Canada

Health and Welfare Canada
Santé et Bien-être social Canada

79-EHD-41

recommended safety procedures for the selection and use of demonstration-type gas discharge devices in schools

ERRATA

Recommended Safety Procedures for the selection and use of demonstration-type gas discharge devices in schools

79-EHD-41

PAGE iii

CONTENTS

(SEE REVERSE SIDE)

STANDARDS OF FUNCTIONING

5. Every device shall function in such a way that the emission of X-rays therefrom, under all possible conditions of operation and for as long as the device has its original components or has replacement components recommended by the manufacturer, is such that the average exposure rate of X-rays to an object having a 10 square centimetre cross section and centred at 5 centimetres from any accessible external surface of the device does not exceed 0.5 milliroentgen per hour.

RECOMMENDED SAFETY PROCEDURES FOR THE SELECTION AND USE OF DEMONSTRATION-TYPE GAS DISCHARGE DEVICES IN SCHOOLS

Environmental Health Directorate
Health Protection Branch

Published by authority of the
Minister of National Health and Welfare

79-EHD-41

COPIES OF THIS REPORT CAN BE OBTAINED FROM:

Information Directorate
Department of National Health and Welfare
Brooke Claxton Building
Ottawa, K1A 0K9

CONTENTS

FOREWORD

Modern science laboratories in educational institutions employ as teaching aids a variety of equipment for demonstration and experimentation. Many of the devices used are capable of emitting X-rays, microwaves or other potentially hazardous radiations at levels greater than considered acceptable.

One class of demonstration device in widespread use in schools is the gas discharge tube. Some gas discharge tubes, in particular the cold cathode type, can emit X-rays at significantly high levels. Unless such tubes are used carefully, and with due regard for good radiation safety practices, they can result in exposures to students that are in excess of the maximum levels recommended by the International Commission on Radiological Protection.

This document has been specially prepared to assist science teachers and others using demonstration-type gas discharge devices to select and use such devices so as to present negligible risk to themselves and to students. It contains useful information on safety procedures that should be followed when performing these demonstrations or experiments. Clearly a document such as this cannot cover all possible situations, nor can it substitute for the exercise of sound judgement, so the recommendations may need modification in unusual circumstances. Interpretation or elaboration on any point in this document can be obtained by contacting the Radiation Protection Bureau in Ottawa.

This document was drafted by Dr. W.M. Zuk and Mr. E. Rabin.

AVANT-PROPOS

Dans les laboratoires de sciences modernes des établissements d'enseignement, divers appareils sont employés comme outils didactiques à des fins de démonstration et d'expérimentation. Bon nombre de ces appareils peuvent émettre des rayons X, des micro-ondes ou d'autres rayonnements potentiellement dangereux à des intensités de rayonnement supérieures aux limites acceptables.

Le tube à décharge est l'une des catégories de dispositifs pour démonstrations dont l'usage est répandu dans les écoles. Certains de ces tubes, particulièrement les tubes à cathode froide, peuvent émettre des rayons X dont l'intensité est très élevée. Si les personnes qui utilisent de tels tubes ne sont pas prudentes ou n'observent pas les mesures de protection contre les rayonnements, les élèves peuvent être soumis à des irradiations supérieures à celles qui sont recommandées par la Commission internationale de protection contre les radiations.

Le présent document s'adresse particulièrement aux professeurs de sciences et à d'autres personnes qui emploient des dispositifs à décharge pour démonstration, afin de les aider à choisir et à utiliser de tels dispositifs de manière à ce que leurs élèves et eux-mêmes courent le moins de risques possible. Le document renferme des renseignements utiles sur les mesures de sécurité à observer au cours des démonstrations ou des expériences. Il est évident qu'un document du genre ne peut couvrir toutes les situations possibles ni remplacer le bon sens. Il se peut donc que les recommandations doivent être modifiées dans des circonstances particulières. On peut obtenir des explications ou des éclaircissements sur des aspects quelconques du document en communiquant avec le Bureau de la radioprotection à Ottawa.

Le présent document a été rédigé par Messieurs W.M. Zuk et E. Rabin.

1. INTRODUCTION

In Canada, as in many other countries, increasing numbers of demonstrations and experiments in school science programs involve use of potential sources of ionizing radiation. As a result, large numbers of students under the age of 18 years are susceptible to being unnecessarily exposed to ionizing radiation. It is particularly important that all such exposure be avoided. Because it occurs at an early age, any gonadal irradiation from such demonstrations makes for maximum contribution to the population genetic dose. For this and other reasons, the International Commission on Radiological Protection (I.C.R.P.) has recommended[1,2] dose limits for pupils in schools of one-tenth of the dose limits recommended for individual members of the public.

In 1972 the Radiation Protection Bureau surveyed secondary schools in the Ottawa area to determine what demonstration-type radiation emitting devices were available in the schools and to assess the nature and extent of hazards associated with their use. Particular emphasis was placed on gas discharge tubes because of an earlier U.S. study[3] which revealed that cold cathode gas discharge devices were widely available in U.S. schools and were capable of emitting X-rays at hazardous levels. The results of the Ottawa area study, described briefly in section 3, confirmed the U.S. findings and pointed to the need for regulatory action to control demonstration-type gas discharge devices. The survey results also strongly indicated that there was a definite need for safe use guidelines for such devices. Interim guidelines were produced and widely circulated in Canada shortly after the results of the survey were known. The intent of this document is to formalize the interim guidelines and to provide more comprehensive recommendations which, when adhered to, will ensure that demonstration-type gas discharge devices present no radiation hazard either to pupils or teachers.

2. GAS DISCHARGE TUBES

For many years, gas discharge tubes have been in widespread use in schools for experimental treatment of atomic physics. These devices are designed to demonstrate the production, properties and effects of electrical discharges in gases and the luminous phenomena which accompanies them. Some discharge tubes are specifically designed to generate X-rays; in others, X-ray emission is incidental to the intended purpose. In its basic form, a gas discharge tube consists of a partially evacuated, sealed glass tube, containing the gas of interest at a predetermined pressure, and two or more electrodes for applying a high voltage to the enclosed gas.

Gas discharge tubes are usually classified in accordance with the means used to produce electron emission from the cathode. Discharge tubes in which the electrons are produced by means of thermionic emission are referred to as hot cathode tubes. By employing a heated filament to produce the electrons, such tubes have been designed to demonstrate the desired effects with operating voltages below 5000 volts and without accompanying x-radiation. Several demonstration-type hot cathode tubes are available commercially. In the 1972 survey, referred to in Section 1, no x-radiation was detected from such tubes when operated at voltages within the manufacturer's specified operating range.

