April 18, 1961

G. W. STEEN

2,980,800

X-RAY UNITS

Filed July 24, 1958

2 Sheets-Sheet 1

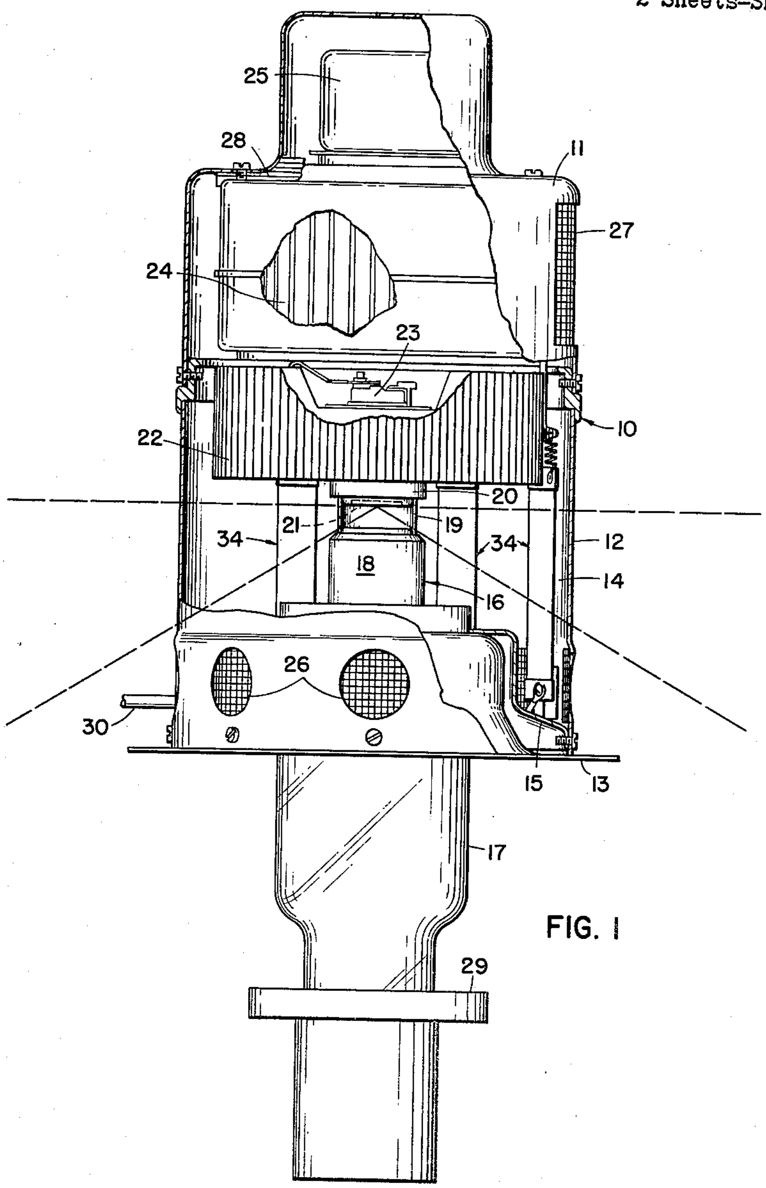

FIG. 1

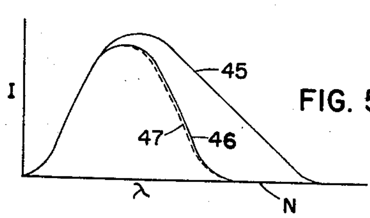

FIG. 5

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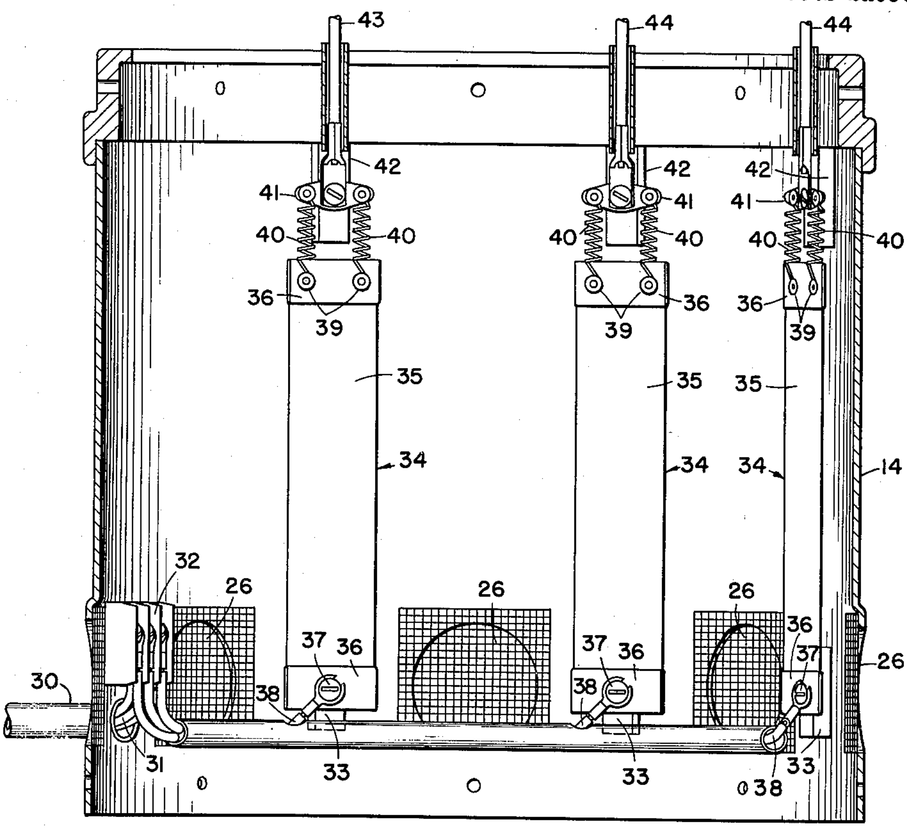

FIG. 2

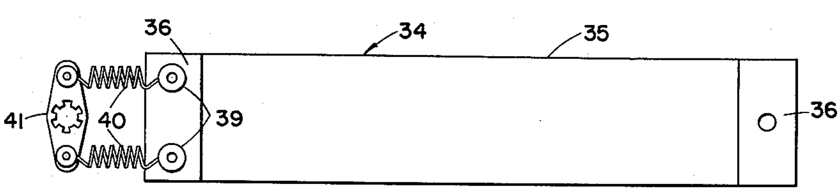

FIG. 3

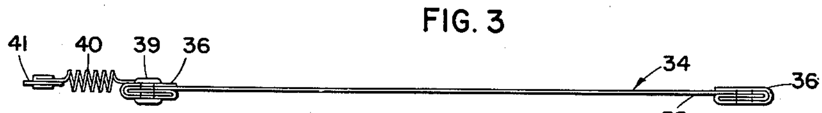

FIG. 4

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X-RAY UNITS

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4 Claims. (Cl. 250—90)

This invention relates to improvements in X-ray units adapted for use in radiographing annular sections of hollow bodies, and has particular reference to a new self-contained X-ray unit which is capable of producing, in a single exposure, a high quality radiographic picture of an entire weld, for example, of a pipe line.

When using a self-contained X-ray unit for radiographing the annular welds of a pipe line it is highly desirable to employ in the unit an X-ray tube which generates an X-ray beam extending throughout a radius of 360° completely encircling the unit. Such a 360° tube can thus be expected to radiograph the entire circumferential weld of a section of pipe line when inserted within the pipe substantially on the axis thereof and operated in that position.

