Dec. 23, 1958 R. J. WAGNER ET AL 2,866,101

X-RAY APPARATUS

Filed Aug. 29, 1955 6 Sheets-Sheet 1

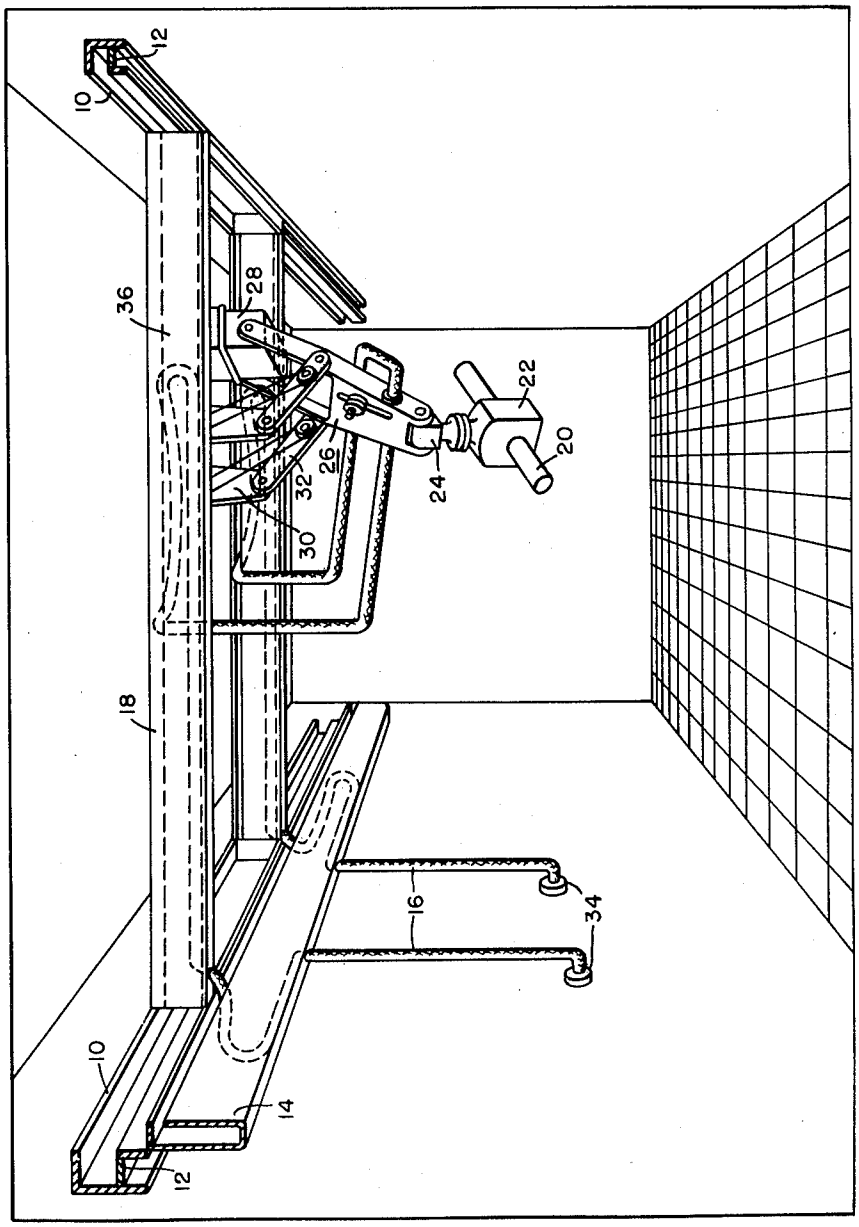


Fig. 1.

WITNESSES

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Dec. 23, 1958 R. J. WAGNER ET AL 2,866,101

