

DESIGN AND CONSTRUCTION OF A DIAGNOSTIC PULSED X-RAY TUBE

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Abstract

A pulsed X-ray Tube based on the field emission cold cathode principle has been designed and constructed. The device produced X- ray pulses of duration of (1.2) μ sec and intensities of (90) mR at a distance of (10) cm from the window, when a (150) KV is discharged across the electrodes of the tube. The intensity of the x ray radiation at various distances was determined at various cathode anode spacing to determine its optimum value. Special efforts were made in the design to be demountable, easy to maintain, and offering a practical possibility for future industrial and medical application.

Keywords: Pulsed x ray, cold cathode, Marx generator.

Introduction

A conventional X-ray tube usually comprises of a metal resistive filament (cathode) which emits electrons when heated to over 1000 °C. Also, a metal target (anode) which emits X-ray when bombarded by a beam of accelerated electrons⁽¹⁾. The intensity of the X-ray radiation is proportional to the value of electron current, and the square value of the accelerating voltage. This design process faced several inherent technical limitations like, firstly, thermionic cathodes generally have slow response time and high power consumption. Secondly, high temperatures would reduce the life- time of the X-ray tube, due to the failure of the metal filament. It is estimated that the average life time of a conventional X-ray tube in a typical X-ray machine is less than one a year and a large portion of X-ray tube failures, in diagnostic X-ray units, are filament related. In addition, the electrons when emitted are usually randomly distributed. Although, they can be focused by a bias electron field, the resulting electron beam a non-Gaussian intensity distribution which affects the imaging resolutions. The cold emission mechanism is much more attractive in extracting electrons, as compared with thermionic emission. Because the electrons are emitted by the applied voltage at room temperature, and the resulting output current would be voltage-controllable⁽²⁾. Field (cold) emission cathodes have found applications in a variety of vacuum electronic devices such as field emission displays and electron guns in electron microscopy⁽³⁾ the

concept of cold- cathode X-ray tubes has been previously investigated using materials, and recently diamond and carbon Nanotubes (CNT)^(4,5). The development process has always been hindered by the lack of cathodes that can deliver stable currents, comparable to the values used in conventional X-ray tubes (10-50) mA for fixed anode and (50-500) mA for rotating anode tubes⁽⁶⁾. In the present work, the design development, and performance of an indigenous pulsed X-ray tube equipped with copper cathode is reported. Moreover, the operation parameters are characterized and their effect on x ray signal is also reported.

Experimental Technique

A diode type tube is designed and built of which a schematic diagram is shown in Fig. (1). The basic structures of the tube consist of cone shaped tungsten anode, disc-shaped a copper cathode and a vacuum chamber housing the above components at a pressure (10^{-6}) torr. The vacuum pressure inside the tube chamber is obtained using a diffusion pump type (Alkatel crystal-100) coupled with a double stage rotary pump type (Alkatel 2004). The walls (stainless steel) of this chamber is electrically grounded, and voltage of 150KV is applied to the anode via a Teflon insulated connection. A thin aluminum sheet (1mm) is used as a window to allow the X-ray beam out. A Marx impulse generator which was specially built for this work shown schematically in Fig. (2) is used to supply the energy to the X-ray tube⁽⁷⁾. Ignition mechanism of the shock impulse is normally

started by a small thyratron device acting as a slit spark gap (F2). The number of main capacitors may be varied between (1-7) such that it is possible to apply impulse voltages between (20-150) KV at the X-ray tube depending on the desired hardness of the radiation.

The tube was characterized by the following steps:

- 1- The optimum cathode-anode spacing which gives highest beam intensity is determined.
- 2- The pulse duration of the generated X-ray beams are measured by a high speed storage oscilloscope.
- 3- The focal spot size of the X-ray beam is determined, using experimental set up Fig. (3).
- 4- The radiation intensity is measured at different distance from the X-ray port by using film density method and a dosimeter device.

