

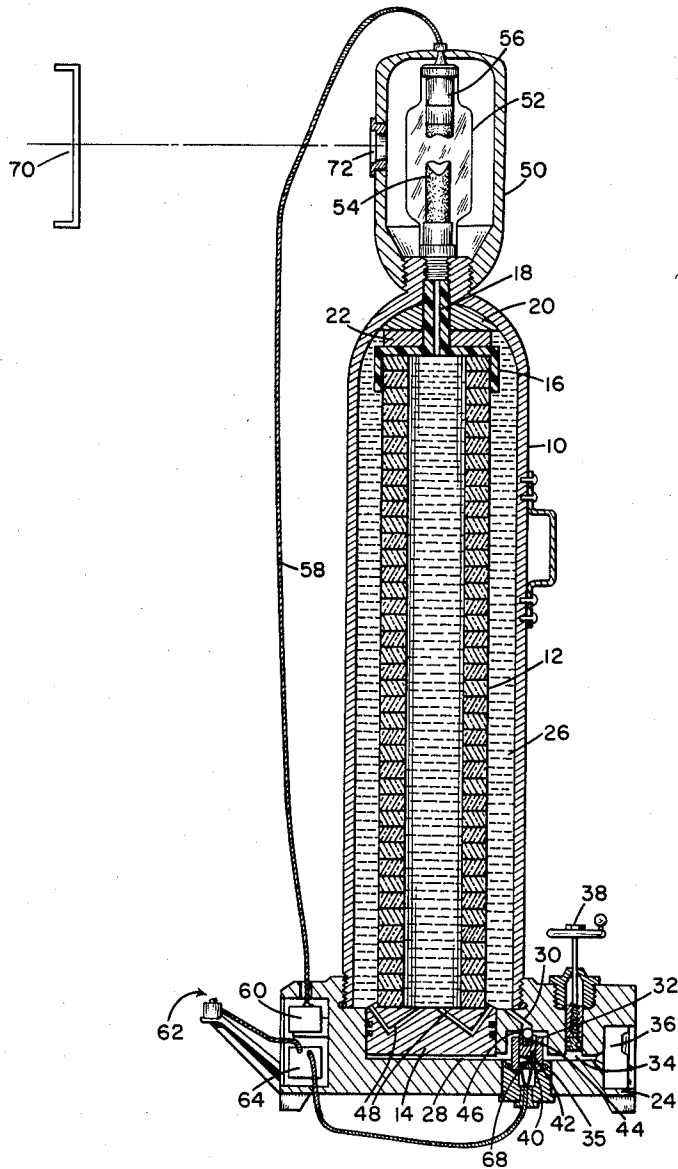
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PIEZOELECTRICALLY POWERED X-RAY EQUIPMENT

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3,217,163 PIEZOELECTRICALLY POWERED X-RAY EQUIPMENT

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This invention relates generally to X-ray equipment and, more particularly, to a piezoelectrically powered X-ray tube.

For a related invention see copending application Serial No. 191,054, Alfred L. W. Williams et al., filed concurrently herewith and assigned to the same assignee as the instant application.

In the art prior to this invention it has been the practice to use a generator coupled to a transformer to provide alternating current which, by means of a rectifier, is converted into a unidirectional wave form. Recently, improvements in X-ray tubes have made it possible to apply directly alternating current high voltage.

In both cases, however, the X-ray output depends upon the entire cycle wave form and not only the peak voltages occurring during each period. It has been found, and it is common knowledge, that this accounts for a variation in radiographic results which can be obtained from like units although they are operated at the same peak voltage.

The total time that the tube is energized is, next to the tube current and the kilovoltage output, the most important factor for developing a proper exposure technique. Hence, if the wave form of the applied voltage varies, over or under exposure can result. Various instruments are now part of the X-ray machinery to check and possibly control such variations.

The various electrical components contribute heavily to such characteristics due to variations in the details of their construction.

This invention represents a radical departure from the conventional approach overcoming the difficulties that have plagued the industry for some time with regards to the matter above noted.

The heart of this invention is embodied in piezoelectrically responsive elements which are adapted to generate an electric potential and in which the electrical discharge from the elements, which, incidentally, also function as a condenser, is applied to the X-ray tube. This discharge can be made to occur gradually or during an extremely short period of time. See United States Letters Patent No. 3,009,975 issued November 21, 1961, and copending application Serial No. 150,808 filed November 7, 1961, assigned to the same assignee as the instant invention. One approach is to gradually squeeze the piezoelectrically responsive elements and then suddenly release the pressure over a comparatively short period of time. Particularly in this operation it will be observed that, electrically, the wave on the release cycle instantly reaches a peak voltage or value. Thus X-ray pictures have been obtained of members of the human body with an exposure time of less than $\frac{1}{10}$ of a second.

