April 15, 1958 W. J. DALY 2,831,123

X-RAY FLUOROSCOPIC DEVICE

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Fig. 1.

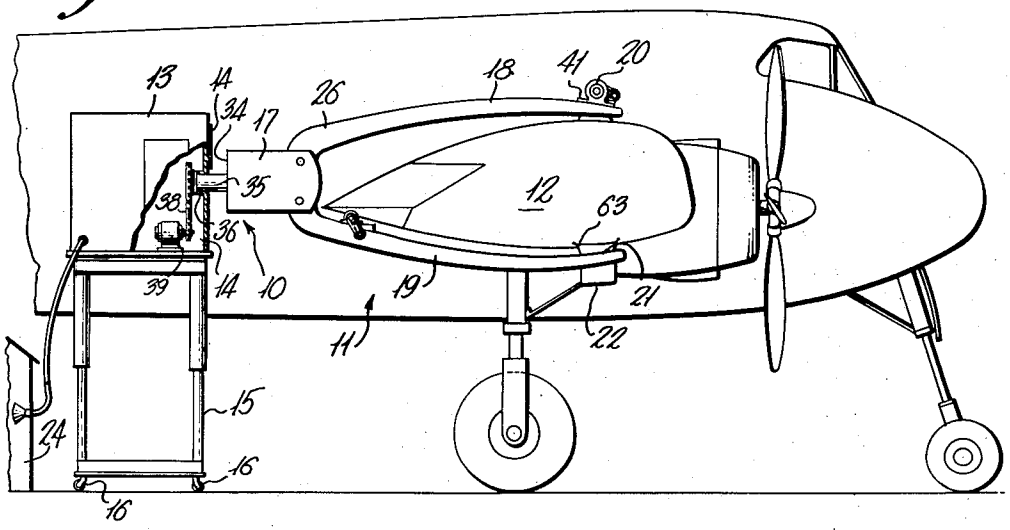
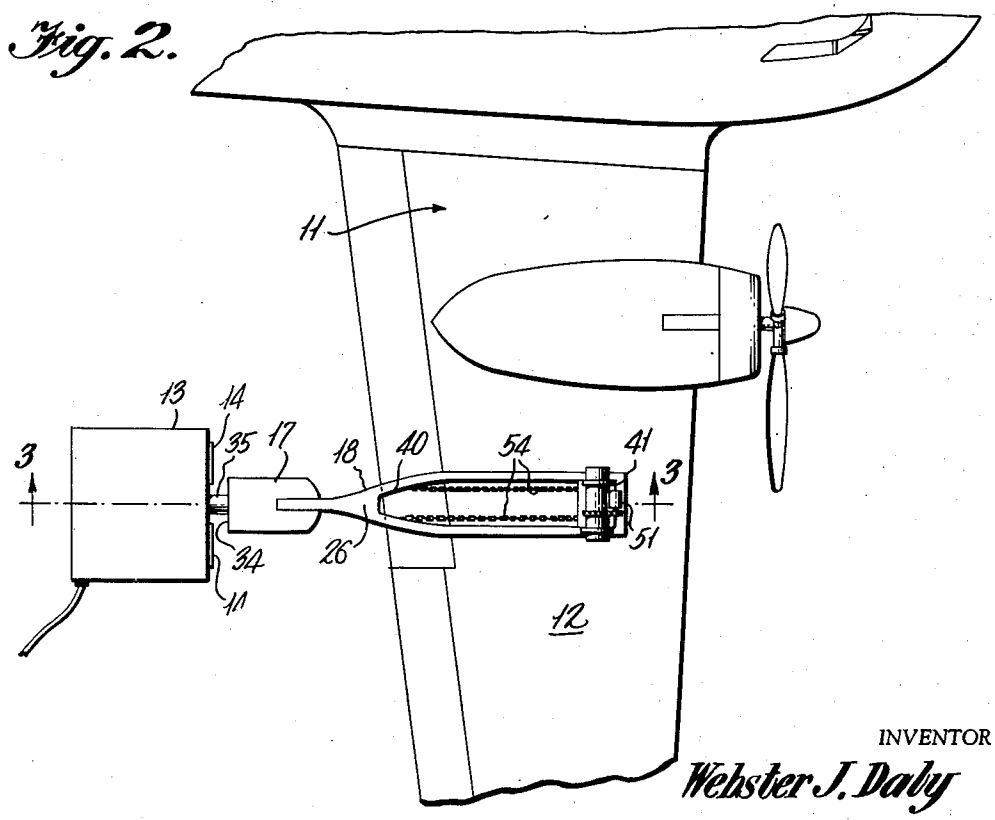