X-RAY APPARATUS

Filed Aug. 29, 1955 6 Sheets-Sheet 2

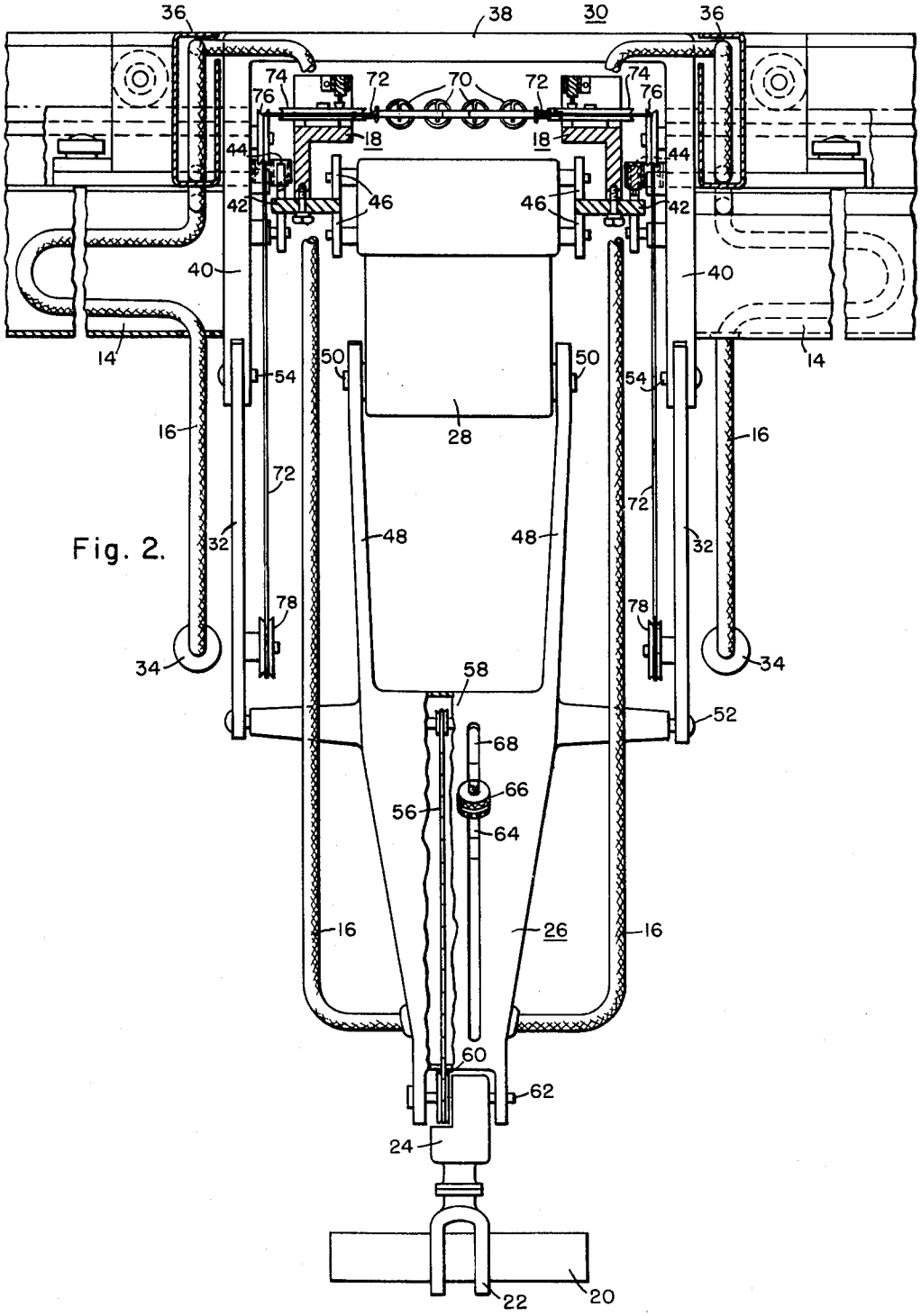


Fig. 2.