A device constructed in accordance with this invention may be in the category of low-voltage to very high-voltage X-ray units. The conventional voltage range for most X-ray units is from about 50 to several hundred kv. However the invention is not in any way structurally limited to this range.

It is therefore the primary object of this invention to improve the general performance, accuracy, dependability and safety of X-ray equipment.

It is a further object of this invention to radically simplify the construction and operation of an X-ray device by eliminating numerous weighty and bulky components heretofore required.

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It is a further object of this invention to provide a high voltage yet light weight portable X-ray unit.

It is a further object of this invention to provide an X-ray apparatus adapted to be employed for microprobes or for X-ray analysis of rapidly moving members.

It is a further object of this invention to provide an X-ray apparatus for establishing from a single charge of electrical energy a radiographic picture and/or to provide a phosphorescent screen capable of retaining the image put upon it by the X-rays for a predetermined period of time.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the drawing the single figure is an elevational view partly in section of a device in accordance with this invention.

An aspect of the present invention resides in the provision of an X-ray device powered by the discharge of a condenser in which an X-ray tube is effective to emit X-rays in response to electrical energization of a given voltage and polarity. A condenser arrangement is electrically connected to the X-ray tube to discharge an accumulated potential of a predetermined polarity and voltage to the tube, and an arrangement is provided for charging the condenser.

Turning now to the drawing there is shown a hollow housing 10 constructed of a conventional heavy duty steel cylinder with one end open and the other end being formed substantially semi-spherically. The housing is generally rigid and, particularly the spherical end thereof, is constructed to prevent longitudinal displacement thereof.

Disposed within the housing 10 is a plurality of annular, piezoelectrically responsive, elements 12, forming a longitudinally extending stack. The elements are individually polarized in a direction parallel to the axial center of the housing and the elements are electroded face to face and at opposite ends to establish electrical connection in series. The piezoelectric elements are composed of crystal elements or piezoelectrically responsive ceramics. Preferably, the elements are made of polycrystalline ceramic materials such as barium titanate, lead titanate-zirconate or the like.

For added support of the annular piezoelectrically responsive elements 12, a support member (not shown), for instance in cruciform, can be suitably inserted into the stack. Care must be taken, however, that the support member consists only of insulating material or, alternatively, is heavily insulated to avoid jumping of the electric charge.

The stack of piezoelectric elements 12 is suitably grounded by means of a grounding member 14 contacting one electrode (not visible as such) on one outer end of the stack 12. The grounding member 14 is hereafter also referred to as a piston member. The opposite end of the piezoelectrically responsive stack of elements 12 constitutes the "hot side" which is partly encircled by a ceramic insulating member 16. A centrally located conduit in the member 16 carries a hot lead cable 18 which is electrically connected to the other outer electrode (also not visible). To avoid elasticity in the semi-spherical portion of the housing 10 there is cast, or melted, into this housing portion a low melting point metal, for instance such as a bismuth alloy. The same constitutes a support and an abutment against which the stack of piezoelectric elements can be compressed. Interposed between the support or abutment 20 there is shown a spacer member 22 made of a metallic material, the function of this spacer being primarily to prevent or to take up slack in the aforescribed construction.

A partly hollow base 24 constituting part of the main housing 10 is threadedly connected with the main housing. The base establishes a means for precompressing or pressure adjustment of the stack of piezoelectric elements 12.

The base 24 of the housing 10 contains the various components necessary to apply mechanical pressure to the piezoelectric elements. The pressure is applied by means of a hydraulic circuit which includes a high and a low pressure reservoir for hydraulic fluid. The low pressure reservoir comprises, basically, all the space within the main housing 10 not occupied by the stack of piezoelectric elements, and the main high pressure reservoir 28 is located between piston 14 and the base. A channel within the bottom of the piston will also work satisfactorily. The low pressure and the high pressure reservoirs 26, 28, respectively, are in fluid communication by means of a passageway 30. A solenoid valve 32 of substantially conventional construction is interposed therebetween to control the flow of fluid between the two reservoirs as hereafter further described, and a retainer member 35 secures the valve 32 to the base 24. What may also be considered part of the high pressure reservoir 28 is a fluid channel 34 which is operably exposed to a pressure gauge 36 mounted to the base 24 and a manual hand valve 38 extending into the channel 34 and effective to control the fluid pressure therein. It should be noted that there always exists fluid flow communication between reservoir 28 and channel 34 although the solenoid valve is physically interposed therebetween.

More specifically, the solenoid valve 32 includes a spring 40 and a plunger 42 biased by the spring. The plunger 42 has a small axial bore in which there is disposed a compression spring 44 which biases a ball member 46 into the opening of passageway 30. The ball member 46 is suitably sized to fit sealingly into the opening of passageway 30 to prevent any fluid intercourse between the high and the low pressure reservoirs.