Results and Discussion

The optimum cathode- anode spacing is measured by measured the intensity of X-ray radiation at different anode-cathode spacing. Also the dose rate as function of ϕ_C/ϕ_N ratio is recorded when ϕ_C is the cathode diameter while ϕ_N is the anode diameter. The result as shown plated in Fig. (4), which is shows that the maximum radiation intensity was obtained when ϕ_C/ϕ_N ratio is equal to 3.6 this spacing was kept fixed for the rest of the installation process.

The pulse duration at optimum cathode – anode spacing are measured using high speed storage oscilloscope. The pulse width (FWHM) of (1-2) ms was measured, when an 150KV is discharged between the tube electrodes. One may mention that such pulse durations are quit suitable for dynamical imaging purpose and may also be considered with in the safety limited when used in medical applications.

Focal spot size of X-ray beam is also measured using the experimental set up shown in Fig.(3) this arrangement includes a special photo-camera with an aperture of 2 mm. however, the effective focal spot size is recorded on-x-ray film (Kodak type)and calculated to be 4.2 mm in diameter. The following expression is used in calculated of focal spot size.

$$F = \frac{h}{g} - t \left(\frac{1}{g} + 1 \right)$$

$$g = \frac{b}{a}$$

where:

h = is the apertures of camera.

a, b = distances shown in Fig.(3).

The radiation intensity at different distance from the tube window is measured by two methods. One, dose-meter device and the second is by an X-ray film. The results are shown in Figs. (5 & 6).

It may be conclude that the exponential–type behavior is exhibited by both methods. To demonstrate the viability of pulse X-ray tube, image of dose meter device was taken using polaroid film place behind the object outside the X-ray chamber. In this set up a voltage was set at 150 KV (value commonly used for medical imaging)⁽¹⁾. The effective focal spot of the X-ray source is about 4.2 mm in diameter. The distance between the source and the object is 20 cm. As shown in Fig.(7). Fine structures of the device was clearly resolved by single shot X-ray pulse produced when (150) KV discharge across the X-ray tube. Welding of two pieces of steel (15 mm thickness) was also observed by using three shoots of pulse X -ray, the image on X-ray film (Fig.(8)) showed very clear structure of steel welding.

Conclusion

Cold cathode tube design has overcome some of the limitations normally faced in the conventional hot – filament X-ray tube. Due to the following reasons:

- 1- Elimination the resistance heated metal filament.
- 2- The smaller focal spot of the cold tube allows a higher resolutions imaging.
- 3- The present tube is demountable and very easy in maintain.
- 4- The shorter pulse durations and the higher resolution images makes this tube suitable for medical applications in such case the patient not need to expose to high radiation dose in long duration as in conventional X-ray machine.
- 5- The tube can be work at different voltage depending on the selection number of capacitors applied.