Dec. 23, 1958 R. J. WAGNER ET AL 2,866,101

X-RAY APPARATUS

Filed Aug. 29, 1955 6 Sheets-Sheet 3

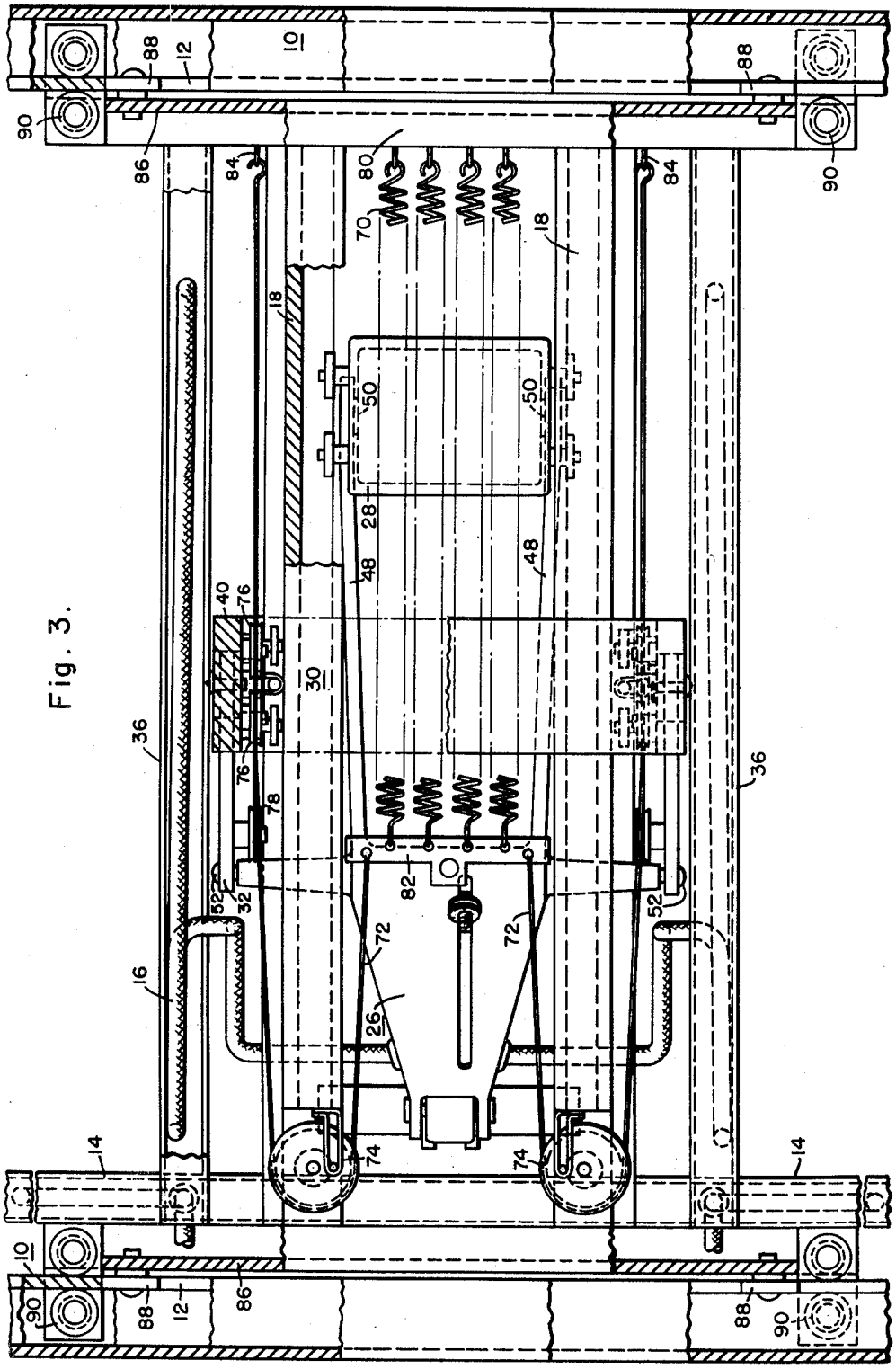


Fig. 3.

Dec. 23, 1958 R. J. WAGNER ET AL 2,866,101

X-RAY APPARATUS

Filed Aug. 29, 1955 6 Sheets-Sheet 4

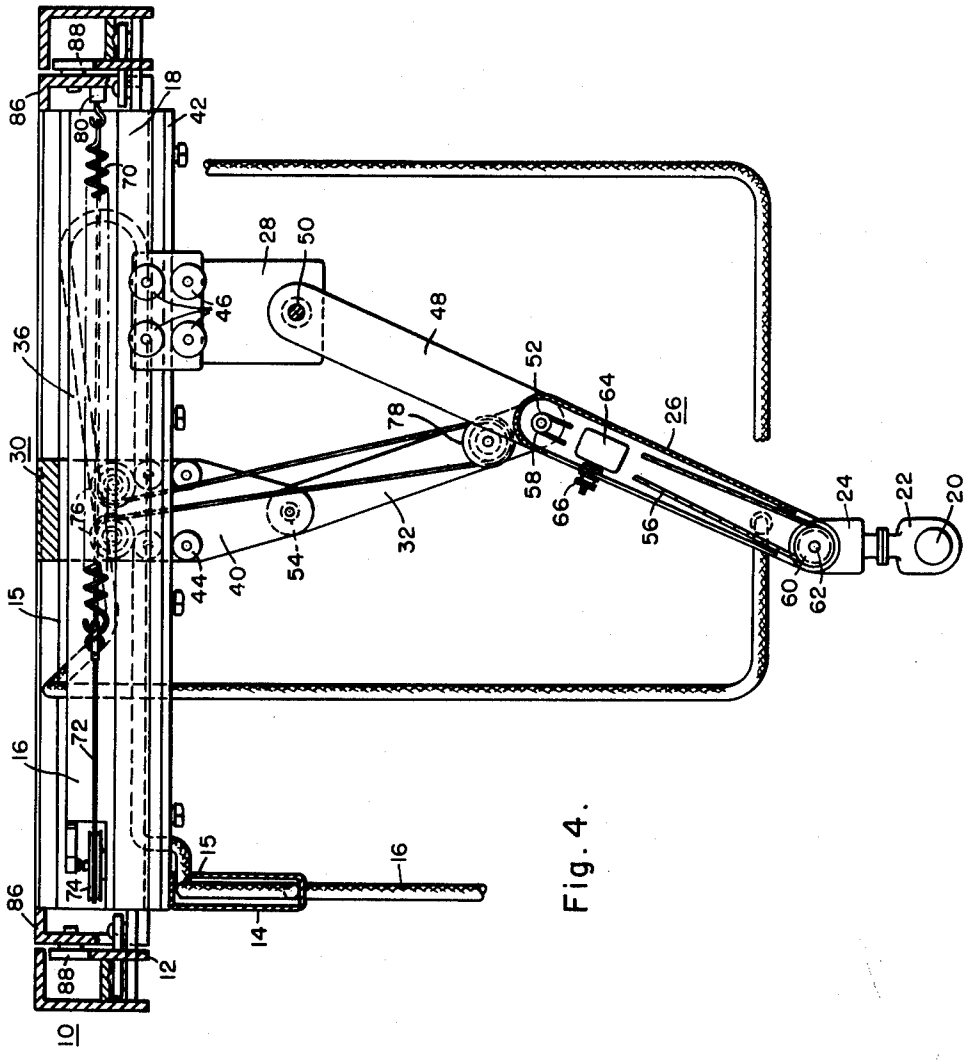
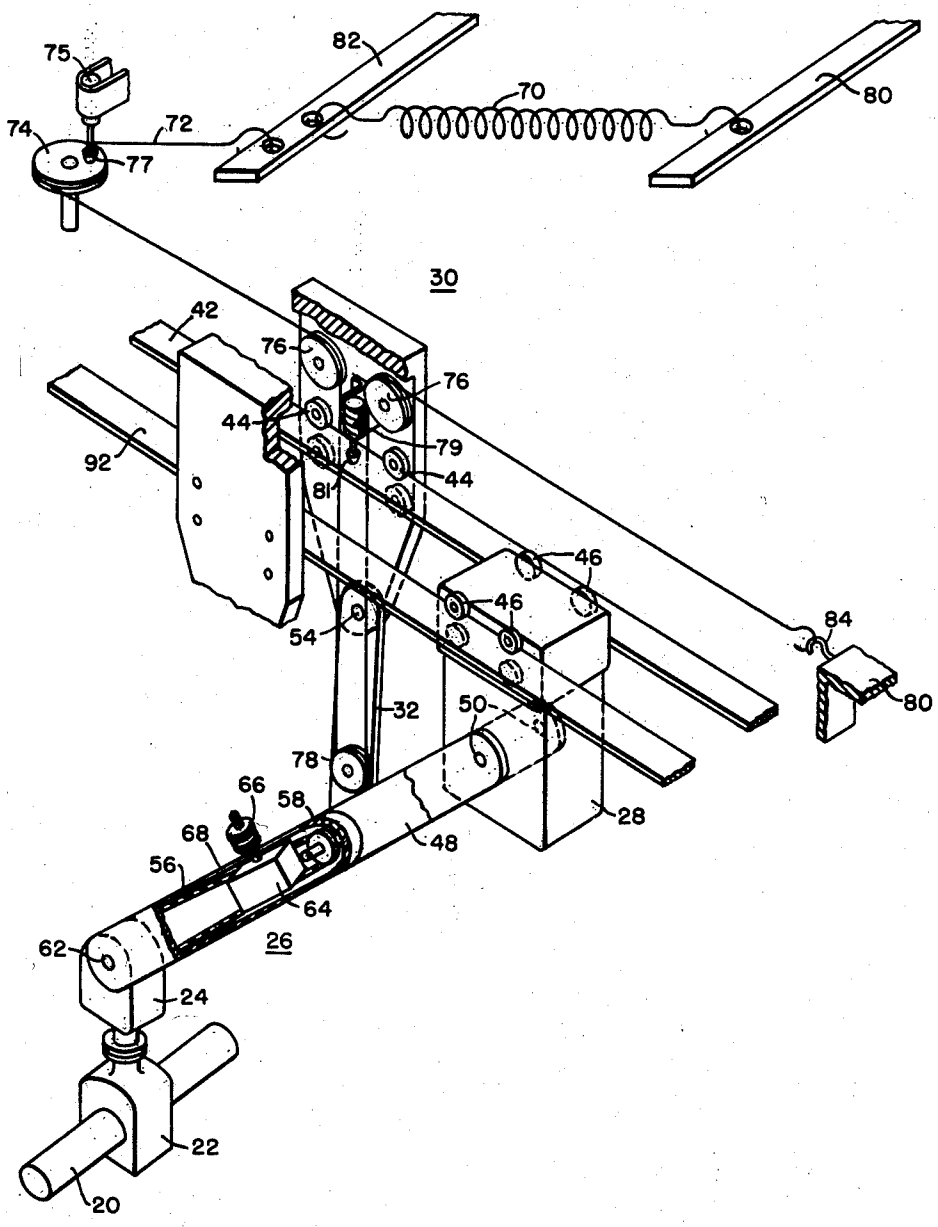