Fig. 2.



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Fig. 3.

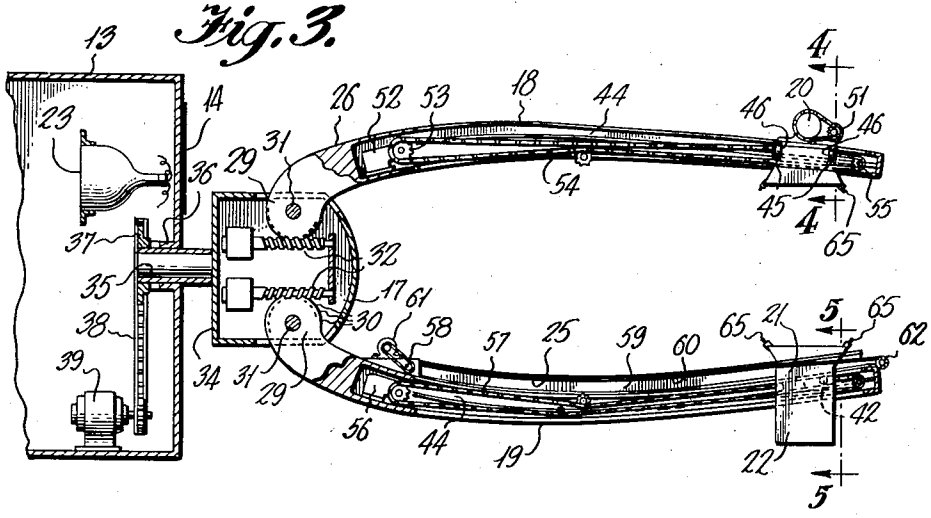


Fig. 4.

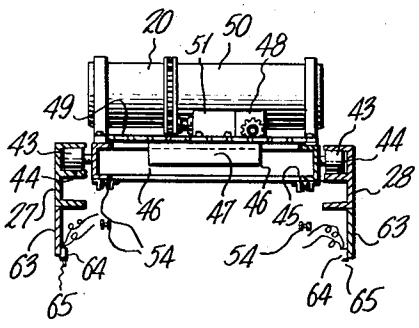
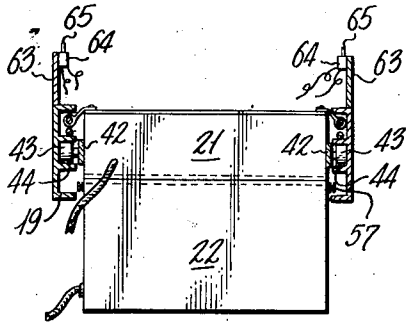


Fig. 5.



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X-RAY FLUOROSCOPIC DEVICE

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8 Claims. (Cl. 250—91)

The present invention relates in general to mobile supporting apparatus for equipment for use in the inspection and structural analysis of manufactured structures, metallurgical studies, and the like, and more particularly to mobile X-ray supporting apparatus for X-ray inspection and analysis of air frame structures and components thereof.

