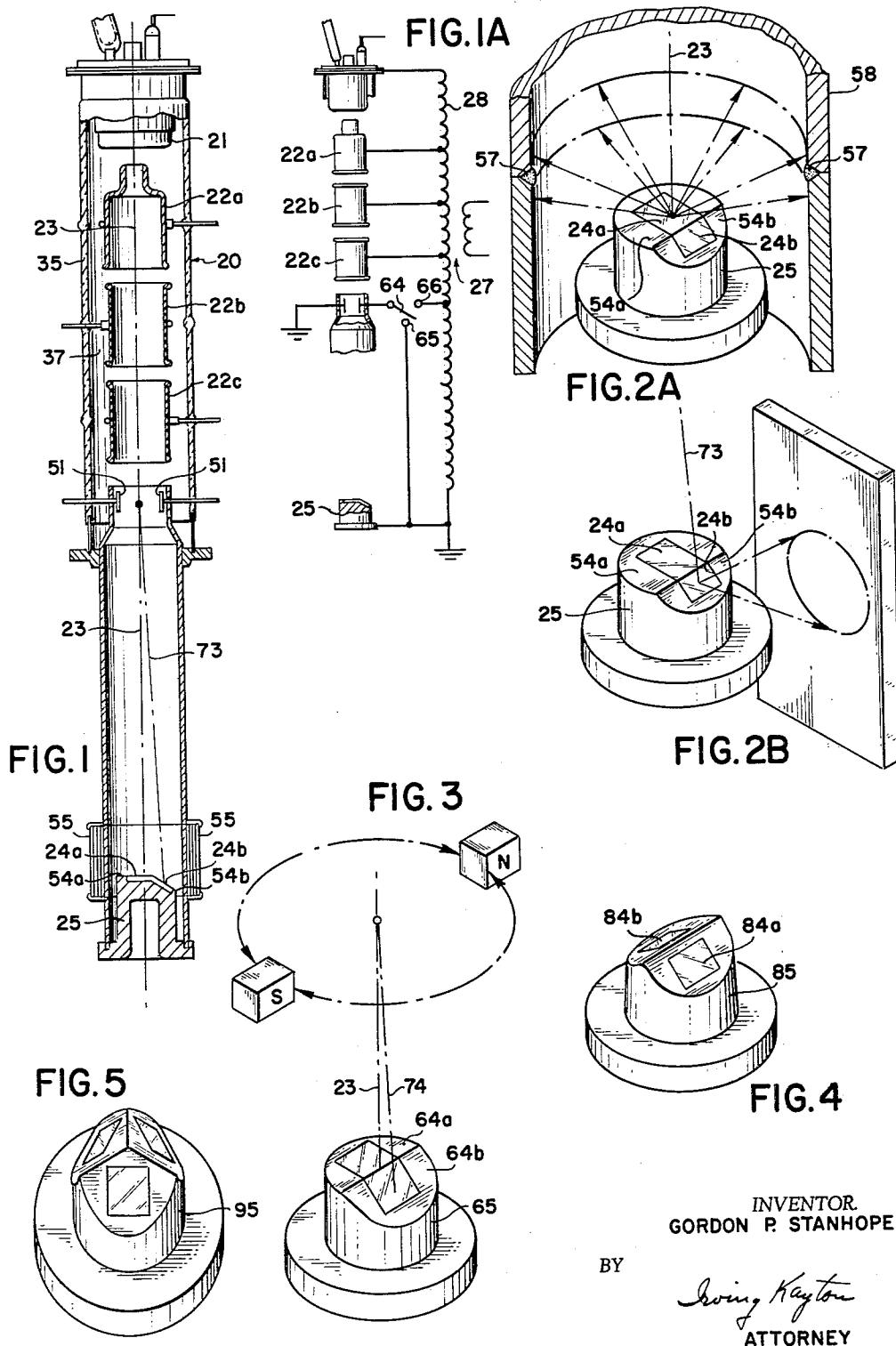


Nov. 24, 1964

G. P. STANHOPE
X-RAY TUBE WITH MEANS TO SELECTIVELY DEFLECT
THE ELECTRON BEAM TO PLURAL TARGETS
Filed Aug. 14, 1962

3,158,745



1

3,158,745

X-RAY TUBE WITH MEANS TO SELECTIVELY DEFLECT THE ELECTRON BEAM TO PLURAL TARGETS

Gordon P. Stanhope, Berea, Ohio, assignor to General Electric Company, a corporation of New York
Filed Aug. 14, 1962, Ser. No. 216,794
1 Claim. (Cl. 250-99)

This invention relates to X-ray tubes and more particularly, to an X-ray tube wherein the emergent beam of X-radiation may exit the tube window directed in one of at least a plurality of alternative angles or patterns.

