19BME308 - Medical Radiation Safety

UNIT I - INTRODUCTION TO RF AND MICROWAVE RADIATION

1.5 RF Radiation Measuring Instruments

Technical checklist for instrument specifications

The list below is not arranged in any particular order. The order of priority for the various choices will depend on the needs of the user. Some aspects may only be relevant to analogue meters since some facilities are implicit in the design of the new digital generation of instruments. Hence the checklist can be adjusted for relevance.

1 Frequencies to be covered and the frequency coverage of the instruments being considered

2 Choice of probes: diode or thermocouple sensor detector, where there is a choice. Suitability for pulse and amplitude modulated signals (if required). For diode types, check the maker's provision to reduce the measurement errors referred to earlier.

3 Dynamic range

4 Overload safety margin, especially for pulsed modulation

5 Quantities to be measured: Wm^{-2}; Vm^{-1}; Am^{-1}.

6 Meter scaling

7 Required operating temperature and humidity range

8 Investigate protection against out-of-band responses carefully!

9 General facilities required ('needed' rather than 'nice'): maximum hold; alarm; space/time-averaging, etc.

10 Mass and ergonomics

11 Knowledge of reliability and durability

12 Options, e.g. optical fibre connection, etc

13 Battery options

Measuring equipment

The measuring equipment used for X-ray measurement may be unfamiliar to those who have not had to involve themselves in ionising radiation. There is a considerable variety of types of instrument available and the basic operation of these is covered in the following paragraphs.

Ionisation chamber instruments

The basis of the measurement of X-rays in this type of instrument involves the determination of the amount of ionisation caused in a gas-filled chamber. Ionisation involves the production of ion pairs consisting of a negative ion (electron) and a positive ion. The chamber may use air or other gases, the air chambers usually being vented to the atmosphere. Dessicators may be required to reduce moisture levels in open chamber instruments.

Figure 1.1 illustrates the general principle of operation. The chamber has two conductive plates, one being connected to the high voltage positive DC supply terminal and the other to the negative supply terminal. The negative (return) connection is via a high resistance R. The chamber has a thin window, not depicted in the diagram, which minimises the attenuation of X-rays at the low energy end of the spectrum. When the chamber is exposed to an X-ray source, ionisation takes place as indicated in the diagram. The positive voltage on the upper plate will attract the negative ions (electrons) and the positive ions will be attracted to the lower plate.

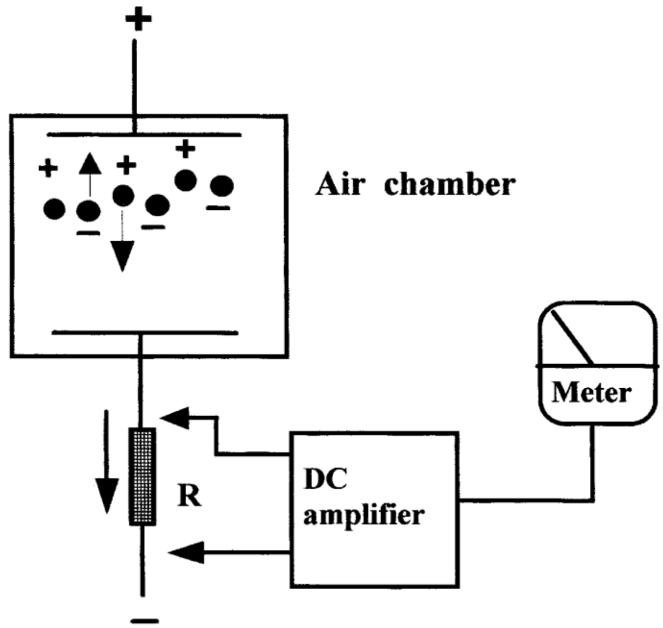

Figure 1.1 *Ionisation chamber X-ray measuring instrument – basic concept*

As a result a very small current which will be proportional to the number of ion pairs produced and thus the X-ray doserate, will flow through resistance R. As a result, it will develop a corresponding voltage across it. As the currents are very small, amplification is required to provide a current sufficient to operate a moving coil meter. The current flow arrow in the diagram indicates conventional current flow (positive to negative). It is necessary to ensure that the X-rays fill the chamber window otherwise some error may result. However, in the author's experience using several instruments of differing types on a variety of transmitters, very close agreement was found on each occasion even though the instruments had different chamber aperture sizes.