X-ray equipment for inspection and analysis of structures is by nature rather cumbersome and difficult to manipulate, particularly when employed in such applications as X-ray analysis of large manufactured articles and structures. This arises both from the character of the X-ray facilities, and from the fact that the source of X-ray energy and the visualizing facility such as the fluorescent screen, photographic plates or the like, must be located so that the structure being analyzed is interposed between the source and the visualizing facility along the principal emission axis of the source. Such equipment is difficult to manipulate with the precision necessary for accurate X-ray analysis and, when used on industrial locations, presents substantial problems in protection of the X-ray equipment against damage and avoidance of accidental exposure of the photographic plates arising from spurious radiation. Also, there is always present the problem of affording adequate protection to personnel against exposure to X-ray energy.

An object of the present invention, therefore, is the provision of novel apparatus for supporting X-ray equipment adapted for the inspection and analysis of structures, structural components and the like which has a high degree of mobility and which is arranged to facilitate precise location of the X-ray source and visualizing facilities relative to the structure being inspected.

Another object of the present invention is the provision of novel mobile supporting apparatus for industrial X-ray equipment and the like wherein provision is made for precise independent control of the X-ray source and visualizing components from protected remote locations.

Another object of the present invention is the provision of novel mobile supporting apparatus for industrial X-ray equipment having facilities for remote visual inspection of the X-ray image and for remote control of photographic plates to shift the same between exposure locations and exposure-preventing facilities.

Another object of the present invention is the provision of novel mobile supporting apparatus for industrial X-ray equipment having means for producing stereoscopic and planographic X-ray records subject to precise control from protected remote locations.

Other objects, advantages and capabilities of the present invention will become apparent from the following detail description taken in conjunction with the accompanying drawings, showing only a preferred embodiment of the invention.

In the drawings:

Figure 1 is a side elevation of an industrial X-ray supporting unit with parts of the control cab broken away

to reveal the interior thereof, the unit being illustrated in a position of use;

Figure 2 is a top plan view of the industrial X-ray supporting unit;

Figure 3 is a vertical longitudinal section view taken along the line 3—3 of Figure 2;

Figure 4 is a vertical transverse section view illustrating the structure of the terminal portion of the upper X-ray tube supporting arm taken along the line 4—4 of Figure 3;

Figure 5 is a vertical transverse section view illustrating the construction of the terminal portion of the lower visualizing facility supporting arm taken along the line 5—5 of Figure 3.

Referring to the drawings wherein like reference characters designate corresponding parts throughout the several figures, the industrial X-ray unit of the present invention, generally indicated by the reference character 10, is illustrated in Figures 1 and 2 in a typical position in use in relation to an airplane 11, as an illustrative example, to make an X-ray inspection of the structure of the wing 12 of the airplane in connection with studies of the internal structure of the metal and the like. The X-ray unit 10 comprises in general an operator's cab 13 in the form of a generally rectangular enclosure of sufficient size to conveniently accommodate a human operator, which is suitably shielded as by lining the same with lead to protect the operator against exposure to Roentgen radiation. One wall of the operator's cab 13 preferably contains a plurality of windows 14 fitted with lead glass, or like optically transparent protective material which is substantially impervious to X-rays, to give the operator a clear view of the work field. The operator's cab 13 is preferably supported on a hydraulic or electrical hoist framework 15 to support the cab at selected elevations above the ground level or floor level in the working area under the control of the operator, the hoist 15 having friction relieving means 16 such as wheels, casters or the like, for ease of mobility of the X-ray unit. Projecting from the wall of the operator's cab 13 having the windows 14 therein, is a control hub or mechanism housing 17 having a pair of bowed arms 18, 19 which project along shallow arcuate paths arching away from each other from pivotal mountings at the inner ends of the arms 18, 19 within the control hub 17. The outer terminal portion or free end of the uppermost arm 18 supports an X-ray tube 20 for adjustment in a manner to be later described, and the terminal portion of the lowermost arm 19 movably supports a conventional fluoroscope 21, and a television camera 22 arranged to detect the fluoroscope image and transmit the same to television monitor tubes 23 connected by a closed circuit television network to the television camera 22 and located within the operator's cab 13 and any one or more of a plurality of remote viewing stations such as an office, a supervising booth or the like, one of which is schematically illustrated at 24 in Figure 1. Additionally, means are provided in the lowermost arm 19 for positioning a photographic plate or film, generally indicated at 25, in overlying relation to the fluoroscope 21 for permanently recording the X-ray image of the subject field.