In the industrial application of X-radiography, it is sometimes desirable to have the emergent X-ray beam extend over a full 360° pattern. Such a panoramic pattern has application, for example, to inside-out radiography of a complete circumferential pipe weld which is accomplished by inserting the X-ray tube output window within the pipe or pressure vessel itself in the region of the weld. This provides a complete circumferential radiograph of the weld with a single exposure. In other industrial applications, it is necessary, on the other hand, to utilize a conical X-ray beam for radiographic purposes, as in inspection for flaws of castings, aircraft assemblies and the like. Both these industrial applications may require similar energy levels; thus, for both the 360° circumferential beam and for the conical beam, a useful energy level may be in the range of 100 to 500 kilovolts-peak. However, it has heretofore been necessary to have two separate and different X-ray tubes when both inside-out radiography and conical beam radiography were required.

It is accordingly an important object of this invention to provide an improved X-ray tube capable of providing a plurality of emergent X-radiation patterns.

It is another object of this invention to provide an improved X-ray tube capable of providing both a 360° X-ray beam and a conical X-ray beam as required.

The major advantage of the X-ray tube in accordance with the invention is that a single X-ray tube may be utilized for an entire range of industrial applications. Thus, both inside-out radiography of circumferential pipe welds as well as examination by conical beam of castings and the like, may be accomplished by a single tube.

In accordance with the principles of the invention, the above objects and advantages are provided by an X-ray tube with a special target anode having a plurality of flat target faces disposed at an angle to each other, in combination with means for causing the electron beam to impinge upon any one of the target faces dependent upon which radiation angle or pattern is required at the time. The electron beam is deflectable between the plurality of target anode surfaces whereby the emergent X-radiation from one anode surface is at an angle or has a pattern, different from the emergent X-radiation from a second surface by virtue of the difference in the angular orientations of the two surfaces.

In a preferred embodiment of the invention to be discussed in detail below, one angular orientation of one target anode surface is perpendicular to the electron beam, whereupon the emergent X-radiation is disposed in a circumferentially complete 360° radiation pattern, while the second target anode surface is disposed at an obtuse angle to the electron beam to thereby provide a conical radiation pattern.

In another application of X-radiation, analysis of materials by X-ray absorption analysis is provided. In such an arrangement, X-rays are passed through a test specimen and then applied to the diffraction crystal, the output of which provides the information for identifying the composition of the test specimen. Such an arrangement

2

is especially practical when trying to ascertain whether a specific substance is contained within the test specimen. Since the type of target anode material determines in substantial measure the wavelength of the output X-ray beam, it is understandable that different target materials are appropriate for specimens having different constituents, to provide the most efficient or effective examination. For this reason, it is desirable to be able to provide an output X-ray beam from the tube which may be derived from a plurality of separate target anode materials.

In the instance of X-ray emission analysis as for quantitative analysis of an element or contaminant in a specimen, the X-ray wavelength required is one which is at an energy level only slightly in excess of that required for exciting characteristic radiation from that element. Too high an energy level may result in non-linear and unpredictably interdependent background radiations scattered by the sample which would mask the measurement of the element of interest, or would have to be discriminated against to obtain the proper measurement. Where more than one element is under analysis, having spaced characteristic radiation wavelengths, it follows that more than one target material is called for. Use of a plurality of target materials desirably eliminates the need for filters in the primary or secondary beams, since filters often result in a serious reduction of the intensity of the desired radiation.