Fig. 4.

Fig. 5.


75
82
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30
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92
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20

Dec. 23, 1958 R. J. WAGNER ET AL 2,866,101

X-RAY APPARATUS

Filed Aug. 29, 1955 6 Sheets-Sheet 6

Fig. 6.

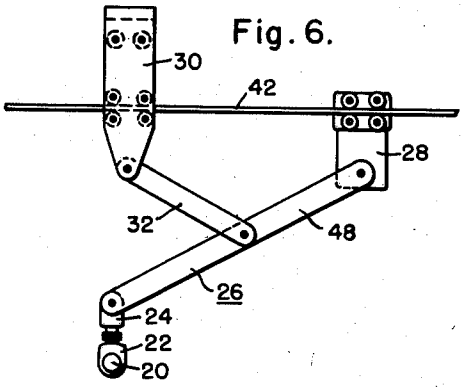


Fig. 7.

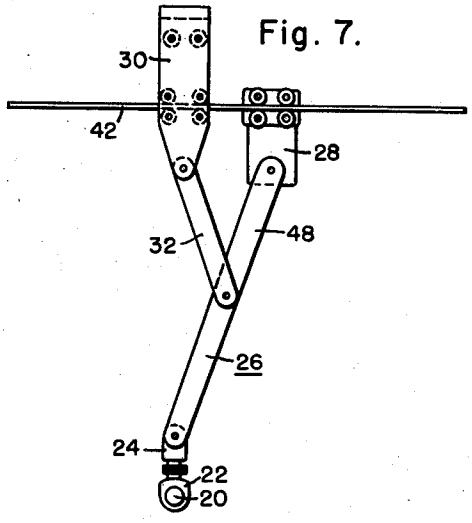


Fig. 8.

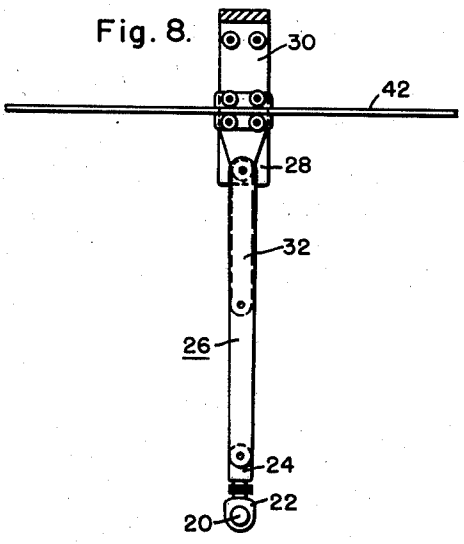


Fig. 9.