The second catagory of discharge tubes does not employ a heated cathode; the electrons are released from the cold cathode surface by positive ion bombardment. The positive ions are generated by ionization of gas atoms contained in the tube. Such tubes are classified as cold cathode tubes. A variety of high voltage sources is used to operate cold cathode discharge tubes, but induction coil power supplies, because of their low price, are used most frequently. The applied voltages from induction coil supplies can only be adjusted crudely by spark gas distances and hence are usually considerably higher than the minimum required to operate the cold cathode discharge tubes. The 1972 survey revealed that a number of different types of cold cathode discharge tubes emitted X-rays incidental to their intended purpose and that the exposure rate increased markedly if the minimum voltage necessary to show the desired effect was exceeded.

Some typical gas discharge tubes employed as demonstration aids in schools are shown in Figures 1 to 9, and are described briefly in the remainder of this section.

2.1 Cold Cathode X-Ray Tube

The typical cold cathode gas discharge X-ray tube found in schools is the "Muller" type, shown in Figure 1. Such tubes are unshielded and are usually operated with an induction coil. These tubes will produce X-rays when energized with either a forward or a reverse potential. X-rays are emitted in all directions from the tube although the most intense output is in the hemisphere facing the anode. This is illustrated in Figure 10, which shows measured exposure rates from two unshielded cold cathode X-ray tubes.

It should be noted that there can be wide variations in measured exposure rates between individual tubes and from the same tube from day to day. This is characteristic of gas discharge tubes and is reflected in the variations in the measured maximum exposure rates given in Table 2.

The X-ray tubes are potentially the most hazardous of the cold cathode gas discharge tubes. From the measured exposure rates shown in Figure 10 and Table 2, it is evident that the ICRP limits given in Appendix 1 would be exceeded in a very short time of exposure.

2.2 Shadow or Fluorescence Effect Tube

The typical shadow or fluorescence effect tube is shown in Figure 2. As in the case of the X-ray tube, such tubes are typically unshielded and are usually operated with an induction coil power supply.

This tube is used to demonstrate that the energy of the electron beam from the cathode is converted into visible radiation by fluorescence of the glass walls when the walls are bombarded by the electrons. The metallic maltese cross intercepts part of the electron beam and casts a "shadow" on the wall of the tube opposite the cathode. From observation of the shadow it can be shown that the "cathode rays" travel in straight lines.

Fluorescence effect tubes are capable of emitting X-rays which are incidental to the effects which these tubes are designed to demonstrate. In common with the cold cathode X-ray tubes, the X-ray emission levels vary widely between individual tubes and can be unacceptably high, as can be seen from the measured exposure rates given in Table 2.

2.3 Magnetic or Deflection Effect Tube

The deflection effect tube is designed to demonstrate that the rays emanating from the cathode consist of charged particles that can be defleted by a magnetic field. This type of discharge tube, shown in Figure 3, is also one from which X-ray emission is incidental to the intended purpose of the device. In addition to the usual variation between individual tubes, there is a variation in X-ray emission with time of operation; the emission tends to decrease after the tube has been operating for several minutes.

2.4 Heat Effect Tube

The heat effect tube, shown in Figure 4, contains a thin foil target positioned between the anode and a concave cathode. This type of tube is designed to demonstrate that the cathode rays are rapidly moving electrons whose kinetic energy is converted to heat when the electrons collide with the foil. The concave cathode focuses the electrons on a small spot on the foil, which can be heated to white heat and destroyed unless care is taken in operating the tube. This has, in fact, occurred in the tube illustrated in Figure 4.

This type of tube can emit X-rays both under forward and reverse polarity, but particularly so under reverse polarity conditions. As can be seen from Table 2, X-ray emission can be substantial.

2.5 High or Low Vacuum Effect Tube

This type of gas discharge tube, shown in Figure 5, is used to demonstrate the flow of electrons in low and high vacuum. In the low vacuum tube the path of the electron beam between the cathode and a positive electrode is made visible by excitation of the gas molecules IN THE TUBE. In the high vacuum tube the beam is not visible and the presence of electrons from the cathode is shown by fluorescence of the tube wall near the anode.

Some tubes of this type emit X-rays but, the general, at somewhat lower levels than the types of tubes already described.

2.6 Other Gas Discharge Tubes

There are other gas discharge tubes available, for demonstrating the properties of electron beams and discharge phenomena in gases, from which X-ray emission does not occur. These include the vacuum discharge tube ((Figure 6), the kinetic energy tube (Figure 7), the canal ray tube (Figure 8), and the Geissler tubes (Figures 9).

3. RADIATION HAZARDS

3.1 Radiation Protection Bureau Survey

In 1972 the Radiation Protection Bureau surveyed secondary schools in the Ottawa area to determine what demonstration-type radiation emitting devices were being used and to assess the nature and extent of hazards associated with their use. The thirty schools surveyed has a total enrollment of approximately 32 000, of which it was estimated that approximately 6500 students took classes in which radiation emitting devices of various types were used as teaching aids.

A total of 347 actual or potential X-ray sources were found in these schools. More than half of these sources were gas discharge tubes. A detailed summary of the numbers and types of gas discharge devices and of the power supplies found in the surveyed schools is given in Table 1.

3.2 Exposure Rates

The results of radiation measurements on representative samples of the X-ray tubes and gas discharge tubes are given in Figure 10 and Table 2. The measurements on the two X-ray tubes in Figure 10 were carried out in the Radiation Protection Bureau's laboratories, using a regulated D.C. power supply having a controllable and accurately variable output. The majority of measurements on the other X-ray tubes and gas discharge tubes were carried out at the schools using their induction coil power supplies.

As can be seen from Figure 10 and Table 2, there were wide variations in measured maximum exposure rates between individual tubes of any particular type. This was due to a combination of the variety of power supplies used in the schools and the variations in the behavior of individual tubes. In general, the exposure rate measurements were made at the minimum voltage required to make the device operate. This voltage was found to be dependent on the general condition or age of the tube and also could vary significantly from day to day for any particular tube.

It is also evident from Figure 10 and Table 2 that unshielded X-ray tubes are potentially the most hazardous of the could cathode gas discharge tubes. However, the fluorescent effect, deflection effect, heat effect and vacuum effect tubes also emitted X-rays at unacceptably high levels.

In general, no instructions regarding safe operating voltages were available for most of the gas discharge tubes. Typically, if the minimum voltage necessary to show the desired effect was exceeded the exposure rate increased markedly. For example, with one of the shadow effect tubes the minimum operating voltage was found to be 11kV. At this voltage the measured exposure rate at 30 cm from the surface of the tube was 12 mR/h. With the operating voltage increased to 12kV, the exposure rate increased to 550 mR/h.