A further use of X-radiation is in the study of the diffraction characteristics of a specimen material when irradiated with particular and known wavelengths of X-radiation. The diffraction characteristics of the specimen will vary and be dependent upon the incident radiation wavelength, and it is, therefore, important to have easily controlled and readily available sources of X-radiation with differing characteristic wavelengths.

It is another object of this invention, therefore, to provide an improved X-ray tube having an output beam for use in diffraction, emission or absorption analysis which may be derived from one of an available plurality of different metallic target anode materials.

This object is accomplished in accordance with the principles of the invention by providing a target anode having a plurality of surfaces, each consisting of a different metallic material and deflecting the electron beam of the X-ray tube to the desired one of the plurality of angularly related target anode surfaces.

The novel features believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings.

In the drawings:

FIGS. 1 and 1A are cross-sectional and schematic views of an X-ray tube in accordance with the principles of the invention, utilizing electrostatic electron beam deflection;

FIGS. 2A and 2B are views of the anode construction of the tube of FIGS. 1 and 1A under different operating conditions;

FIG. 3 is an alternative tube construction to that of FIGS. 1 and 1A; and

FIGS. 4 and 5 are alternative anode constructions to those of FIGS. 1 through 3.

In FIGS. 1 and 1A, there is shown an end-grounded X-ray tube 20, constructed in accordance with the present invention. It comprises cathode 21 to generate a stream of electrons which are guided and controlled by consecutive control electrodes 22, individually identified as 22a, 22b and 22c, to form a beam, indicated generally by axis line 23, which impinges upon one of the two target plate surfaces 24a or 24b supported on the faces

54a and 54b, respectively, of anode 25. Control over which of the target plates 24a or 24b the electron beam strikes is effected by deflection electrodes 51.

A suitable source of high voltage, external to X-ray tube 20, is shown here as resonant transformer 27 whose secondary or stack winding 28 is electrically connected between cathode 21 and anode 25 to establish a high voltage field to locate the potential gradient in the general direction of axial path 23 to be taken by the high voltage electron beam moving from cathode 21 to target anode 25. In this embodiment the accelerating potential is preferably 300 k.v.p. Intermediate connections from transformer winding 28 are made to control electrodes 22a, 22b and 22c, to establish the fields to help guide and shape the electron beam in its passage between cathode 21 and anode 25. To be properly effective, control electrodes 22 should be in coaxial alignment with each other and with common axis 23. A three-point support is provided for each control electrode 22 to provide a relatively stable supporting system to maintain the coaxial disposition of the electrodes.

The ultimate support for control electrodes 22 is derived from a unitary dielectric column, as a tube or cylinder 35, of glass or ceramic. Cylindrical column 35 supports the control electrodes 22, and also confines and encloses them in an evacuated chamber or region 37 within cylinder 35. This chamber 37 is hermetically sealed to maintain a high vacuum. Glass column 35 is supported at its opposite ends on the supporting structures associated with cathode 21 and anode 25, respectively. The connections between the column and those supporting structures are made as hermetic seals, in order to maintain the desired vacuum within the unitary glass column 35. The details of those supporting and sealing connections are considered in detail in the United States Patent No. 3,034,009, of M. J. Zunick et al., entitled "Pin Seal Accelerator Tubes."

With the exception of deflecting electrodes 51 and target anode 25, the X-ray tube of FIGS. 1 and 1A is a conventional X-ray tube of the type disclosed in detail, for example, in the United States Patent No. 2,853,622 of C. W. Hansen, entitled "Electron Discharge Apparatus," utilizing the unitary dielectric support envelope and mounting devices of the above mentioned United States Patent No. 3,034,009.

The target plates 24a and 24b are embedded in the faces 54a and 54b of target anode 25. The bulk of anode 25 is of copper, while target plates 24a and 24b are preferably of tungsten bonded in the copper. The faces 54a and 54b of anode 25 are disposed such that surface 54a and plate 24a are perpendicular to the axis line 23 defining the path of the electron beam when undeflected. Target plate 24a in surface 54a is positioned such that the electron beam impinges upon plate 24a when the electron beam is not deflected. The target surface 54b and plate 24b are disposed, in this embodiment, at an angle of 22.5° from the plane defined by surface 54a. When, under the influence of the deflecting electrodes 51, the electron beam is deflected, it impinges upon target plate 24b in surface 54b.