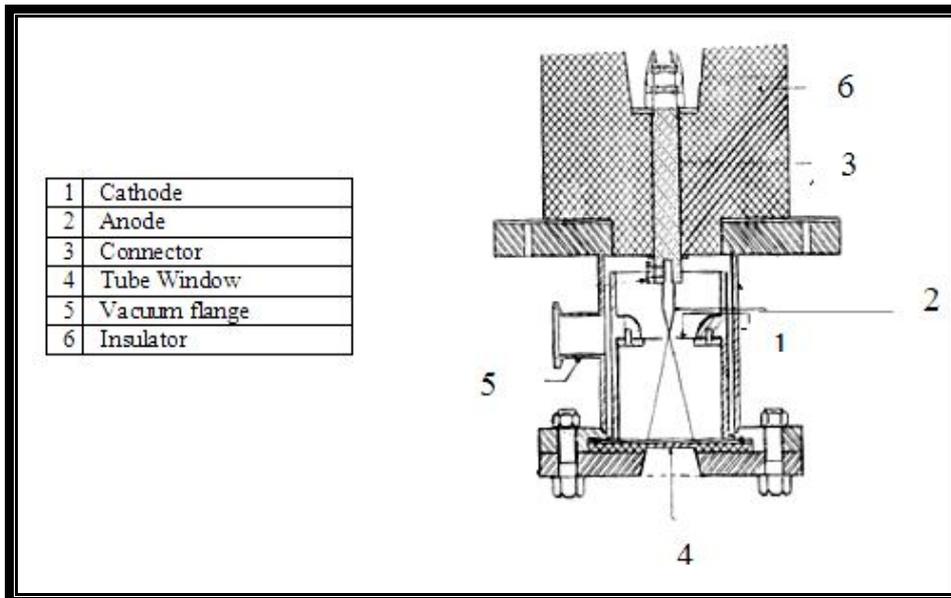


Fig. (1): Cross section in X- ray Tube.

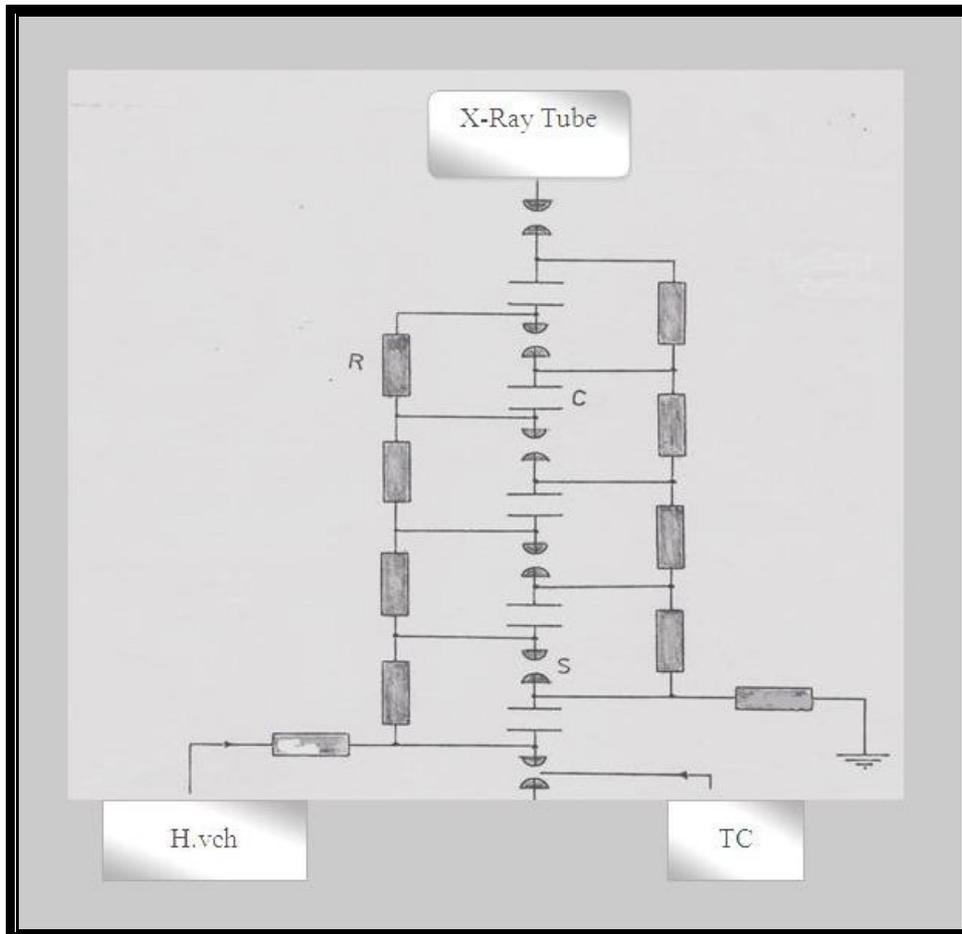


Fig. (2): High Voltage (150 KV) Marx generator circuit diagram used in this work to supply impulse voltage across the X-ray tube.