Measurements carried out by provincial authorities in other schools in Canada yielded similar results and confirmed that the Ottawa findings were representative of the situation across Canada.

3.3 Poor Demonstration Procedures

The majority of science teachers interviewed during the RPB survey had little or no knowledge of radiation protection principles or practices with the result that very poor demonstration procedures were the rule rather than the exception. Most of the teachers demonstrating gas discharge tubes were unaware of the fact that devices of this type, other than X-ray tubes only, could produce X-rays at significant levels. As a result, the tubes were operated without any shielding or other precautions consistent with good radiation protection principles. Furthermore, with the induction coil power supplies used to power these devices, the applied voltages were usually considerably higher than the minimum voltages required to operate the device. Typically the demonstration would be performed on a bench or table with students clustered around the device.

Demonstration procedures used with cold cathode X-ray tubes were found to be bad both in the RPB survey and in the investigations carried out by provincial authorities. A typical experiment with the X-ray tubes was to demonstrate the ability of X-rays to discharge a charged electroscope. For example, in the Ottawa area, four of the nine cold cathode X-ray tubes were used for this purpose. In three of these demonstrations the tubes were completely unshielded and the students were in the same room as the tube. In each case the tube was placed on a table and pointed "away" from the class toward a charged electroscope. The distances between the students and the X-ray tubes in these demonstrations varied from "2 to 6 feet" in one demonstration to "about 25 feet" in another. The measured exposure rates from one of the three tubes used in this way is given in Figure 10 (tube 2). (The same demonstration procedures were used with the fourth X-ray tube except that some car batteries were placed around the tube to act as shielding.)

The other typical use of cold cathode X-ray tubes is for fluoroscopy demonstrations, and bad demonstration practices were observed. For example, three of the X-ray tubes in the Ottawa area were used for fluoroscopy demonstrations. Two of these involved fluoroscopy of inanimate objects only. The experimental arrangement was the same in both demonstrations. The X-ray tube was enclosed within a wooden box lined with 1/16 inch thick lead sheet. The objects to be viewed were placed on a cardboard tray inside the box through an access opening and a hand-held fluoroscope (of the type shown in Figure 11) was placed over the opening. The X-ray tube was then activated and each student looked through the fluoroscope. The viewing times were "about 15 seconds" per student in one of these demonstrations and "a few seconds only", in the other.

Radiation measurements on one of these two experimental setups showed that with an induction coil power supply and the minimum voltage necessary to operate the X-ray tube, the exposure rates were as follows:

With fluoroscope removed:	
At the access opening	20 R/h
At 30 cm above the access opening	3 R/h
With fluoroscope in position:	
At the eyepiece	70 mR/h
At 30 cm from the sides of the box	15 mR/h

The third and worst demonstration involved fluoroscopy of pupils' hands using a completely unshielded cold cathode X-ray tube. The setup for the demonstration is illustrated in Figure 11. According to the teacher conducting the demonstration, students were invited to view their own hands "for a few moments".

The X-ray tube used in this demonstration is the one designated as number 1 in Figure 10. At 2.5 cm from the surface of this tube, which was about the distance at which the pupils held their hands, the measured exposure rate was about 936 R/h. This meant that the annual dose limit of 0.75 rem to the hands, as recommended by the International Commission on Radiological Protection(1), (see Appendix 1) was exceeded in 3 seconds. Furthermore, at 60 cm from the surface of the tube, which was approximately the distance from the tube to the pupils' gonads, the measured exposure rate of 8.83 R/h meant that the recommended annual dose limit of 50 mrem was reached in about 20 seconds, and the recommendation that no pupil receive more than one-tenth of the yearly dose limit in any one experiment was exceeded in approximately 2 seconds. Clearly this type of demonstration is contrary to basic radiation protection principles and should never be carried out.

4. STANDARDS FOR NEW GAS DISCHARGE DEVICES

All new demonstration-type gas discharge tubes sold in Canada must conform to the requirements of the Radiation Emitting Devices Regulations for Demonstration-Type Gas Discharge Devices. These Regulations which came into effect in 1976, specifiy standards of design, construction and functioning, with respect to radiation safety of such devices, and are mandatory requirements for new devices only. While it is the responsibility of the manufacturer or distributor to ensure compliance with the requirements of the Regulations, the science teacher should be familiar with the requirements so as to be reasonably certain that the devices being purchased do, in fact, conform to the Regulations.

The Regulations applicable to demonstration-type gas discharge devices, in effect at the time of printing of this publication are reproduced in Appendix 2. These Regulations may be amended from time to time to keep abreast of changing technology in the field. Information on the currency of the Regulations and details of any promulgated amendments can be obtained by contacting the Radiation Protection Bureau, Health and Welfare Canada, Ottawa, Ontario, K1A 1C1.

One basic requirement of the Regulations is that a gas discharge device must incorporate sufficient shielding so that under all possible conditions of operation the X-ray emission rate, measured at a distance of 5 centimetres from the external surface of the device, does not exceed 0.5 milliroentgen per hour. This, together with the other safety features specified by the Regulations, ensures that such devices can be used safely and will not pose a radiation hazard either to students or teachers, provided that the manufacturer's instructions for use are followed.

Unfortunately, there are large numbers of gas discharge devices still available in schools which were manufactured prior to the advent of the Radiation Emitting Devices Regulations. As a rule, these older devices do not incorporate the safety features required of new devices, and can cause significant radiation exposures unless proper safety precautions are taken in using them.

5. RECOMMENDED SAFETY PRECAUTIONS

For optimum safety the older types of demonstration gas discharge tubes should be replaced by new tubes that conform to the standards specified in the Radiation Emitting Devices Regulations for such devices. Nevertheless, the older types of tubes can still be used with reasonable safety provided that the guidelines given below are followed.

5.1 General Safety Recommendations

1. A gas discharge tube should only be used after the instructions provided with the device have been carefully read.
2. A gas discharge tube should be operated with a power supply having a reasonably accurate and controllable high voltage output.
3. A gas discharge tube should never be operated above the voltage(s) recommended in the instructions.
4. No gas discharge tube should be kept in operation longer than is necessary to demonstrate the desired effect.
5. During demonstrations students should be no closer than 2 metres to the device.
6. No fully assembled and ready to be energized gas discharge tube demonstration should be left unattended in an area accessible to students.

