) an inverted L-shaped mast assembly rotatably mounted on the carriage assembly near the end of the horizontal leg of the L assembly for rotation

about a vertical axis, the L assembly having a depending vertically disposed mast horizontally spaced from said vertical axis;
(c) a vertically reciprocal vertical carriage mounted on the mast; and,
(d) a bifurcated arm mounted on the vertical carriage for rotation about a horizontal axis intersecting the vertical axis at a point.

12. An X-ray apparatus comprising:
(a) a support assembly including a horizontal carriage for movement to a selected location in a horizontal plane;
(b) a depending mast supported on the horizontal carriage and rotatable about a vertical axis;
(c) a vertical carriage reciprocally mounted on the mast;
(d) an arm cradle rotatably mounted on the vertical carriage for rotation about a first horizontal axis;
(e) a C-arm mounted on the arm cradle for rotation about an orbital axis;
(f) extensions of said three axes intersecting at a point;
(g) a penetrating ray energy source and a coacting mechanism mounted in spaced relationship on the C-arm with the source positioned to emit a beam of rays through said point; and,
(h) said mechanism being positioned in the path of the beam.

13. In an X-ray mechanism the combination of:
(a) a bifurcated arm having spaced ends;
(b) a support assembly including a depending mast carrying said arm for rotation about intersecting horizontal and vertical axes, said horizontal axis intersecting the mast;
(c) an X-ray tube mounted on the arm near one end and adapted to emit a beam of rays through said intersection; and,
(d) an X-ray stimulated device carried by the arm near its other end and positioned in the path of said beam.

14. The mechanism of claim **13** wherein said device is mounted for adjustable movement toward and away from said tube.

15. The device of claim **14** wherein:
(a) said device is an image intensification tube; and,
(b) a cassette carrier is swingably mounted on the image tube for selective movement into and out of the path of said beam.

16. In an X-ray mechanism the combination of:
(a) a tiltable X-ray table;
(b) an arm support assembly movable over a predetermined area in a horizontal plane;
(c) said assembly including a depending mast;
(d) a carriage reciprocally mounted on the mast;
(e) an arm mounted on the carriage and carrying spaced penetrating ray energy source and coacting mechanisms; and,
(f) telescoping coupling means connecting the arm to the table while permitting reciprocation of the arm in a horizontal path toward and away from the table.

17. In combination:
(a) a supporting assembly including a support movable in a horizontal plane to any location within a predetermined area;
(b) a generally vertical mast member supported by the support;
(c) a carriage mounted on the mast for vertical reciprocation;
(d) a cradle mounted on the carriage;
(e) a bifurcated arm connected to the cradle;
(f) power means interposed between the arm and the cradle to cause selective relative rotation;
(g) a penetrating ray energy source and a coacting mechanism mounted on the arm with the mechanism positioned in the path of rays emitted from the source;
(h) an X-ray table including a table top and means to tilt the top from a horizontal position and return, and,
(i) coupling means connecting the mechanisms to the table while permitting movement of the arm longitudinally and transversely with respect to the table top.

18. In an X-ray mechanism the combination of:
(a) a tiltable X-ray table including a top and a parallel tubular guide;
(b) an arm support assembly movable over a predetermined area in a horizontal plane;
(c) said assembly including a depending mast;
(d) a carriage reciprocally mounted on the mast;
(e) an arm mounted on the carriage and carrying spaced penetrating ray energy source and coacting mechanisms;
(f) coupling means connecting the arm to the table guide;
(g) a flexible power transmitting device extending through the guide and having its ends connected to the carriage; and,
(h) power means connected to the power transmitting device for moving the device and causing reciprocation of the carriage.

19. In an X-ray mechanism the combination of:
(a) a C-arm support cradle delineating an arcuate guide slot open at its ends and along a concave face;
(b) an arcuately curved C-arm mounted in the guide slot for movement along an arcuate path delineated by said slot;
(c) first and second mountings secured to said arm and spaced along said arcuate path, said slot having a sufficient transverse dimension to permit one of said mountings to pass into and out of said slot as said arm moves along said path;
(d) a penetrating ray emitting source of the first mounting near one end of the C-arm and adapted to emit a beam of penetrating rays; and,
(e) a coacting mechanism on the second mounting near the other end of the C-arm and positioned in the path of a beam emitted by said source.

20. In an X-ray mechanism the combination of:
(a) a C-arm cradle delineating an arcuate guide slot open at its ends and along a concave face;
(b) an arcuately curved C-arm mounted in the guide slot for movement along an arcuate path delineated by said cradle;
(c) an arcuately spaced pair of mountings secured to said arm, said slot having a sufficient transverse dimension to permit said mountings to pass into and out of said slot as said arm moves along said path;
(d) a penetrating ray emitting source on one of the mountings near one end of the C-arm and adapted to emit a beam of penetrating rays;
(e) a coacting mechanism on the other mounting near the other end of the C-arm and positioned in the path of a beam emitted by said source; and,
(f) said arm being movable from a position wherein the source mounting projects into the slot along said arcuate path to a position wherein said coacting mechanism mounting projects into said slot.