R : Resistance 50 KV 100W.

C : Capacitor 5Mf 50 KW.

T_c : Triger Circuit.

H.vch : high voltage charger.

S : Spark Gap.

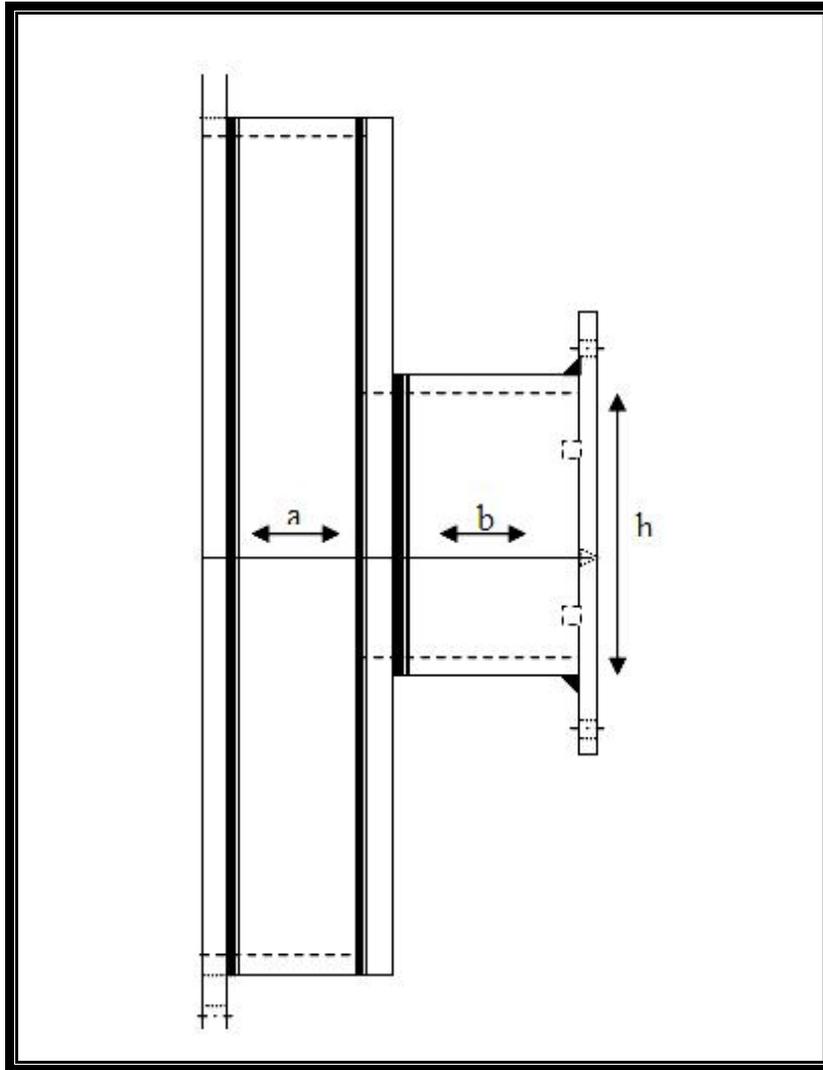


Fig.(3): Cross section in camera used in measuring focal spot size of X-ray beam.