5.2 Specific Recommendations

5.2.1 X-Ray Tubes

1. Unshielded tubes - An unshielded X-ray tube must not be used in a classroom demonstration or student experiment. The X-ray tube should be shielded with lead sheet of at least 1/8 inch thickness so that the useful X-ray beam is localized.
2. Shielded tubes - In any demonstration using a shielded X-ray tube in which the X-rays emanate from a beam port, the primary beam must always be directed away from the class toward an unoccupied area. (It should be noted that the types of demonstrations carried out with X-ray tubes can be performed just as well with the X-ray tube fully enclosed within a shielded cabinet.)
3. To reduce student exposure to scatter radiation, in cases where the primary beam is directed in the open, it is important to keep a distance of at least 3 metres between the students and the equipment. No student should be allowed to use such equipment.

4. Where an X-ray tube and its associated experimental apparatus is fully enclosed within a shielded cabinet which meets the leakage standards specified in Appendix 2 students may be permitted to use the X-ray equipment but only under direct supervision by qualified teacher or instructor.

5. Under no circumstances are students to be used as subjects in fluoroscopy demonstrations.

6. Any fluoroscopic screen which is to be viewed directly must be shielded by leaded glass. Similarly, any other viewing port in a shielded cabinet must be of leaded glass.

5.2.2 Other Gas Discharge Tubes

1. Unshielded gas discharge tubes such as the heat effect, deflection effect, fluoroscent effect and high and low vacuum effects tubes should be used only by the teacher or instructor.

2. The tubes should be operated at the lowest voltage necessary to show the desired effect, and with the proper polarity.

3. If students are required to carry out experiments with gas discharge tubes, they should do so only under direct supervision of a qualified teacher or instructor and only after they have been made aware of the limitations and potential hazards of the devices.

REFERENCES

1. "Radiation Protection in Schools for Pupils up to the Age of 18 Years"; International Commission on Radiological Protection, Publication 13, 1968.

2. "Recommendations of the International Commission on Radiological Protection. ICRP Publication 26"; Annals of the ICRP, Volume 1, Number 3, 1977.

3. "Radiation Sources in Secondary Schools. Report of a Limited Survey"; U.S. Department of Health, Education, and Welfare, Bureau of Radiological Health, Office of Regional Operations, Technical Report ORO 69-5, 1969.

APPENDIX 1

DOSE EQUIVALENT LIMITS FOR PUPILS IN SCHOOLS

The International Commission on Radiological Protection, in its most recent recommendations (ICRP Publication 26, 1977), concludes that the exposure resulting from demonstrations or experiments with radiation sources is likely to involve a very large number of people and might thus contribute significantly to the general exposure. For this reason the ICRP reaffirms the detailed recommendations with regard to "school exposure" given in ICRP Publication 13, "Radiation Protection in Schools for Pupils up to the Age of 18 Years". The objective of these recommendations is to achieve a situation whereby the annual dose equivalents received by individual pupils will be most unlikely to exceed one-tenth of the dose equivalent limits recommended for individual members of the public.

The annual dose equivalent limits for students are therefore:

Whole Body	0.05 rem (0.5 mSv)
Thyroid	0.30 rem (3 mSv)
Thyroid of children up to 16 years of age	0.15 rem (1.5 mSv)
Gonads and red bone marrow	0.05 rem (0.5 mSv)
Other organs	0.15 rem (1.5 mSv)

It is also recommended that no pupil receive more than one-tenth of the above dose equivalent limits in the course of any one demonstration or experiment.

It should be noted that the ICRP intended compliance with these dose equivalent limits to be achieved through proper, safe design of equipment and experiments rather than by detailed monitoring.

APPENDIX 2

RADIATION EMITTING DEVICES REGULATIONS FOR DEMONSTRATION-TYPE GAS DISCHARGE DEVICES

The Radiation Emitting Devices Regulations establishing standards of design, construction and functioning for demonstration-type gas discharge devices were passed by Governor-in-Council on February 3, 1976 and were published in the Canada Gazette, Part II of February 25, 1976. These Regulations define a demonstration-type gas discharge device as:

"*being a device that*

(a) contains an electronic device in which glow discharges or X-rays or both may be produced by the acceleration of electrons and ions; and

(b) is designed to demonstrate the production, properties or effects of glow discharges or X-rays, or the flow of electrons or ions."

The specific requirements of the Regulations are reproduced below.

"PART V"

DEMONSTRATION-TYPE GAS DISCHARGE DEVICES

1. In this Part,

"cabinet" of a device means a structure that encloses and confines the X-ray source of the device and the material to be irradiated in the device;

"device" means a demonstration-type gas discharge device;

"gas discharge tube" means an electronic tube in which glow discharges or X-rays or both may be produced by the acceleration of electrons or ions;

"model designation" means any combination of letters or figures or both letters and figures by which a device that bears that designation is claimed to have characteristics and design features that are uniform.

2. Every device that contains a gas discharge tube not specifically designed to generate X-rays shall be designed and constructed to include the following safety features:

(a) a permanent mark or label that

(i) is clearly visible under conditions of normal use,

(ii) identifies the device by setting out the name of the manufacturer, model designation, and date and place of manufacture,

(iii) indicates the intended polarity of each terminal of the device, and

(iv) indicates the power supply or maximum voltage to be used with the device; and

(b) shielding that

(i) is sufficient to enable the device to comply with the standards of functioning set out in section 5, and

(ii) is either non-removable or is so constructed that its removal renders the device inoperable.

3. Every device that contains a gas discharge tube specifically designed to generate X-rays shall have, on the external surface of the tube, a readily discernible mark or label that

(a) identifies the tube by setting out the name of the manufacturer, model designation, and date and place of manufacture; and

(b) bears the words "WARNING - THIS TUBE PRODUCES X-RAYS WHEN ENERGIZED. USE ONLY WITH APPROPRIATE SHIELDING. ATTENTION-CE TUBE PRODUIT DES RAYONS X LORSQU'IL EST ACTIVÉ. NE DOIT ÊTRE UTILISÉ QU'AVEC UN BLINDAGE APPROPRIÉ.

4. Every device that contains a gas discharge tube specifically designed to generate X-rays shall enclose that tube in a cabinet that is constructed to include the following safety features:

(a) the x-radiation warning sign described in section 6 of this Part, clearly visible on and permanently affixed to the external surface of the cabinet;

(b) a readily discernible mark or label, permanently affixed to the external surface of the cabinet, that

(i) identifies the manufactuer, model designation and date and place of manufacture of the device, and

(ii) warns that the tube generates X-rays when energized;

(c) if the power source for the device is not an integral part of the device, a mark or label that

(i) is permanently affixed to the external surface of the cabinet, and

(ii) is clearly visible under normal conditions of use,

and that indicates

(iii) the intended polarity of the terminals of the device, and

(iv) the power supply or maximum voltage to be used with the device;

(d) a warning light that

(i) is in clear view of the operator,

(ii) indicates when X-rays are being generated, and

(iii) is connected in such a way that no X-rays can be generated if the light malfunctions;

(e) shielding that

(i) is sufficient to enable the device to comply with the standards of functioning set out in section 5 of this Part, and

(ii) is either non-removable or is so constructed that its removal renders the device inoperable; and

(f) the interlocking of all doors or panels that allow access to the interior of the cabinet so that if any door or panel is opened or removed X-rays cannot be generated.