Circumscribing anode 25 in the region of target plates 24a and 24b is that portion of the X-ray tube forming the output window 55. Window 55 is a thin walled cylinder of beryllium oxide having a wall thickness of approximately 100 mils. Window 55 is therefore effectively transparent to X-radiation. The electron beam that may impinge upon the tungsten target plate 24a under the influence of the 300 k.v.p. accelerating potential, provides an output X-radiation pattern in the plane of anode surface 54a of 360° and in the plane perpendicular to that surface, of approximately 30° commencing from the center of target plate 24a and subtending an angle whose two sides are approximately 5° relative to surface 54a and 35° relative to surface 54b, as shown in FIG. 2A. Since the beryllium oxide window 55 is in the cylindrical

form described, the entire radiation pattern emerges from the tube undisturbed and illuminates the circumferential weld 57 of pipe 58 under inspection.

When the electron beam impinges upon target plate 24b in surface 54b, as shown in FIG. 2B, however, the output beam provides the usual conical radiation pattern. The angle of the cone in the arrangement shown is 45° with surface 54b defining one side of the angle. Anode 25 is a copper cylinder with a section removed to form surface 54b as by a plane cutting through that end section of the cylinder at an angle of 22.5° to end surface 54a.

Deflecting electrodes 51 may be energized by a tap off the secondary of transformer 27 as shown in FIG. 1A, or by an auxiliary winding. One of the deflecting electrodes 51 is grounded while the other electrode may either be grounded, or switched to place it in circuit with that part of the secondary winding providing the deflection potential through single pole double throw switch 64 or some other suitable electronic or solid state switching device. With switch 64 positioned on contact 65, electrodes 51 are grounded; the deflecting electrodes are therefore inactive and the beam proceeds along axis line 23 to strike surface plate 24a of the target anode 25. With switch 64 positioned on contact 66, the deflection portion of the secondary winding is brought in circuit with the electrodes 51. The electron beam is thereby deflected along a path indicated by line 73 to strike the angled target surface 24b of target anode 25.

To insure that the electron beam impingement is restricted to the two target plate surfaces 24a and 24b under the tube operation, the following typical values may be assigned to the various parameters involved. With a distance L of ten inches between the center of the deflecting electrodes 51 and anode surface 54a, a deflection distance D of 0.2 of an inch represents the total deflection of the center of the electron beam at its point of impingement at surface 24a and its point of impingement on surface 24b, with a distance d of 0.45 of an inch between the two deflecting electrodes 51, and with a deflection electrode length l of 1.6 inches, a deflection voltage V_d applied to the electrodes 51 of 3.7 k.v.p. is necessary, with an accelerating voltage V_a of 300 k.v.p. The general equation:

$$V_d = 2 \cdot d \cdot D \cdot V_a / L \cdot l$$

defines the general relationship applicable to any tube.

With the electrostatic deflection derived from the tap off secondary winding 28, the magnitude of deflection is always constant, since synchronized deflection relative to the accelerating potential is always obtained. Thus, because electrostatic deflection is always directly proportional to the ratio of deflecting voltage and accelerating voltage, and because the secondary voltages of the transformer are always in constant ratio and phase, i.e., V_d/V_a is constant, deflection is constant for any magnitude of tube accelerating potential, both instantaneously and for various k.v.p. values.

When an auxiliary winding is used with A.C. operation in lieu of a tap off the stack winding, the power source for the deflecting coils must be synchronized with the main power supply and an appropriate amount of phase shift introduced where necessary to insure proper synchronization.

Deflection of the electron beam by electromagnetic means rather than the electrostatic system disclosed in FIGS. 1 and 1A may, where the circumstances so indicate, be appropriately utilized. Permanent magnets may also be mounted about the tube in the same region as, but in lieu of, the electrostatic deflecting electrodes, for the purpose of providing the required deflection. In such an arrangement it may be desirable to use a D.C. accelerating voltage for the X-ray tube rather than the A.C. potential applied in FIGS. 1 and 1A. In FIG. 3, a target anode construction is shown for use with deflection by permanent magnet. The axis line 23 intercepts the line of intersection of the angled and perpendicular faces 64b

and 64a of target anode 65. With the permanent magnet oriented in a first position with the magnetic pole pieces as shown in FIG. 3, deflection of the electron beam is as indicated along line 74 and impinges upon the target plate in surface 64b. With the polarity reversed, that is, the permanent magnet rotated 180° about the tube, the beam is deflected to the target plate of surface 64a.