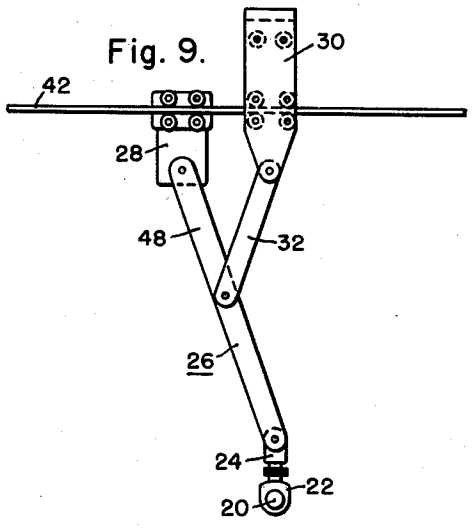
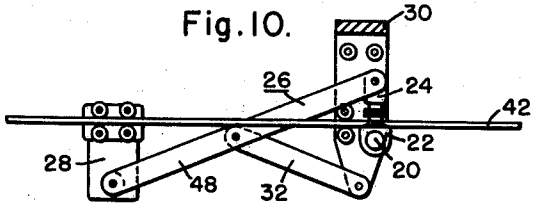


Fig. 10.



United States Patent Office 2,866,101 Patented Dec. 23, 1958

2,866,101

X-RAY APPARATUS

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Application August 29, 1955, Serial No. 531,171

4 Claims. (Cl. 250—91)

The present invention relates, in general, to X-ray apparatus and, more particularly, to X-ray tube positioning apparatus by which the operative position of an X-ray tube, relative to the patient or object being subjected to X-rays from that tube, can be more readily determined.

It is an object of the present invention to provide an improved X-ray tube positioning apparatus.

It is another object to provide an improved X-ray tube positioning apparatus which will allow a substantially straight-line vertical movement of the X-ray tube as may be desired, relative to the patient or object subjected to the X-rays from that tube.

It is a different object to provide an improved X-ray tube positioning apparatus which is counterbalanced to compensate for the load of the X-ray tube, as well as any weight of the various components of the apparatus itself.

It is a further object to provide improved X-ray apparatus including X-ray tube positioning apparatus which is counterbalanced over the complete range of desired travel of the X-ray tube.

It is an additional object to provide improved X-ray apparatus which is operative to keep the resultant movement of the X-ray tube synchronized with the movement of the positioning apparatus itself, such that the X-ray tube is maintained in the desired orientation relative to the patient or object being subjected to X-rays from the X-ray tube.

It is still another object to provide improved X-ray apparatus including an improved guide member arrangement for handling the power supply cable for the X-ray tube.

These and other objects of the present invention will be apparent upon reading the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a perspective view of the apparatus in accordance with the present invention showing the X-ray tube positioning apparatus including the power supply cable handling apparatus;

Fig. 2 is an end view of a portion of the apparatus taken in a direction parallel to the transverse support track in accordance with the present invention;

Fig. 3 is a top view of a portion of the apparatus in accordance with the present invention;

Fig. 4 is a side view of a portion of the apparatus in accordance with the present invention;

Fig. 5 is a partial perspective view of a portion of the apparatus in accordance with the present invention; and

Figs. 6 through 10 are schematic views of a portion of the apparatus in accordance with the present invention showing the operation of the X-ray tube support and positioning apparatus to show how the apparatus can be extended and folded or inverted.

Referring to Fig. 1 of the drawings, there is shown X-ray tube positioning and support apparatus in accordance with the present invention as this apparatus may be set up in a typical X-ray examination room. A pair of first support track members **10** are positioned in a first direction along opposite walls of the examination room,

such as, for example, parallel to the greatest or longitudinal dimension of the room. Each of these track members **10** includes a rail surface **12** along which the X-ray support apparatus moves on suitable rollers or the like. One of the track members **10** includes an X-ray tube power supply cable guide or handling apparatus **14** for the cable **16**. A pair of second or transverse track members **18** are provided for supporting the X-ray tube positioning apparatus. The latter or second track members **18** move along the first track members **10** for any desired degree or length of the provided room. An X-ray tube housing **20** is supported through a tube yoke member **22** and a tube support arm **24** by means of a support link member **26**, which is connected between a first movable support carriage member **28** and a second movable support carriage member **30**. A radius arm **32** is connected between the second carriage member **30** and the link member **26**. The power supply cables **16** are connected between suitable source terminals **34** and pass through the first cable guide member **14** and one or more second cable guide members **36**. The illustration of Fig. 1 shows one of the second cable guide members **36** is provided within each of the pair of transverse track members **18**.

In Fig. 2, there is shown a view of a portion of the apparatus shown in Fig. 1 taken in a direction parallel to the pair of second or transverse track members **18**. In Fig. 2, there is also shown the first or inner support carriage member **28** and the second or outer support carriage member **30**. The second carriage member **30** is in the form of a saddle member which includes a top portion **38** and a pair of downward support arms **40** between which the inner carriage member **28** can pass and also between which the rail portions **42** of the respective second track members **18** are positioned. The outer carriage member includes at least one support roller **44** for each of the support arms **40**, which support rollers **44** roll on the rail portions **42** of each second track member **18**. The inner carriage member **28** includes support rollers **46** which also ride on the rail portions **42** of the second track members **18**. The power supply cables **16** are shown passing from the source terminals **34** through the respective first cable guides **14** and the second cable guides **36** to the support link member **26** of the inner carriage member **28** through which they pass to the tube support arm **24** and the tube yoke **22** to the X-ray tube within the tube housing **20**.