STANDARDS OF FUNCTIONING

5. Every device shall function in such a way that the emission of X-rays therefrom, under all possible conditions of operation and for as long as the device has its original components or has replacement components recommended by the manufacturer, is such that the average exposure rate of X-rays to an object having a ten square centimetre cross section.

WARNING SIGN

6. The x-radiation warning sign referred to in paragraph 4(a) of this Part is a sign that

(a) is shown in two contrasting colours:

(b) is clearly visible and identifiable from a distance of one metre;

(c) has no outer dimensions less than 2 centimetres;

(d) bears the words "CAUTION - X - RAYS, ATTENTION-RAYONS X"; and

(e) is designed in accordance with the following diagram:

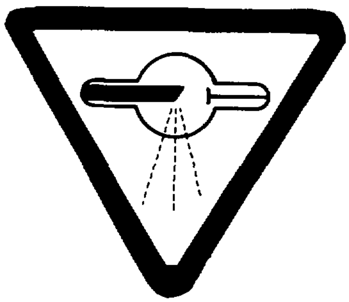


Table 1

Summary of the Ottawa - Area Survey Results

Device	No. found
X-Ray Tubes	
Cold Cathode X-Ray Tubes	20
Coolidge X-Ray Tubes	2
Cold Cathode Gas Discharge Tubes	
Shadow or Fluorescent Effect	19
Magnetic or Deflection	24
Heat Effect	6
High or Low Vacuum Effect	31
Kinetic Energy Effect	8
Canal Ray	3
Geissler	17
Spectral Discharge	59
Helmholtz (E/M)	3
Perrin Tube	1
Hot Cathode Demonstration Tubes	29
Sources of High Voltage	
Tesla Coil	28
Induction Coil	52
Van de Graaff	24
Wimshurst	20
Transformers (> 10 kV)	2

Table 2

X-Ray Exposure Rates from Gas Discharge Tubes

	Type of Tube	Range of Maximum Exposure Rates at 30 cm (mR/h)
1.	Cold Cathode:	
	X-Ray	4000 - 35 000
	Shadow or Fluorescent Effect	8 - 750
	Magnetic or Deflection Effect	2 - 340
	Heat Effect	13 - 300
	Vacuum Effects	1 - 130
	Geissler	<1
	Kinetic Energy Effect	<1
	Canal Ray	<1
	Spectral Discharge	<1
2.	Hot Cathode	
	X-Ray	<1
	*Other	<1

*Heat Effect, Shadow Effect, etc.