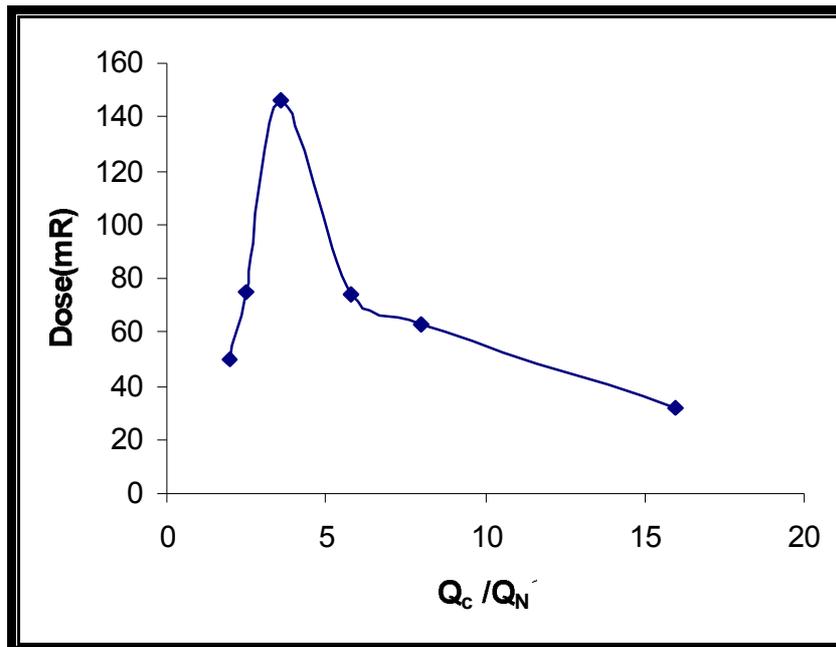


Fig. (4): Intensity of X-ray beam (mR) as a function of $\phi C/\phi N$.

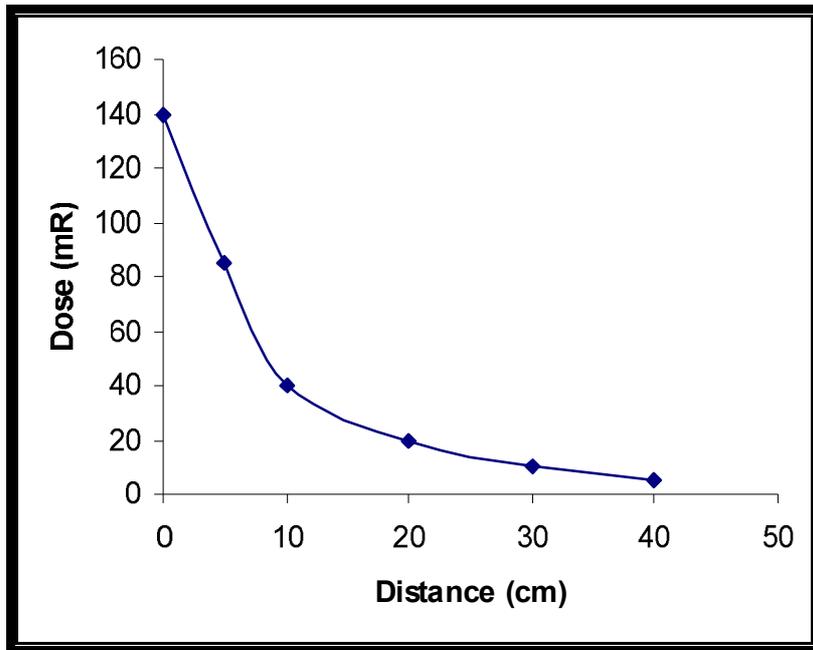


Fig. (5): Intensity of X-ray beam (mR) at different distance from X-ray window.