In using a unit of this type it is necessary to drag or propel the unit substantially along the axis of the pipe to a point where a weld to be radiographed lies within the annular field of radiation. Therefore, electrical extensions or leads connecting the tube and associated components or devices to sources of electrical energy must likewise be propelled or dragged along with the unit.

This provides a serious problem in units wherein electrical devices are mounted adjacent the end of the tube opposite the end nearest the electrical supply because in such cases electrical conductors to the devices must necessarily pass through the field of radiation. Radiographs produced by such units will contain images of the conductors, which images may obscure some of the details of the image of the radiographed welds, or in any event may lead to confusion in a latter study of the radiographs.

The present invention overcomes this objection by providing a novel conductor which is transparent to the X-radiation which it intercepts. This is accomplished by making the conductor of material and dimensions selected according to the materials and dimensions of other elements, such as windows, through which the X-ray beam passes, so that X-rays of the particular wave lengths which would normally have been absorbed by the conductor are absorbed by the other elements before the beam reaches the conductor, whereby the conductor is transparent to substantially all the X-rays which it intercepts.

It is, accordingly, a primary object of this invention to provide a new and improved self-contained X-ray unit producing high quality radiographs of selected subjects which is compact, sturdy, light in weight, and reliable in operation.

Another object is to provide a novel radiographic X-ray unit wherein the component parts are located in positions where they may operate at greatest efficiency without interfering with the radiographic process.

Another object is the provision, in an X-ray unit of the character described, of suitable means for air-cooling the X-ray tube.

Another object is to provide an X-ray unit of the above character wherein electrical conductors which are located in the path of the X-ray beam are so constructed and arranged that they are substantially indistinguishable in the radiographs produced by the unit.

Other objects and advantages of this invention will become apparent from the following description taken in connection with the accompanying drawings, wherein

Fig. 1 is an elevational view of an X-ray unit with the housing partially removed to disclose the invention;

Fig. 2 is an enlarged sectional view of a portion of the interior of the unit;

Figs. 3 and 4 are enlarged front and side elevational views respectively of an electrical conductor used in the unit; and

Fig. 5 is a graph illustrating certain characteristics of the invention.

Referring to the drawings, and more particularly to Fig. 1, the device includes a housing **10** which is formed of two cylindrical sections, a forward section **11** and a rear section **12**, which are joined at one end in coaxial relation and are closed at their other ends. The rear section **12** has a relatively rigid and sturdy end wall **13** and the side wall or shell **14** thereof is formed of thin sheeting of aluminum or other selected material having relatively good X-ray transparency characteristics.

Upon the inner surface of the end wall **13** is an annular bracket **15** which serves to support an X-ray tube **16** within the housing. The cathode end **17** of tube **16** extends outwardly through end wall **13**. The opposite end of the tube constitutes a hollow anode-supporting portion **18** to which is sealed one end of an annular window **19** formed of thin nickel tubing or other selected X-ray transparent material. The anode **20** is sealed to the opposite end of the window **19** and has in it a target **21** formed of tungsten or other selected material which is capable of emitting copious supplies of X-rays when bombarded by electrons in the manner of a conventional X-ray tube. Window **19** encircles the target **21** and X-rays which are emitted by the target pass outwardly of the tube through the window in the form of a beam of radiation which extends radially throughout an angle of 360° about the longitudinal axis of the unit as indicated by dotted lines in Fig. 1, the beam being restricted in size in a direction axially of the device by the length of the window.

Electron bombardment of a target and consequent production of X-radiation generates considerable heat in the anode **20**. Therefore, to dissipate such heat, the anode is provided with an enclosing finned radiator **22** which carries a suitable thermostat **23**. A suction type fan **24** is located within the forward section **11** of the housing adjacent radiator **22** and is adapted to be operated by a conventional motor **25**. When the fan is rotated by the motor, cool air is drawn into the housing through a group of screened inlet openings **26** in housing section **12**, and is directed through the fins of the radiator. In this way heat, which is transferred from the anode to the radiator, is dissipated. The resultant warmed air is exhausted through a screened outlet **27** in section **11**.