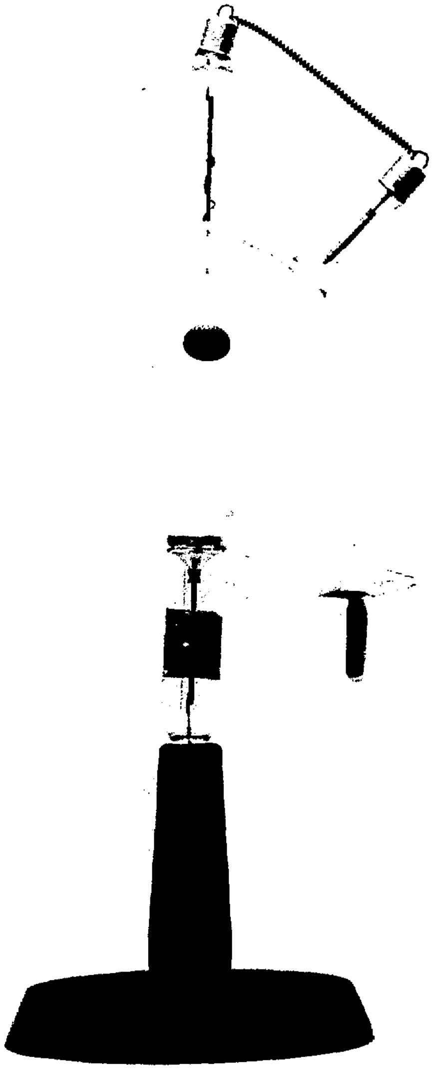


Figure 1

Cold Cathode X-Ray Tube

Figure 2

Shadow or Fluorescence Effect Tube

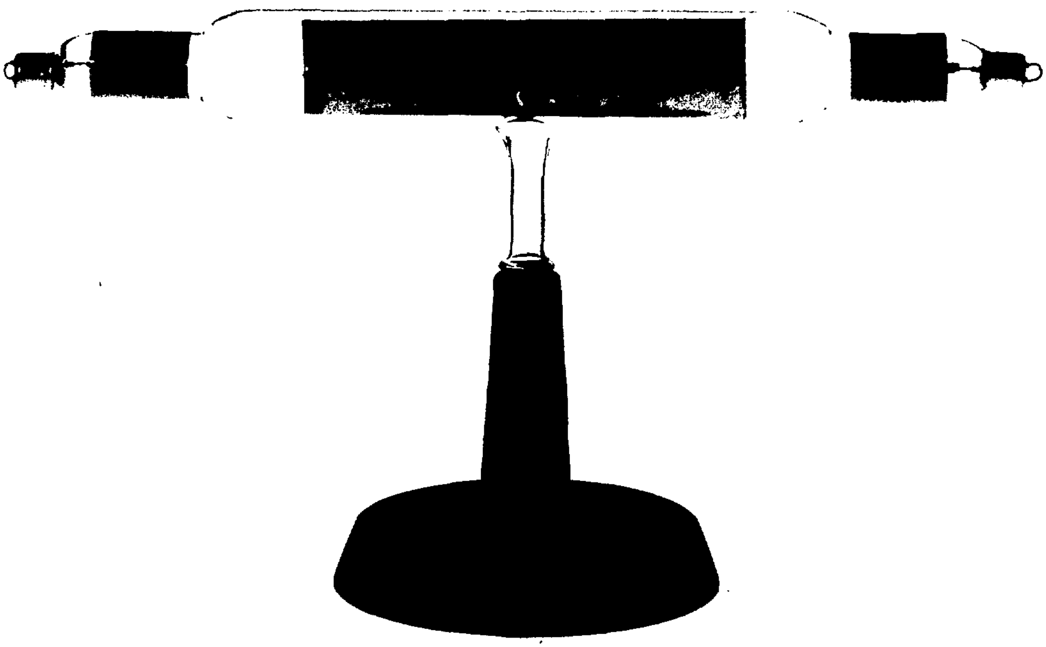


Figure 3

Magnetic or Deflection Effect Tube

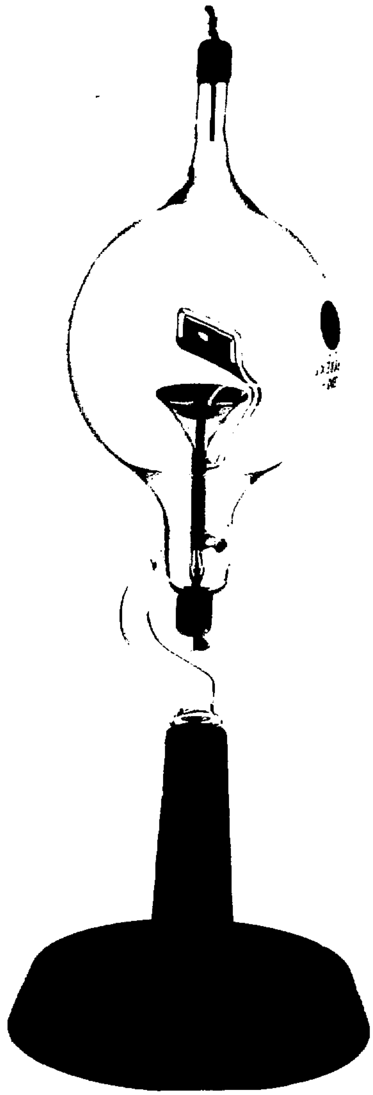


Figure 4

Heat Effect Tube

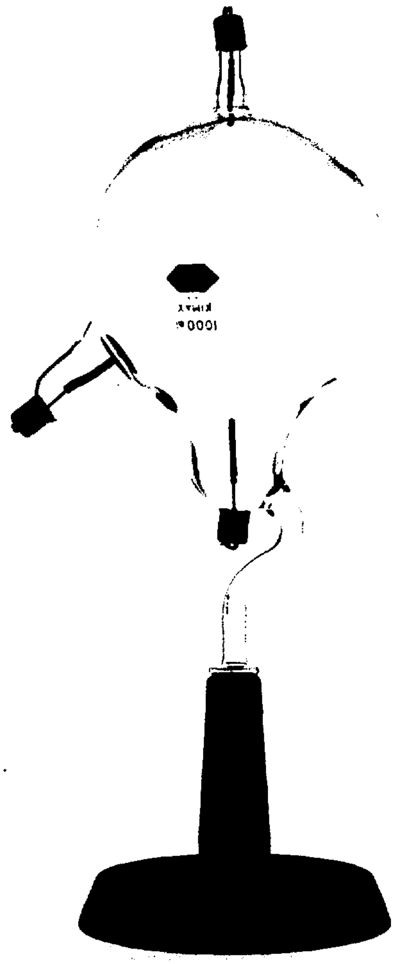


Figure 5