21. A C-arm construction comprising:
(a) first and second spaced, curved, track members;
(b) first and second spaced, curved, tubular frame members between the track members; and
(c) a plurality of spaced coupling assemblies coupling the members together, each of said assemblies comprising:
  (i) first and second stud members each projecting transversely through the like numbered frame member and connected to the like numbered track member to fix like numbered members together; and,
  (ii) means coupling the stud members together.

22. The device of claim **21** wherein each stud member has a threaded portion threaded into a member and the

threads of each pair are identical whereby rotation tending to loosen one stud member of a coupled pair tightens the other.

23. The device of claim 22 wherein each stud member threads into a track member and each stud member has a shoulder abutting a like numbered frame member to clamp like numbered frame and track members together.

24. In a C-arm mechanism, the improvement which comprises:

(a) a C-arm cradle including four bearing clusters;

(b) a C-arm including a pair of tracks each journaled in two of said bearing clusters;

(c) each of said clusters including three rollers engageable with said tracks, the rollers of each cluster being mounted on a different one of four supports; and,

(d) the supports being removably connected to the cradle and independently removable whereby the clusters may each be removed as a unit for replacement or repair.

25. In an apparatus having an overhead supported mast assembly including a track, a vertically movable weight mounted on the assembly, and a flexible member connecting the weight to a counterbalance, the combination of:

(a) a fail safe member pivotally connected to the weight;

(b) a pulley journaled on the member and horizontally offset with respect to the weight to member connection;

(c) said member including track engageable portions adapted to engage the track and prevent downward relative movement;

(d) biasing means between the weight and the member biasing said portions toward engagement with the tracks; and,

(e) a flexible member reeved around the pulley to connect weight to the overhead support and pivot the member against the action of the biasing means and maintain said portions out of holding engagement with the track.

26. The device of claim 25 wherein the weight and element have coacting stop surfaces limiting relative pivotal movement against the action of the biasing means.

27. In a penetrating radiation apparatus having a support system carrying a source of radiation and a coacting mechanism wherein the system includes relatively rotatable components and wherein the system includes components which are relatively movable lineally, the improvement which comprises:

(a) lineal motion arresting means carried by certain of the components and coactable with other of the components to arrest relative lineal motion therebetween;

(b) rotary motion arresting means carried by one component and coactable with another component to arrest relative rotation therebetween;

(c) control circuitry connected to each of said motion arresting means for electrically controlling said arresting means and thereby controlling the arresting of relative movement between said components; and,

(d) said circuitry including a manually actuatable control means positionable to condition said circuitry to produce a desired motion arresting condition, said control means having:

(i) a first position wherein both lineal and rotative motion is arrested;

(ii) a second condtion wherein lineal motion is arrested and rotary motion is permitted; and,

(iii) a third position wherein rotary motion is arrested and lineal motion is permitted.

28. In a penetrating radiation apparatus having a support system carrying a source of radiation and a coacting mechanism wherein the system includes relatively rotatable components and wherein the system includes components which are relatively movable lineally, the improvement which comprises:

(a) lineal motion arresting magnets carried by certain of the components and coactable with other of the components to arrest relative lineal motion therebetween;

(b) a solenoid controlled rotary motion arresting brake carried by one component and coactable with another component to arrest relative rotation therebetween;

(c) control circuitry connected to said magnets and said solenoid for electrical control thereof, thereby controlling the arresting of relative movement between said components; and,

(d) said circuitry including a manually actuatable switch positionable to condition said circuitry to produce a desired motion arresting condition, said switch having:

(i) a first position wherein the circuitry is conditioned to energize the magnets and de-energize the solenoids, whereby both lineal and rotative motion is arrested;

(ii) a second position wherein the circuitry is conditioned to energize the solenoid and the magnets, whereby lineal motion is arrested and rotary motion is permitted; and,

(iii) a third position wherein the circuitry is broken to de-energize the magnets and the solenoid, whereby rotary motion is arrested and lineal motion is permitted.

29. In combination:

(a) a support system including tracks supporting a horizontal carriage and permitting horizontal movement of the horizontal carriage to a selected location within a predetermined area;

(b) a generally vertical mast assembly depending from and supported by the overhead carriage;

(c) a vertical carriage mounted on the mast assembly for vertical reciprocation;

(d) an arm mounted on the vertical carriage;

(e) an X-ray tube mechanism mounted on the arm;

(f) an X-ray stimulated image producing mechanism mounted on the arm and spaced from the tube mechanism, the image mechanism being positioned to be stimulated by rays emitted from the tube mechanism;

(g) an X-ray table including a table top and means to tilt the top from a horizontal position and return;

(h) a longitudinally disposed guide connected to the table;

(i) coupling and journaling means connecting the mechanisms to the guide and thereby connect the mechanisms to the table while permitting movement of the mechanisms longitudinally with respect to the table top; and,

(j) said coupling and journaling means being releasable to permit the mechanisms to be used selectively either coupled to or independent of the table.

No references cited.

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