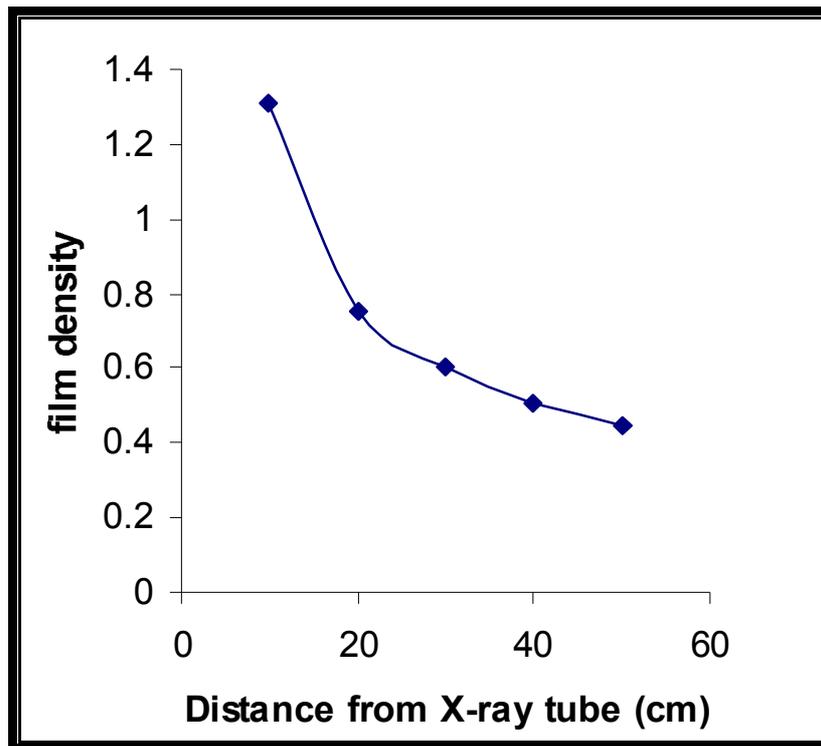


Fig. (6): Film density of X-ray beam at different distance from X-ray tube window.

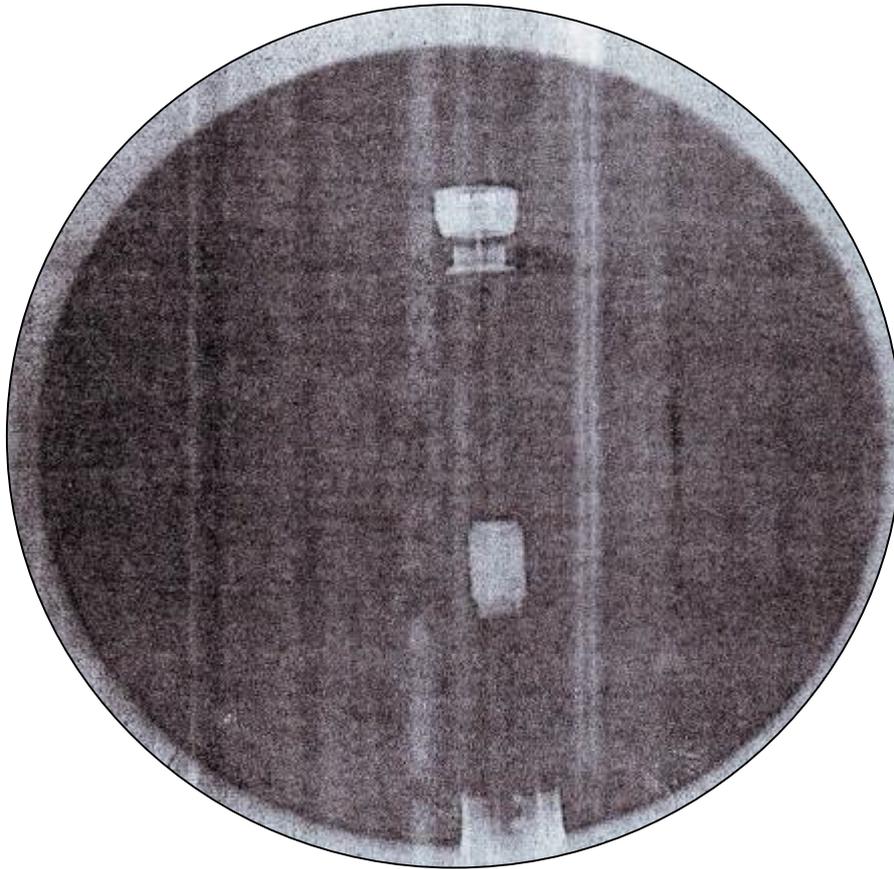


Fig. (7): X-ray Image of dose meter device taken using Polaroid film place behind the object which were 20 cm away from the X-ray source. Single pulse X- ray was used in this case.