High or Low Vacuum Effect Tube

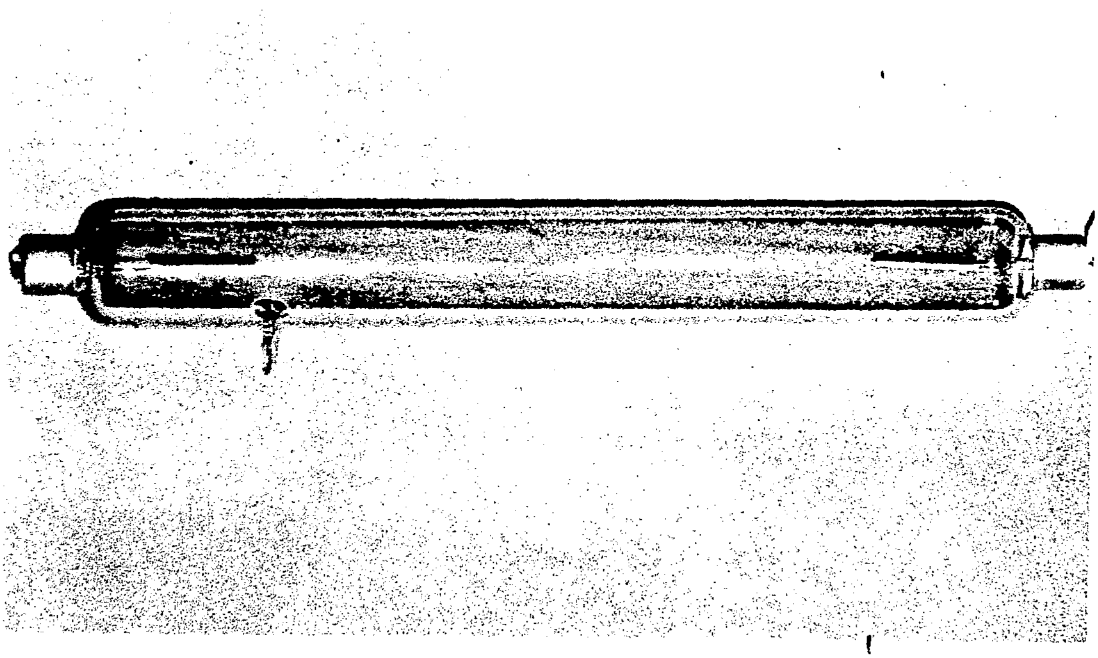


Figure 6

Vacuum Discharge Tube

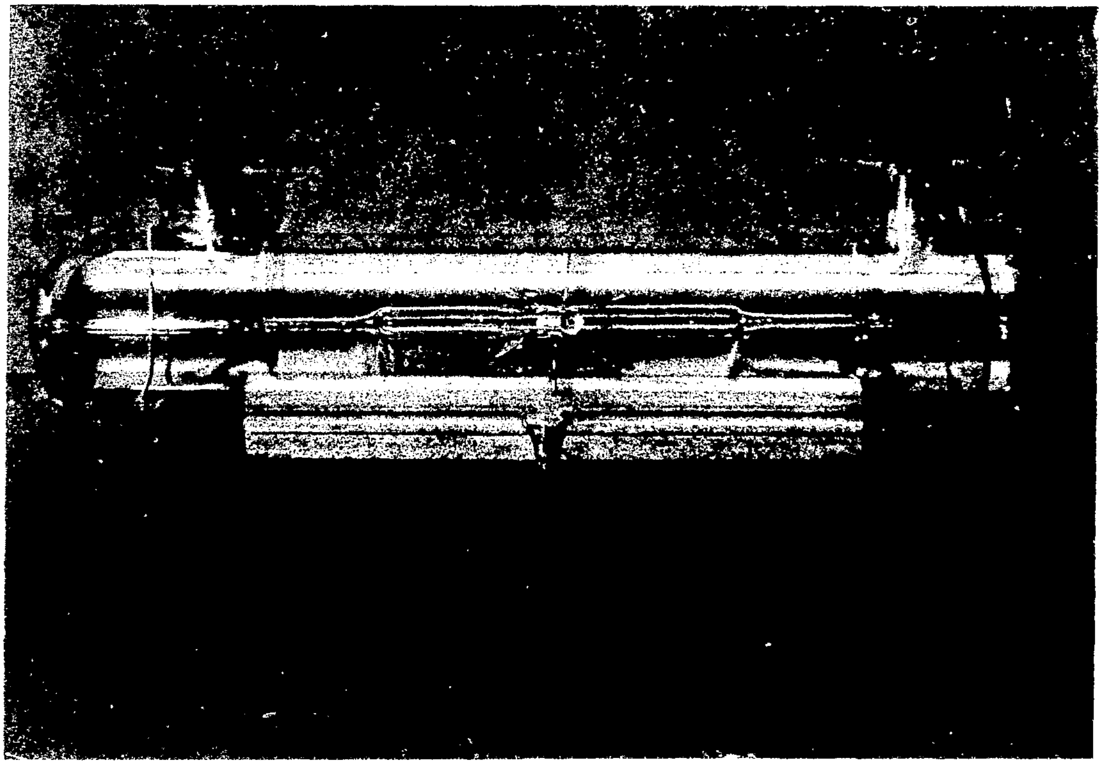


Figure 7

Kinetic Energy Tube

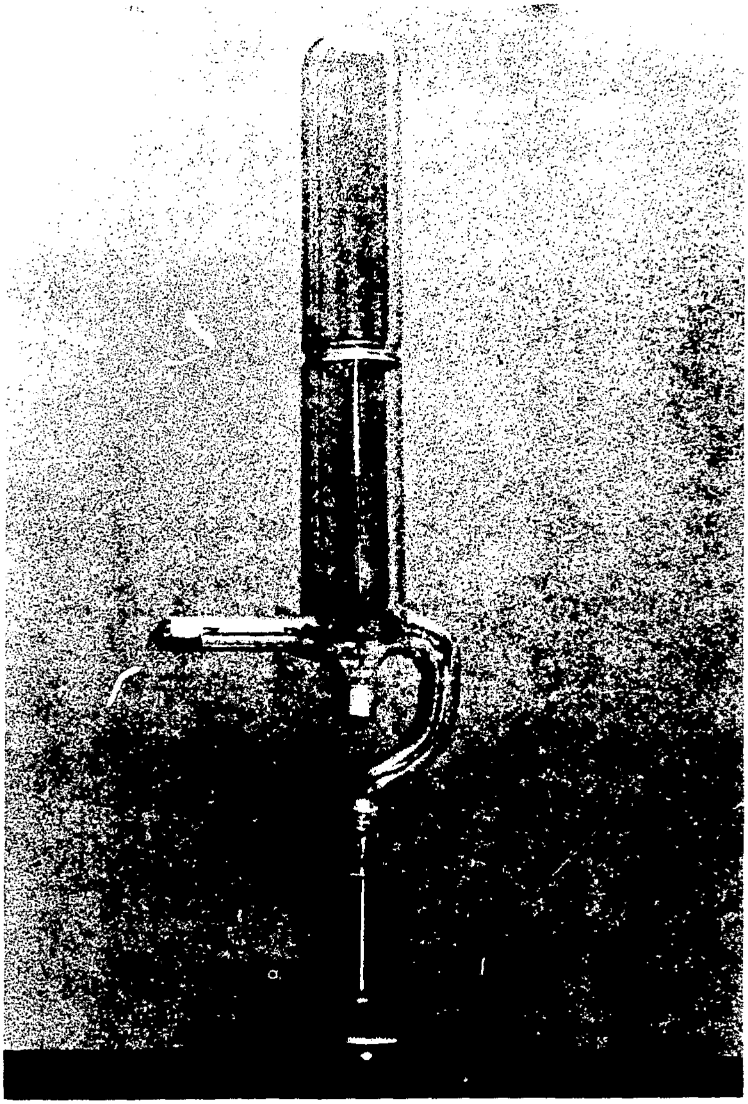


Figure 8

Canal Ray Tube

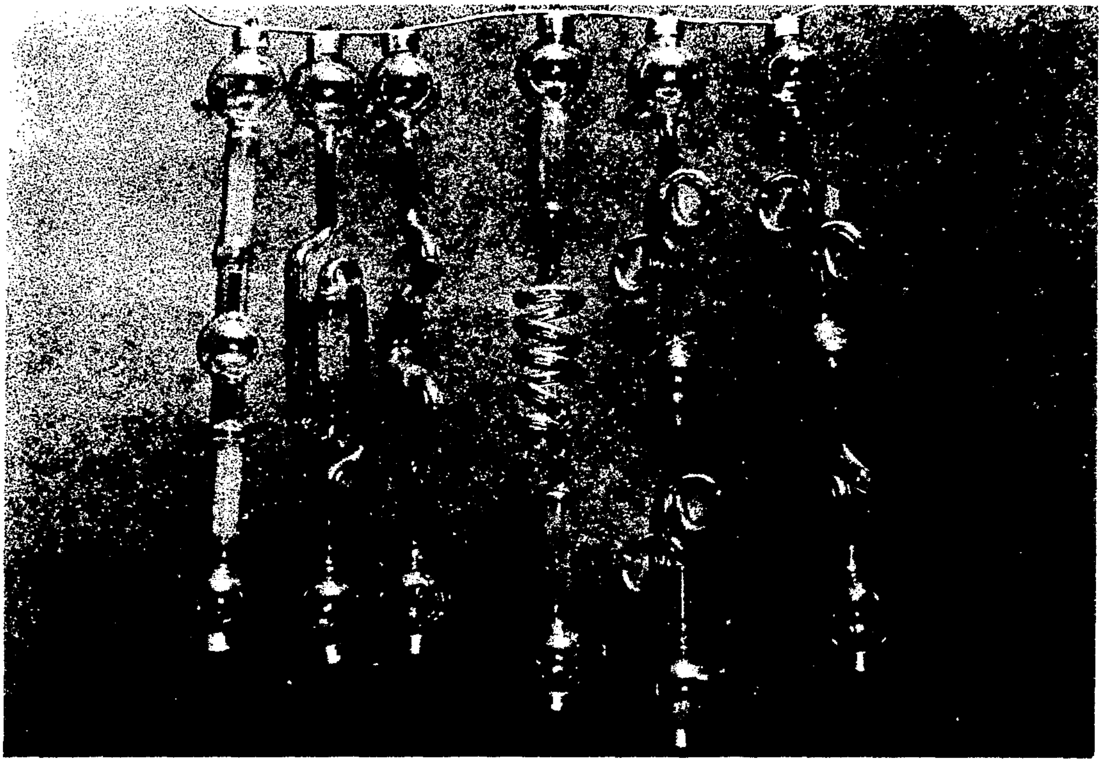
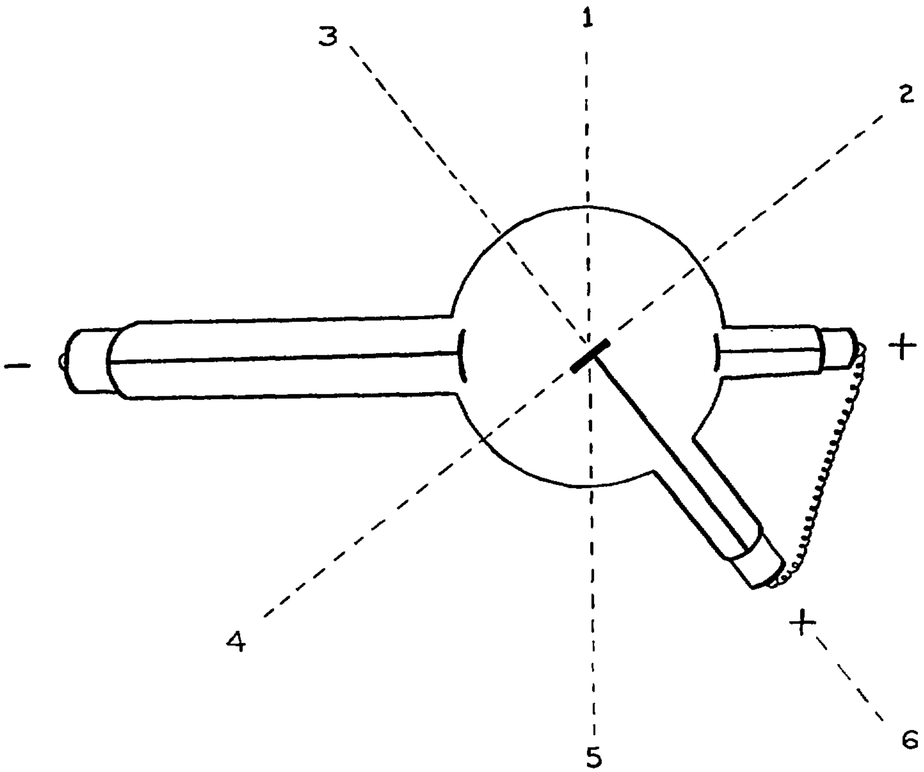


Figure 9

Geissler Tubes