In FIG. 4, there is shown a target anode construction 35 wherein there is no surface perpendicular to the electron beam; both surfaces are angled with the surfaces intersecting along a diametral line at the apex of the anode. In this construction, the X-ray beam emerges in a conical radiation pattern from each of the target plates of surfaces 34a and 34b. The permanent magnet type deflection is appropriate in such an arrangement, since rotation of the magnet by 180° results in direct switching from target anode face 34a to target face 34b. In the case of the utilization of such a tube for X-ray diffraction or emission analysis, one of the target plate surfaces may be of a first material, such as tungsten, while the other target plate surface is of another, such as chromium. The accelerating voltage for an X-ray tube used in diffraction or emission analysis typically is continuously variable up to 75 k.v.p. and up to 100 milliamperes. Any appropriate combination of materials may be utilized. A group of metals from which selection may be made for most practical purposes is tungsten, chromium, molybdenum, copper, nickel, cobalt, iron and silver.

In FIG. 5 is shown another anode construction 95 wherein the anode is multi-faced, whereby the top portion has a pyramidal type construction with each face of the pyramid representing a different target surface. Each surface may support a different target plate material, preferably from the aforementioned group of metals. Deflection of the beam from one to another of the pyramidal anode surfaces may readily be accomplished by rotation of the permanent magnet about the circumference of the tube at the point of deflection. With the target anode construction of FIG. 5, the permanent magnet has three defined operational positions about the deflection region of the tube, spaced 120° apart, to provide electron beam deflection to each of the three surfaces.

While the principles of the invention have now been made clear in illustrative embodiments, there will be immediately obvious to those skilled in the art many modifications in structure, arrangement, proportions, the elements, materials, and components, used in the practice of the invention, and otherwise, which are particularly adapted for specific environments and operating requirements,

without departing from those principles. The appended claim is therefore intended to cover and embrace any such modifications, within the limits only of the true spirit and scope of the invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

An X-ray tube comprising: an anode; a cathode; means for accelerating the electrons from said cathode in a beam to said anode; said anode having at least two distinct electron target surfaces defined by two planes intersecting at an angle, one of said planes being disposed perpendicular to the longitudinal axis of said X-ray tube deflecting electrodes disposed on either side of the path of said electron beam between said cathode and said anode for deflecting said electron beam between said two surfaces, means to selectively vary the direction of the deflection forces from said deflecting electrodes; an output X-ray tube window substantially transparent to X-radiation and cylindrical in shape circumscribing said anode, said cylindrical window being coaxial with the longitudinal axis of said X-ray tube; said electron accelerating means comprising a plurality of accelerating electrodes tapped off a resonant transformer providing an accelerating voltage of magnitude sufficiently great to generate a circumferential beam of X-rays when said electron beam impinges upon said perpendicular target surface and a conical beam when said electron beam impinges upon other of said target surfaces, but insufficiently great to permit said electron beam and the X-rays generated thereby to pass through said anode and out of said tube at any point other than through said cylindrical window.

References Cited by the Examiner

UNITED STATES PATENTS

2,405,477	8/46	Westendorp	250—99
2,531,583	11/50	Ott	250—99 X
2,638,554	5/53	Bartow et al.	250—99
2,665,390	1/54	Zunick et al.	313—330 X
2,812,462	11/57	Maltby et al.	313—55
2,836,757	5/58	Atlee	313—330
2,853,622	9/58	Hansen	250—87
2,946,892	7/60	Bas-Taymaz	313—330
3,034,009	5/62	Zunick et al.	313—330

OTHER REFERENCES

"Roof-Top-Target Tubes," Electronics, by E. F. Weller, March 14, 1958, pp 138—139.

RALPH G. NILSON, *Primary Examiner*.