The support link member **26** includes a pair of extension arms **48** which are pivotally connected to the inner carriage member **28** at the pivot connections **50**. The link member **26** is pivotally connected to the radius arms **32** at the pivotal connections **52**. The radius arms **32** are similarly pivotally connected to the downward extending arms **40** of the outer carriage member **30** at pivotal connections **54**.

A tube position synchronizing member or chain **56** is provided within the link member **26** and is connected between a sprocket **58** which rotates through the pivotal connections **52** with the radius arms **32**, and a second sprocket member **60** which rotates through the pivotal connection **62** with the tube arm **24**.

A trimmer weight **64** is provided within the link member **26** and is connected to an adjustable trimmer weight control knob **66** which is operative with a slot **68** in the link member **26**.

A suitable counterbalancing member is provided, which is illustrated as including four tension springs **70**, which are connected through a counterbalance cable **72** which passes over crossover or first pulleys **74** and second support pulleys **76** which are connected to the respective downward extending support arms **40** of the outer car-

riage member 30 and around a support pulley 78 on each of the radius arms 32.

With reference to Fig. 3, there is shown the tension springs 70 connected at one end to an anchor member 80 which is rigidly connected between the second track members 18. The other end of each of the spring members 70 is connected to a connector member 82 to which each of the counterbalance cables 72 are connected. Each of the pair of cables 72 from the connector member 82 passes around the first or crossover pulley members 74 to a first of the second pulley members 76 of the outer carriage member 30 and then around the support pulley 78 connected to the radius arm 32, and then back over a second of the second support pulley members 76 of the outer carriage member 30 and back to a second connection 84 to the anchor member 80. The inner carriage member 28 is shown in Fig. 3 displaced from between the support arms 40 of the outer carriage member 30. The link member 26 is shown connected between the radius arms 32 at the pivotal connections 52, and the extending arms 48 of the link member 26 are shown connected to the opposite sides of the inner carriage member 28 at the pivotal connections 50. The power supply cable 16 is shown passing from the link member 26 to a position within the second cable guide member 36 and then through the first cable guide members 14.

The second track members 18 are connected between end interconnecting members 86 with the latter members including support rollers 88 which ride on the rail surfaces 12 of the first track members 10. Lateral support rollers 90 are provided for the end support members 86, which latter support rollers 90 also are operative with an upright portion of the support rails 12 of the first track members 10.

In Fig. 4, there is shown a partial section side schematic view of the apparatus in accordance with the present invention showing the X-ray tube housing 20 held by the tube yoke 22 and the tube arm 24 which latter arm 24 is pivotally connected to the link member 26 at the pivotal connection 62. The sprocket member 60 is provided at the pivotal connection 62 and is operative through a synchronizing chain or like member 56 with another sprocket member 58 provided at the pivotal connection 52 between the radius arm 32 and the link member 26. Preferably, the sprocket 60 has a ratio of 2:1 as compared to sprocket 58 for the particular apparatus illustrated. This sprocket ratio is determined by the dimensions of the link member 26 and the radius arm 32. The link member 26 is pivotally connected to the inner carriage member 28 at pivot connection 50. Each of the radius arms 32 is pivotally connected to one of the downward support arms 40 of the outer carriage member 30 at the pivotal connection 54. The power supply cable 16 is shown passing from the first cable guide 14 to the second cable guide 36 and then down to the link member 26. The rail portion 12 of the first track member 10 is shown operative with the support rollers 88 of the end support member 86 which is connected between the second track members 18. The support rollers 46 of the inner carriage member 28 are shown to be operative with the rail section 42 of one of the second track members 18. The support roller 44 of the outer carriage member 30 is shown operative with the rail surface 42 of one of the second track members 18. One of the tension spring members 70 is shown connected between the anchor member 80 of the transverse end support member 86 and the counterbalance cable 72. The latter cable 72 passes around a first or crossover pulley 74 and then back to a first of the support pulleys 76 of the outer carriage member 30. The cable 72 then passes around the pulley 78 connected to the radius arm 32 and back over a second of the support pulleys 76 of the outer carriage member 30, from which it passes to the second anchor connection 84 as shown in Fig. 3.

In Fig. 5, there is shown a partial section and perspective view of a portion of the apparatus in accordance with the present invention, showing in more detail the arrangement of the tension spring members 70 connected between the anchor member 80 and the connector member 82. The counterbalance cable 72 is shown connected to the connector member 82 and passing around one of the crossover pulley members 74, each of which latter pulley members is pivotally connected to one of the second track members 18. A suitable brake member 75 is provided to lock the movement of the pulley 74, with a friction stop member 77 being provided to engage the pulley 74 as desired. The counterbalance cable 72 then passes around the first of the support pulleys 76 of the outer carriage member 30, around the pulley 78 which is pivotally connected to one of the radius arms 32, and then back over the second of the support pulleys 76 of the outer carriage member to the connection 84 with the anchor member 80. A suitable brake member 79, which may be electrically operated, is provided to effectively lock the outer carriage member 30 to the rail surface 42 of the second track member 18. A friction stop member 81 is provided to actually engage the rail surface 42.