EXPOSURE RATES FROM UNSHIELDED TUBES

TUBE NO.	EXPOSURE RATE mR/h AT 60 cm ALONG RADIAL NO.					
	1	2	3	4	5	6
1	8830	3640	3820	180	120	100
2	6690	1480	9000	340	230	200

Figure 10

Exposure Rates from Unshielded Cold Cathode X-Ray Tubes

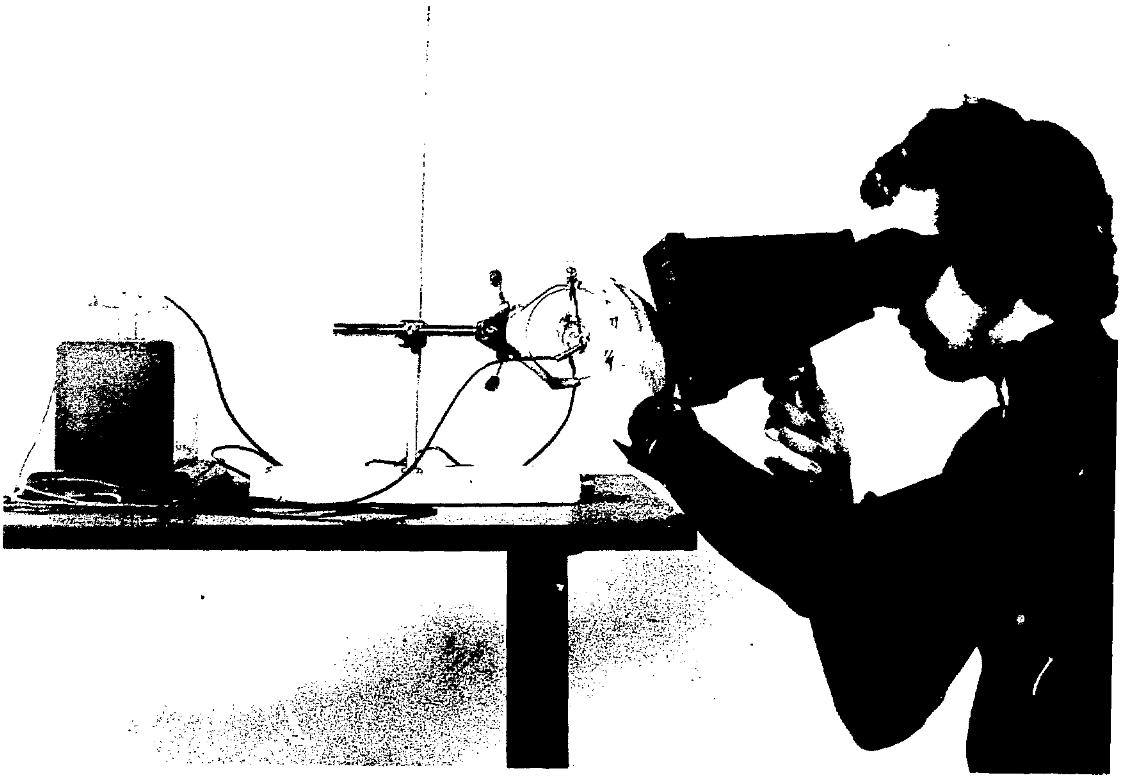


Figure 11

Experimental Arrangement for the Hand Fluoroscopy Demonstration