The fan and motor are preferably mounted as a unit upon the wall of section **11** by suitable vibration dampening means **28** which functions to prevent transferral of possible vibration through the housing to the X-ray tube.

A unit of the type described can be used to X-ray various hollow structures such as pipe lines, or more particularly the annular welds between sections of pipe. To accomplish this the unit is mounted on suitable motive means (not shown) and dragged or propelled substantially along the axis of the pipe to a point where a weld to be radiographed lies within the annular field of X-radiation. Therefore electrical extensions or leads connecting the tube and other components to sources of electrical energy must likewise be propelled or dragged along with the unit.

The X-ray tube is preferably located in the rear section of the housing and leads thereto may be readily connected to terminals thereon, such as terminal **29**, without passing through the field of X-radiation. However, the motor **25** and the thermostat **23** are located in the forward end of the unit. Therefore, leads which trail the unit as it progresses along a pipe, must necessarily pass through the field of X-radiation in order to be connected to those components in the forward section.

Such extension of leads through a field of X-radiation normally results in the impression of images of the leads upon a radiograph, which images may result in confusion in the subsequent study of the radiograph, or may even obliterate portions of the image of a weld.

In accordance with this invention, I have found it possible to provide electrical conductors or leads which may be positioned within a field of X-radiation without producing a readily distinguishable image in a radiograph. In the shell **14** of the trailing section **12** of the housing I have mounted one end of a conduit **30** through which leads **31** (Fig. 2) enter the interior of the housing. Leads **31** are connected to fixed terminals **32** mounted on the inner wall of the housing. Also fixedly mounted in spaced relation on the inner wall of the housing are a number of insulating blocks **33**, to each of which is secured one end of a respective X-ray transparent conductor **34**.

The conductors **34** each comprise a strip of metal foil **35** formed of X-ray transparent material such as aluminum, beryllium, magnesium, or other selected material. The ends of the strips **35** are folded and interlayed with small three-ply folded sheets **36** of copper or other conductive material, which thus form strong and rigid terminations for the foil strips and by which the ends of the conductors are enabled to be securely connected to the insulating blocks **33** as by screws **37**. The strips are connected by respective leads **38** to respective portions of the terminal device **32**.

The other ends of the conductors are similarly interlayed with reinforcing sheets **36** and each carries a pair of fixed terminal pins or eyelets **39** to each of which is connected a small coil spring **40**. Each pair of springs **40** is connected to the ends of a small arm **41** which is pivotally connected to an insulating block **42** mounted on the inner wall of the housing **10** similarly to blocks **33**. To each arm **41** is connected a lead, one lead **43** extending to the thermostat and the other leads **44** to the motor **25**.

The conductors **34** are thus disposed on and in spaced relation to the X-ray transparent shell **14**. The springs **40** function to maintain the strips **35** taut so that in each case a wide flat surface will be continuously directed toward the X-ray generating target **21**.

The strips **35** must be formed thin enough so that the X-ray beam will pass through substantially unaltered. I have found that if a shell **14** is formed of aluminum substantially 1/16" thick, and the window **19** of nickel approximately .020" thick, then the strips **35** may be of aluminum foil approximately .003" thick. Such strips may, of course, be comprised of two superimposed aluminum foils .0015" thick.

In the structure shown in Fig. 1, the X-ray beam passes through the annular window **19** and the tubular shell **14**, whereby the beam is necessarily modified to the extent that the window and shell absorb some of the radiation. Therefore, it is desirable that the conducting strips **35** be characterized by their ability to transmit substantially the same portions of the X-ray beam that are transmitted by the window or shell, or both.