The support roller 44 of the outer carriage member 30 is shown riding on the rail surface 42 of one of the second track members 18. The inner carriage member 28 is shown with its support rollers 46 rolling on the rail surfaces 42 of the respective second or transverse track members 18. The link member 26 is shown pivotally connected to the inner carriage member 28 at pivotal connection 50. The tube arm 24 is shown connected to the tube yoke 22 and the housing for the X-ray tube 20. The tube arm 24 is pivotally connected to the link member 26 at pivotal connection 62. The synchronizer chain or like member 56 is shown passing around the sprocket member 58 which rotates with the radius arm 32 relative to the link member 26. The trimmer weight 64 is adjustable along the slot 68 within the link member 26 by means of the adjustable control member or knob 66.

In Figs. 6 through 10, there is schematically illustrated the operation of the inner carriage member 28 relative to the outer carriage member 30 along the rail surfaces 42 of the respective second or transverse track members 18. The link member 26 is shown pivotally connected between the inner carriage member 28 and the radius arm 32 which latter radius arm 32 is pivotally connected to the outer carriage member 30. The X-ray tube housing 20 is shown held by the tube yoke 22 and the tube arm 24, which tube arm 24 is pivotally connected to the link member 26.

In Fig. 6, there is shown an extended position of the inner carriage member 28 relative to the outer carriage member 30, and the X-ray tube within the housing is vertically positioned somewhere between its highest position and its lowest position.

In Fig. 7, the tube housing 20, and hence the X-ray tube within it, has been lowered by moving the inner carriage member 28 closer to the outer carriage member 30.

In Fig. 8, the tube housing 20 is shown in its lowermost position with the inner carriage member 28 positioned immediately within the outer carriage member 30.

In Fig. 9, the tube housing 20 has been vertically raised relative to the position shown in Fig. 8, and in Fig. 9, the inner carriage member 28 has passed between and beyond the outer carriage member 30, such that there is now a separation between these two carriage members.

In Fig. 10, the uppermost position of the tube housing 20 is shown with the inner carriage member 28 separated from the outer carriage member 30 such that tube arm 24 and tube yoke 22 are allowed to pass between the pair of rail surfaces 42 of the respective second or transverse track members 18.

In the operation of the apparatus shown in Figs. 1 through 10, the tube housing 20 is supported by an accurate counterbalance support or positioning apparatus and

the position of the X-ray tube within the tube housing **20** may be varied to cover a patient or object in a great variety of positions within the X-ray room shown in Fig. 1. More specifically, straight-line vertical movement of the X-ray tubehead can be obtained with the positioning apparatus fully counterbalanced in any position of the tubehead, and the linkage arrangement between the inner and outer carriage members may be extended and folded to permit maximum room coverage by the X-ray tube within the tube housing **20**. More specifically, the pair of second track members **18** are rigidly held in position relative to each other between end support members **86** and as a unit may be moved along the first track members **10** to longitudinally position the X-ray tube housing **20**, as may be desired. The inner carriage member **28** and the outer carriage member **30** may be moved along the second track members **18**, as desired, to transversely position the tube housing **20**.

If only vertical movement of the tube housing **20** is desired, the outer carriage member **30** may be fixed in position by a suitable locking or brake member **79** relative to the transverse or second track members **18**, and as the tube housing **20** is raised or lowered, the radius arms **32** rotate around the pivotal connections **54** and the inner carriage member **28** is thereby moved along the rail surfaces **42** of the respective second track members **18**, such that a constrained vertical straight-line motion of the tube housing **20** results. On the other hand, if the horizontal positioning of the tube housing **20** is desired without vertical movement, the crossover pulleys **74** may be locked in position by a suitable locking member **75** to prevent their rotation relative to the track members **18**, and the inner carriage member **28** and the outer carriage member **30** may be moved along the second track members **18** to any such horizontal position that may be desired. A very accurate weight counterbalance is provided by means of the tension spring members **70** and the counterbalance cable **72** passing around the support pulley members **76** on the outer carriage member **30** and the support pulley **78** on each of the radius arms **32**. A prior art teaching of the use of a spring member having a straight-line stress-strain relationship to provide a flexible or variable moment equal and opposite to a weight which rotates around a pivot point can be found in the "Transactions of the American Society of Mechanical Engineers" vol. 73 for 1951, pages 141 through 145 in an article entitled "Accurate spring counterbalancing" by W. S. Rouverol.

As the tube housing **20** is raised or lowered, the counterbalancing cable **72** effectively lengthens or shortens the tension spring members **70** to provide the desired counterbalance force for the weight of the X-ray tube **20** and any other parts of the positioning apparatus, the weight of which it is desired to counterbalance. The trimmer weight **64** can be moved within the slot **68** to compensate for a heavier or lighter X-ray tube or tube cone within the tube yoke **22**. For example, when using a heavy tube cone for the X-ray tube within the X-ray housing **20**, the trimmer weight **64** may be locked within the slot **68** at a position farthest away from the tube arm **24**, and to compensate for removal of such a cone, the trimmer weight **64** may be slid toward the other end of the slot **68** to a position closer or closest to the tube arm **24**.