The bowed arms 18 and 19, as more clearly appears in Figures 3–5 are each formed of channel-shaped elongated structural members over the major portion of the arms 18, 19, comprising a web 26 and channel sides 27, 28. The inner end portions of the arms 18, 19 are provided with enlarged toothed segments 29 having teeth 30 along the arcuately curved peripheries of the toothed segments 29, and are pivotally supported for movement within a plane intersecting the horizontal axis of the control hub 17 on pivots 31 fixed to the wall of the hub 17.

The teeth 30 of the toothed sectors 29 of the arms 18, 19 project toward each other from their pivots 31 to a location adjacent the horizontal axis of the hub 17 and are meshed with worms 32 arranged in parallelism with the horizontal axis of the hub and journalled in suitable bearings projecting from the walls of the hub. The worms 32 are driven independently by reversible electric motors 33 supported within the hub 17 adjacent its rear wall 34 and controlled by suitable switches in their supply circuits located within the operator's cab 13. By selective energization of the reversible motors 33 under control of the switches in the operator's cab 13, the worms 32 can be driven to rotate the bowed arms 18, 19 toward or away form each other, independently or synchronously, about their pivots 31 to desired positions of adjustment, whereby the arms 18, 19 may be conditioned to accommodate between them the structural subject such as the airplane wing 12 in proper relation to intercept the X-ray energy emanating from the X-ray tube 20 toward the fluoroscope 21.

Projecting from the rear wall 34 of the control hub 17 is a hollowed shaft 35 which is integral with the control hub 17 and is in coaxial relation with the projected horizontal axis of the hub 17. The hub shaft 35 is journalled for rotation about its axis in a suitable bearing 36 in the adjacent wall of the operator's cab 13. A sprocket 37 is mounted on the end of the hub shaft 35 which projects beyond the inner end of the bearing 36 to be driven by a chain 38 trained about a suitable sprocket on a reversible electric motor 39 located within the operator's cab 13 for effecting rotation of the control hub 17 and its associated arms 18, 19 about is axis. Suitable switches controlling the energizing circuit of the reversible motor 39 are also provided within the cab 13 for facilitating control of the chain drive for the hub 17.

As is illustrated in Figure 2, each of the bowed arms 18, 19 are provided with transversely enlarged regions extending over a substantial distance adjacent their free ends, and over a major portion of these transversely enlarged regions the webs 26 of the arms 18, 19 are provided with an elongated opening 40 for accommodating carriages 41 and 42 for longitudinal movement along the arms 18, 19. The carriages 41, 42 are each provided with rollers or wheels 43 projecting laterally therefrom relative to the axis of movement of the carriages 41, 42 which are received within inwardly opening tracks 44 formed along the channel sides 27, 28 and bounding the openings 40 to guide the carriages 41, 42 during movement longitudinally of the arms 18, 19. The carriage 41 supported on the uppermost arm 18 is provided with inwardly opening tracks 45 which extend transversely of the longitudinal axis of the arm 18 to receive rollers or wheels 46 projecting from a tube carriage 47 to accommodate the tube carriage for movement transverse of the longitudinal axis of arm 18 for the purpose of making stereoscopic X-rays. To effect remote control of this transverse movement of the tube carriage 47 in connection with stereoscopic X-ray exposures, a reversible electric motor 48 is mounted on the tube carriage 47 and is associated with a chain 49 affixed at its opposite ends to lateral margins of the carriage 41 to draw the carriage 47 back and forth along the carriage 41 during rotation of the motor 48. Suitable switches are provided in the operator's cab 13 for controlling energization of the motor 48.

The tube carriage 47 is designed to support the X-ray tube 20 and comprises a bearing housing schematically indicated at 50 to support the X-ray tube 20 for rotation through an arc of 360° about a horizontal axis extending transversely of the longitudinal axis of the arm 18, and a reduction gear motor 51 for rotating the X-ray tube 20 within its bearing 50.