For example, in Fig. 5 there is shown a curve **45** which diagrammatically illustrates the intensity and wavelength of an X-ray beam and wherein the height of the curve with respect to line N depicts the intensity, and the length of the curve parallel to line N indicates the wavelength. It is known that best results in radiography are obtained by utilizing the hard intense rays which are found to exist in the leading portion of a pulse. Curve **45** shows that a normal X-ray pulse produces hard intense X-rays which, after peak intensity is reached, trail off as progressively softer and less intense rays, as indicated by the long gradual slope of the trailing portion of curve **45**.

The X-rays, however, are modified by the window **19** as shown by curve **46** which illustrates the X-rays after passing through a window formed of nickel approximately .020" thick. It will be noted that the peak intensity of the X-ray beam is reduced only slightly but the soft X-rays are reduced by a substantial amount. However, this reduction in soft X-rays is not of major consequence since, as stated above, the hard radiation is desirable.

In accordance with this invention, when X-rays pass through a conducting strip **27**, preferably made of aluminum foil .003" thick, the resultant curve thereof will be substantially as shown by dotted line **47**. This indicates that the peak intensity, or hard intense radiation, is substantially unchanged by the strip and the soft radiation is reduced by a negligible amount.

Although aluminum foil is preferred as the material from which the conducting strips are made, materials such as beryllium, magnesium, or others may be used, in which case it might be necessary to change the material of either the window or shell, or both, so that the strip will not of itself alter the X-ray beam sufficiently to produce an image thereof on a radiograph.

Therefore, it is to be understood that the material of the conducting strips and the thickness thereof may be balanced against the particular X-ray absorption characteristics of the window or shell or both so that insertion of the strips in the field of the X-ray beam will result in substantially no additional attenuation of the beam.

I have further found that an aluminum foil of approximately .003" thick and approximately one inch wide can satisfactorily conduct conventional levels of currents necessary for efficient operation of devices such as blower fans, thermostats, etc. For heavier currents, the strips may be widened accordingly without varying the thickness in accordance with this invention.

From the foregoing it will be apparent that I have produced an X-ray unit adapted for use in radiographing, in a single exposure, annular sections of hollow bodies and capable of producing high quality radiographic pictures in which images of electrical conductors within the field of the X-ray beam are absent.

The embodiments of my invention herein shown and described are to be regarded as illustrative only, and it is to be understood that the invention is susceptible to variation, modification, and change within the spirit and scope of the adjoined claims.

I claim:

1. In an X-ray unit comprising a hollow housing, an X-ray tube in the housing for generating X-radiation and having a window for transmitting X-rays from the tube as a field of radiation, an electrical conductor extending parallel to the window in the field of radiation, said conductor being an elongated flat strip of metal foil transparent to X-radiation located with one flat surface directed toward the target of said X-ray tube, and means for securely mounting the foil upon the wall of the housing comprising a pair of spaced insulating blocks carried by said wall upon opposite sides of the field of radiation, metal blocks secured to and interlocked with each end of the fold, the metal block at one end of the foil being secured to one of the insulating blocks, the other in-

sulating block having an arm pivotally mounted thereon, and a pair of springs connecting opposite ends of the arm with transversely spaced portions of the other metal block, the springs maintaining the foil in position relatively taut and rigid.

2. An X-ray unit as set forth in claim 1 wherein the housing contains at one end motor-operated cooling means for the X-ray tube and contains electrical connection means in the opposite end for connection to an external source of electrical power, and said electrical conductor is connected at one end to the connection means and at its other end to the cooling means.

3. An X-ray unit as set forth in claim 1 wherein the housing contains at one end electrical connection means for connection to an external source of electrical power, the X-ray tube has an anode terminal located in the end of the housing opposite the connection means, and the electrical conductor is connected at one end to the connection means and at its other end to the anode terminal of the X-ray tube.

4. An X-ray unit as set forth in claim 1 wherein the conductor is transparent to only selected wavelengths of X-radiation.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,980,800 April 18, 1961

Gottfrid W. Steen

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 46, for "latter" read -- later --; column 4, line 74, for "fold" read -- foil --.

Signed and sealed this 12th day of September 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

USCOMM-DC