The synchronizer chain or like member **56** is operative to maintain proper orientation between the tube arm **24** and the link member **26** such that the X-ray tube is properly aligned with the patient as the inner carriage member **28** is moved into position either closer to or further away from the outer carriage member **30** to fold or extend the linkage arrangement. In this respect, a 2:1 sprocket ratio between the sprockets **60** and **58** has been found to be desirable, with the sprocket **58** being fixed in position relative to the radius arm **32** and the sprocket **60** being fixed in position relative to the tube arm **24**.

In the operation of the first power supply cable guide **14** and the second power supply cable guide **36**, the power supply cable **16** is rather heavy and may have a diameter of the order of ⅞ inch or more, and a minimum permissible bending radius of the order of 3 inches or more. In addition the X-ray tube is mounted in positioning apparatus which allows the X-ray tube to travel longitudinally the full length of the room and transversely the full width of the room. Therefore, the cable guide arrangement shown particularly in Fig. 1 should support the power supply cable **16** such that there is no objectionable and variable weight drag to affect the position of the tube housing **20**. The power supply cable **16** enters the first cable guide **14** from the bottom and is clamped to the first cable guide **14** where it so enters the latter guide. The power supply cable **16** is then passed along the bottom of the cable guide **14** for a predetermined distance from which point it is looped back on itself. The free end of the power supply cable **16** is then introduced into the bottom of the second cable guide **36**, where it is fastened to the latter guide. The power supply cable **16** is then passed along the bottom of the second cable guide **36** and looped back on itself with the free end then passing down to the link member **36** through which it passes to supply power to the X-ray tube within the X-ray housing **20**. Practically the only friction force which is involved and which must be overcome is internal bending friction of the power supply cable **16** itself within the respective cable guides **14** and **36**, and the very slight frictional drag where the power supply cable **16** passes over the lip **15** of the respective cable guides, as shown in Fig. 4.

Although specific embodiments of the present invention have been shown and described, it is to be understood that still further modifications thereof can be made without departing from the spirit and scope of the invention. For example, the outer carriage member **30** may be subjected to a twisting or turning moment due to the tension in the counterbalance cable **72** passing around the pulley **78** on the radius arm **32**, so the provision of two pairs of spaced rollers **44** operative with the rail section **42** might be desirable to resist this moment. In this respect one pair of the rollers would be placed above the rail section **42** and the other pair placed below the rail section **42**.

We claim as our invention:

1. In positioning apparatus for an X-ray generator, a track member, a support member movable along the track member including a first carriage member and a second carriage member movable relative to said first carriage member in a direction parallel to said track member; a link member adapted to pivot to different angular positions in a vertical plane about said first carriage; a radius arm for connecting said link member and said second carriage, with said link member and said arm being provided to jointly support said X-ray generator in different vertically spaced positions; and counterbalance means for equilibriating the weight of said X-ray generator, said counterbalance means including a first portion, a second and intermediate resilient means joined at opposite ends thereto, respectively, means for holding said first portion in fixed position relative to said track, and flexible tensioning means for operating the resilient means, said tensioning means being connected to said second portion and extending to said link member at a predetermined point intermediate the ends thereof such that said flexible tensioning means continuously subjects said link member to a moment substantially equal to the product of the weight of said X-ray generator times the horizontal distance between the ends of said link member.

2. Apparatus for variably positioning an X-ray generator to project a radiation beam through an object to be examined comprising a support frame having a horizontally extending track, carriage means supported on

said track for horizontal movement therealong, a link member carrying an X-ray housing and pivotally connected to said carriage means for tilting movement to different angular positions with respect thereto to raise and lower said X-ray tube housing, and counterpoise means to equilibriate the weight of said link member and housing at all vertically and horizontally shifted positions thereof, said counterpoise means comprising a helical tension spring member having one end fixedly secured to said support frame, a first and a second pulley supported on said carriage means, a third pulley carried on said link member intermediate the ends thereof, and a flexible cable extending from the opposite end of said tension spring member over said first pulley, downwardly to and around said third pulley, over said second pulley and finally being attached to said frame.

3. In X-ray apparatus comprising an X-ray tube housing, a horizontal overhead track, first and second carriages movable one relative to the other along said track, a link member tiltable to different angular positions with respect to the vertical about a pivotal connection with said first carriage at one end and carrying said X-ray tube housing at its opposite end for vertical movement of same, a pulley mounted on said second carriage, flexible tensioned means passing over said pulley and having a force-applying connection with said link member intermediate its ends for subjecting said link member to a counter-moment substantially equal to the moment to which said link member is subjected due to its own weight and that which it carries when disposed in said angular positions, and means interconnecting said first and second carriages to separate same in degree according to said angular positions, thereby changing the orientation of said pulley and of said tensioned means with respect to said link member for changing the effectiveness of a given tension force applied by said tensioned means to said link member correspondingly with change in weight-induced moment resultant from change in angular position of said link member.

4. X-ray apparatus comprising an X-ray tube housing, a horizontal overhead track, carriage means movable along said track between travel limit stations, a link member tiltable vertically to different angular positions about a pivotal connection of its one end with said carriage means and carrying said X-ray tube housing at its opposite end for vertical movement of same, first and second pulley means carried by said carriage means and said link member, respectively, and flexible tensioned means extending longitudinally of said track between said travel limit stations while passing over said first pulley means and under said second pulley means whereby a counterbalancing lift force is applied by said tensioned means to said link member while permitting travel of said link member and carriage means in unison longitudinally of said track without influencing the tensioned state of said flexible tensioned means which is free to pass over said first and second pulley means during such travel.

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