A reversible electric motor 52 is supported on the upper arm 18 rearwardly of the opening 40, which is controlled by suitable switches located within the operator's cab 13, for driving a sprocket 53 about which is trained a chain 54. The chain extends longitudinally of the arm 18 and is likewise trained about an idler pulley or sprocket 55, and the two ends of the chain are anchored to the carriage 41 to draw the carriage inwardly and outwardly along the arm 41 in response to energization of the motor 52.

The carriage 42 supported on the tracks 44 of the lowermost arm 19 supports a fluoroscope 21 and television camera 22 within the elongated opening 40 of the arm 19 for movement inwardly and outwardly along the arm 19 under control of a reversible electric motor 56 and a chain drive 57. A lead-shielded film safe 58 is also supported on the lower arm 19 adjacent the rear end thereof for accommodating photographic plates which are desired to be stored in condition for protecting them from exposure to radiation from the X-ray tube 20 until exposure is desired. Guide means 59 such as guide tracks or the like extend along the lower arm 19 above the guide tracks 44 thereon from the film safe 58 to a position overlying the fluoroscope 21, and a chain 60 or other suitable conveyor driven from an electric motor 61 extends from the film safe 58 along the arm 19 and about an idler pulley or sprocket 62 disposed beyond the film exposure position for withdrawing a photographic plate from the film safe 58 and shifting the same to a position overlying the fluoroscope 21 to permit a permanent record of the X-ray image to be recorded.

By the above structure the operator in the control cab 13 may exercise full control over the arms 18 and 19 supporting the X-ray tube 20, the fluoroscope 21, the television camera 22, and the photographic plate positioning mechanism to perform the various operations necessary to complete an X-ray study of manufactured structures and the like with a high degree of convenience and accuracy and with full protection from exposure to X-radiation. The various components necessary for accomplishment of the fluoroscopic examination and the permanent photographic record of the X-ray image may be effectively positioned in proper location to inspect the internal metal structure of relatively thin bodies, such as the airplane wing 12, by manipulation of the motors 39 and 33 to position the arms 18, 19 in proper relation to direct the X-ray energy from the tube 20 through the structure and onto the fluoroscope 21. The present structure facilitates the production of stereoscopic exposures, since the X-ray tube 20 can be shifted from side to side transversely of the longitudinal axis of the upper arm 18 by energization of the motor 48 to position the tube carriage 47 at laterally spaced exposure positions, and energization of the motor 51 to orient the X-ray tube 20 relative to its axis so as to properly direct the X-ray energy along a major propagation axis from such spaced locations onto the fluoroscope 21.

Production of planographic X-ray exposures is likewise facilitated. To accomplish this, the operator, after properly positioning the X-ray tube 20 and fluoroscope 21 at an appropriate initial location, will simultaneously energize the motors 52 and 56 to gradually shift the X-ray tube 20 and fluoroscope 21 correspondingly or oppositely toward or away from the operator's cab 13.

If records are desired of X-ray analysis of enclosure walls or other structural bodies, such as the side walls of an airplane cabin so located that the lower arm 19 cannot be positioned to receive the wall between the arms 18, 19, the upper arm 18 may be pivoted upwardly to a position wherein the X-ray energy can be radiated along a substantially horizontal axis away from the cab 13, and a photographic plate or the fluoroscopic unit formed by the fluoroscope 21 and television camera 22 placed within the enclosure or cabin to image the X-ray pattern.

As is illustrated in Figures 3–5, suitable projecting guard frames 63 may be provided on the arms 18, 19 to project toward each other and extend below and above

the X-ray tube **20** and fluoroscope **21**, respectively, the frames **63** being preferably of truncated triangular configuration with their major bases projected from the arms. Microswitches **64** are provided on the corners of these guard frames **63** and have fingers **65** projecting from one of the electrical contacts of each of the microswitches to engage the structure being studied such as the airplane wing **12**, when either the X-ray tube or the fluoroscope approaches too near the wing and automatically close the associated microswitch **64**. The microswitch **64** will be electrically connected with suitable relays or the like to open the energizing circuits to the various electric motors controlling movement of the components of the X-ray positioning assembly to prevent further movement of the X-ray tube **20** or fluoroscope **21** to a position which may damage these components. The attention of the operator is thereby directed to the improper positioning of the X-ray components so that he can make suitable adjustments to avoid damage to the components.