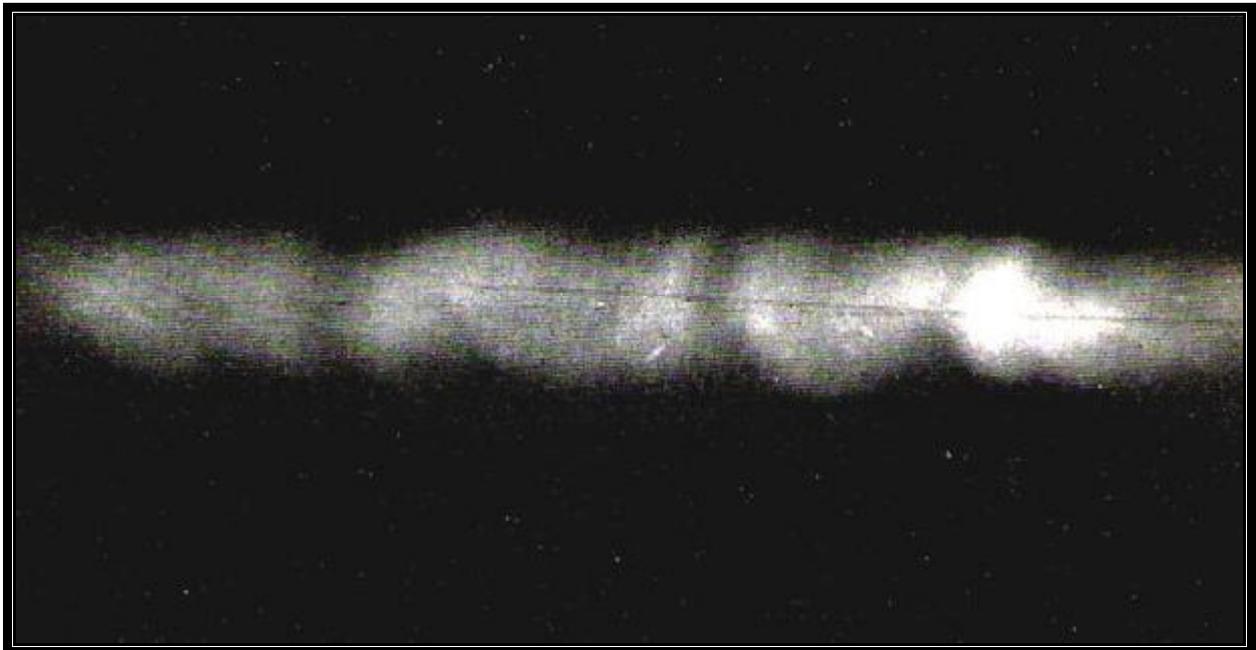


Fig. (8): X-Ray image of steel welding taken using X-ray film (high sensitive Kodak Film), the film was placed behind the object and both placed at 20 cm from the window. Three pulse of X-ray was used in this case.

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الخلاصة

في هذا البحث تم تصميم وبناء انبوب اشعة سينية بنيت على تقنية الانبعاث بواسطة الكاثود البارد. ان الجهاز اعطى اشعة سينية بزمن نبضة قدرها (1.2) مايكروثانية وشدة اشعاع قدره (90) مللي رنتكن على مسافة 10 سم من الانبوب عند تسليط 150 كيلو فولت عبر الاقطاب. ان الخصائص الاخرى كشددة اشعاع على مسافات مختلفة من الانبوب وفضل مسافة بين الكاثود والانود والتي تعطي اعلى شدة تم دراستها ايضا. ان الانبوب صمم ليكون من النوع القابل للتفكيك، سهل الصيانة مع امكانية استخدامه مستقبلا للاغراض الصناعية والطبية.