Preferably, transformer oil is used as hydraulic fluid to simultaneously serve to insulate the piezoelectric elements from the housing 10. Fluid communication between the inner cylinder formed by the piezoelectric elements and the outside thereof is established by means of a plurality of fluid channels 48 contained in the piston member 14.

The spherical end of the hollow housing 10 terminates on the outside with an external thread which is adapted to receive a housing 50 to contain a conventional X-ray tube 52 having an anode 54 and a cathode 56. The hot lead 18 is electrically connected with the anode and, as is shown in the drawing, the cathode is electrically connected by means of wiring 58 to a battery 60 to provide means for heating the cathode.

The housing 50 may be considered part of the main housing 10 and, as a matter of fact, it is usually desirable to fill the housing with a transformer oil and thus the housing 50 can be connected by means of tubes (not shown) with the main housing 10 to establish fluid communication therebetween. The interior of the housing is then part of the low pressure reservoir of the hydraulic circuit.

In operation when the device is to be utilized for taking X-ray pictures, the pressure applying valve 38 is turned in a counter-clockwise direction whereby a partial vacuum is created within the hydraulic circuit causing the hydraulic fluid from the low pressure area to force the spring biased plunger member 42 and, more particularly, the ball 46 free of the opening of the passageway 30 so that the area constituting the high pressure reservoir is completely filled with fluid. It will be appreciated that a motorized valve can be readily substituted for the manual valve. Upon reaching a predetermined point the hand valve 38 can then be turned in a clockwise direction whereupon, immediately thereafter, the spring biased plunger 42 moves back to the "normal" position by virtue

of a slight increase in pressure and the ball 46 is suitably in position to block fluid flow between the two reservoirs. The hand valve is then further actuated until a predetermined pressure has been reached.

In response to the gradual increase of pressure in the high pressure reservoir 28 and fluid channel 34, the piston member 14 is lifted and forced against the stack of piezoelectric elements 12 whereby these piezoelectric elements are compressed. The compression of the piezoelectric elements causes the elements to generate an electric charge of a given polarity which can be applied to the X-ray tube. Adjustment of the stress application rate and time constant of the electric circuit will allow various exposure times at various exposure voltages. In most circumstances it will not be desirable to utilize this charge because of the low voltage element involved. Therefore, it may be desirable to apply the pressure over a period of time which equals or is greater than the time constant of the electric circuit so that the charge is dissipated through the internal resistivity of the ceramic elements 12.

The stack of piezoelectric elements is now in a state of maximum mechanical compression, and the release of such compression causes an electric potential of opposite polarity to be generated. This condition may be likened to a condenser which is charged and can be instantaneously, or almost instantaneously, discharged. The actuation of the X-ray by means of the release spark is accomplished by actuating the solenoid valve 32 by means of push button 62 which is energized by a battery 64 to draw the plunger toward the axial center of the solenoid core, that is, away from the opening of the passageway 30, thereby providing again fluid intercourse between the two reservoirs. This occurs very suddenly and, as a consequence thereof, the release of the compression upon the piezoelectric element is accomplished during a period of time which is very short as compared to the time required to compress the elements. This sudden discharge permits extremely rapid actuation of the device.

Alternatively, depending upon the voltage characteristics that are desired, a set screw (not shown) may be disposed to protrude through the abutment 68 engaging plunger 42. This arrangement serves to restrict the movement of the plunger 42 so that only a small opening is established permitting only a gradual out-flow from the high pressure to the low pressure reservoir.

In summary then, the hydraulic pressure applying system is effective to vary the voltage pulse that is applied to the X-ray tube from constant voltage to capacitor discharge voltage wave form.

In the drawing there is also shown a screen member 70 having a face area of phosphorescent material. The screen member, and, more particularly, the face area, is positioned in operative relation to the window 72 of the housing 50 to effectively retain the X-ray image over a predetermined period of time. Such a screen is of particular importance when the exposure periods are such that the naked eye is not capable to form any visual impression.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. Apparatus for making X-ray pictures of a given body using a sensitized surface for producing a picture, comprising: an X-ray source responsive to electrical energy supplied thereto and having emission characteristics for exposing said surface with X-radiation which has travelled through said body; piezoelectric means for generating and supplying electrical energy to said X-ray source to cause said X-ray source to emit X-rays for

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travelling through said body; and means for applying a predetermined quantity of mechanical energy to said piezoelectric means; said piezoelectric means having a sufficient dimension in the direction of mechanical force applied thereto and sufficient volume effective to transduce the mechanical energy to electrical energy having the required voltage, amperage and duration to energize said X-ray source to effect the desired exposure of said sensitized surface by the X-rays which have travelled through said body.

2. An X-ray apparatus in accordance with claim 1, in which the electrical energy from said piezoelectric means is supplied directly to said X-ray source at a voltage level which increases to the operating voltage level of said X-ray source.

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