While only one preferred embodiment of the invention has been particularly shown and described, it is apparent that other modifications may be made in the invention without departing from the spirit and scope thereof, and it is desired, therefore, that only such limitations shall be placed thereon as are imposed by the prior art and are set forth in the appended claims.

I claim:

1. Industrial X-ray apparatus for X-ray analysis and inspection of structural test objects and the like comprising an operator's enclosure shielded against penetration of X-radiation through the walls thereof, means supporting said enclosure for movement along a surface, a pair of elongated arms projecting from said enclosure for reception of a test object between the remote ends thereof, an X-ray tube supported on the remote end of one of said arms, X-ray imaging means supported on the remote end of the other of said arms, means supporting said arms on a wall of said enclosure for rotation as a group about a horizontal axis projecting from said enclosure wall and for coplanar pivotal movement toward and away from each other about axes adjacent the inner end of said arms and extending perpendicular to said horizontal axis, means for driving said arms about said axes, and means located in said enclosure for controlling said driving means.

2. Industrial X-ray apparatus for X-ray inspection and analysis of structural test objects and the like comprising an operator's enclosure shielded against X-radiation, mobile supporting means for said enclosure for adjustably positioning the same at selected elevations above a supporting surface, a hub member supported in one wall of said enclosure for rotation about a horizontal axis, a pair of elongated arms projecting from said hub member for reception of a test object between the remote ends thereof, an X-ray tube supported on the remote end of one of said arms, X-ray imaging means on the remote end of the other of said arms, said X-ray tube and fluorescent screen having an interconnecting axis intercepting the test object when the same is disposed between said arms, means pivotally mounting the inner ends of said arms on said hub member for coplanar pivotal movement toward and away from each other and from said horizontal axis, driving means for rotating said hub member, driving means for rotating said arms about their pivotal axes independently and synchronously, remote control means for operating said driving means from a location within said enclosure, and means for producing a viewable image of the fluorescent screen image within said enclosure.

3. Industrial X-ray apparatus for X-ray inspection and analysis of structural test objects and the like comprising an operator's enclosure shielded against X-radiation, mobile supporting means for said enclosure for adjustably positioning the same at selected elevations above a supporting surface, a hub member supported in one wall of said enclosure for rotation about a horizontal axis,

a pair of elongated arms projecting from said hub member for reception of a test object between the remote ends thereof, an X-ray tube supported on the remote end of one of said arms, X-ray imaging means on the remote end of the other of said arms, said X-ray tube and fluorescent screen having an interconnecting axis intercepting the test object when the same is disposed between said arms, means pivotally mounting the inner ends of said arms on said hub member for coplanar pivotal movement toward and away from each other and from said horizontal axis, driving means for rotating said hub member, driving means for rotating said arms about their pivotal axes independently and synchronously, remote control means for operating said driving means from a location within said enclosure, carriage means for supporting said X-ray tube, carriage means for supporting said fluorescent screen, means on the remote end portions of said arms supporting said carriage means for rectilinear movement longitudinally and transversely of said arms, means controllable from said enclosure for driving said carriage means, and means for producing an observable image in said enclosure of X-ray images of the test object formed on said fluorescent screen.

4. Industrial X-ray apparatus for X-ray inspection and analysis of structural test objects and the like comprising an operator's enclosure shielded against X-radiation, mobile supporting means for said enclosure for adjustably positioning the same at selected elevations above a supporting surface, a hub member supported in one wall of said enclosure for rotation about a horizontal axis, a pair of elongated arcuate arms projecting from said hub member in oppositely curving relation with each other and with said horizontal axis for reception of a test object between the remote ends thereof, an X-ray tube supported on the remote end of one of said arms, X-ray imaging means on the remote end of the other of said arms, said X-ray tube and fluorescent screen having an interconnecting axis intercepting the test object when the same is disposed between said arms, means pivotally mounting the inner ends of said arms on said hub member for coplanar pivotal movement toward and away from each other about parallel spaced axes symmetrically spaced from and extending transversely of said horizontal axis, first driving means for rotating said hub member, second driving means located in said hub member for rotating said arms about their pivotal axes independently and synchronously, remote control means for operating said first and second driving means from a location within said enclosure, first carriage means for supporting said X-ray tube, second carriage means for supporting said fluorescent screen, track means on the remote end portions of said arms supporting said carriage means for rectilinear movement longitudinally of said arms, means for shifting said X-ray tube and said screen on their respective carriage means in directions extending transversely of said arms, means controllable from said enclosure for driving said carriage means along said track means and said tube and screen relative to their carriages, and means for producing an observable image in said enclosure of X-ray images of the test object formed on said fluorescent screen.

5. Apparatus for X-ray inspection and analysis of air frame structure and the like comprising an operator's cab, hoist means adjustably supporting said cab at selected elevations above supporting surface, wheel means on said hoist, means rendering the same mobile along said supporting surface, a hub member rotatably supported in projecting relation from one wall of said cab, a pair of elongated arms extending from said hub member within a projected plane of the axis of said hub member, means pivotally mounting one end of each of said arms on said hub member for independent movement toward and away from each other within said common plane, said arms having relatively divergent portions adjacent the pivoted ends thereof and terminating in re-

mote relatively converging portions, driving means coupled with said arms adjacent the pivoted ends thereof and coupled with said hub member for shifting said arms independently and synchronously about their pivots and rotating said hub member about its axis, means located within said cab for actuating said driving means, an X-ray tube, means supporting said X-ray tube adjacent the remote end of one of said arms for longitudinal and transverse movement relative to the axis of its associated arm and rotary adjustment about the axis of said tube, a fluorescent screen, means supporting said fluorescent screen on the other of said arms adjacent the remote end thereof for longitudinal and transverse movement relative to the axis of its associated arm, remote control means for positioning said X-ray and fluorescent screen on their associated arms and controllable from said cab, and means for producing a viewable image within said cab of the fluorescent screen image.

6. In industrial X-ray apparatus for X-ray inspection and analysis of structure test objects and the like, the combination recited in claim 3, wherein said means for producing an observable image in said enclosure comprises a closed circuit television system including a television camera rigidly supported on said carriage means associated with said fluorescent screen for sensing the X-ray images formed on said fluorescent screen, and television monitor tube means located in said enclosure for producing an image representative of the image sensed by said television camera means.

7. In industrial X-ray apparatus for X-ray inspection and analysis of structure test objects and the like, the combination recited in claim 4 wherein said means for producing an observable image in said enclosure comprises a television camera, means supporting said television camera in depending relation from said second carriage means to sense the X-ray images produced on said fluorescent screen, a television monitor disposed in said enclosure, and closed circuit television means for producing on the screen of said television monitor reproducers of the images sensed by said television camera.

8. In industrial X-ray apparatus for X-ray inspection and analysis of structure test objects and the like, the combination recited in claim 4 wherein said means for producing an observable image in said enclosure comprises a television camera, means supporting said television camera in depending relation from said second carriage means to sense the X-ray images produced on said fluorescent screen, a television monitor disposed in said enclosure, and closed circuit television means for producing on the screen of said television monitor reproducers of the images sensed by said television camera, and wherein means are provided for photographically recording X-ray images produced by X-ray emission from said X-ray tube through the test object comprising an X-ray protective safe supported on said arm associated with said fluorescent screen at a position spaced toward said enclosure from said fluorescent screen, and means controllable from said enclosure for withdrawing photographic film from said safe and position the same in overlying relation to said fluorescent screen to intercept X-rays emanating from said X-ray tube.

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