The meter can be scaled in doserate. With the newer instruments, scaling in sieverts is usually available. Sometimes the chamber is made of plastic, filled with a gas and sealed. This arrangement can have a good low energy response down to about 6 to 8 keV. It can, however, suffer from the loss of the gas due to permeation through the plastic and may need periodic recharging with gas. Purchasing a spare at the same time as the instrument is purchased is not necessarily a help since this may suffer the same gas loss. If a spare is needed, it should be purchased at about half way through the 'charge life' of the original chamber.

It is generally agreed that the ionising chamber instrument should always be used for transmitter X-ray measurements. A type appropriate to the work must be chosen.

The Geiger-Muller counter

The Geiger-Muller (GM) tube is a much more sensitive device than the ionisation chamber. It is basically a gas-filled tube operating at a voltage below that which would sustain a continuous gas discharge current. Figure 1.2 shows a much simplified representation of a GM tube where the positive plate is the central conductor and the negative plate is the cylindrical cathode. The pulse voltage is developed across the resistor R and coupled to a pulse threshold detector in the instrument circuitry and then into a counter. The tube is filled with a suitable gas, argon or krypton typically being used for tubes intended for X-ray work.

An X-ray photon will cause the production of an ion-pair as before in the ion chamber but in this case the electrons so produced will produce further ion pairs due to the extra acceleration provided by the higher supply voltage, resulting in an avalanche of current. This is known as gas amplification and results in a large pulse of current.

It is important to ensure that only one pulse is counted for each initiating photon, so a small amount of another gas, usually one of the halogen family, is added. This is known as a quenching gas and prevents possible spurious discharges which can result from secondary electron production in the tube.

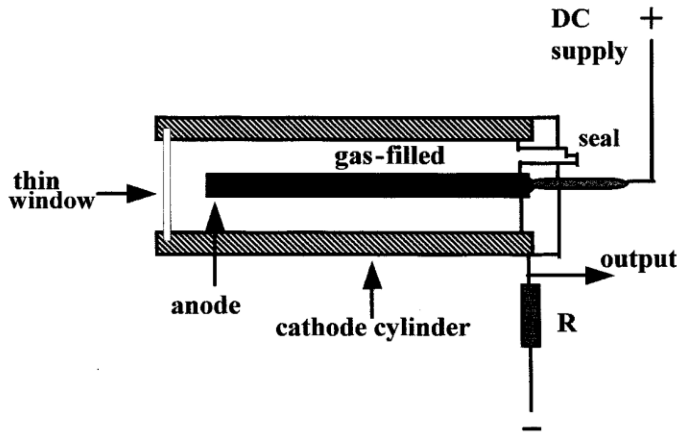

Figure 1.2 *GM X-ray counter tube (Courtesy Philips Electronic tubes)*

The effect is to render the tube insensitive for a short period between pulses and this is known as the ‘dead time’ after a pulse during which a successive pulse will not be counted. In a selection guide from Philips Electronic Tubes the magnitude of the ‘dead time’ ranges from 11 to 230 micro sec. according to the type and function of the tubes. Dead time needs to be taken into account when the manufacturer calibrates the instruments. The energy response of GM tubes is not very flat and in order to flatten it, some tubes are fitted with a filtration cylinder consisting of an arrangement of several types of metal. Specially designed tubes such as those listed by the manufacturer mentioned above, offer X-ray low energy operation down to about 2.5 keV.

When using a GM instrument on amplitude-modulated transmitters with high depths of modulation, the guidance given in the instrument handbook should be followed regarding the modulation test tone frequency to avoid the instrument registering the modulation frequency rather than the X-ray radiation. One instrument illustrated later in this chapter uses a GM tube. GM tube instruments are generally much cheaper than chamber instruments to manufacture, but tend to have a poorer energy response at the low energies involved in many transmitters.

Scintillation counters

Another type of instrument is the scintillation counter. This typically uses a sodium iodide crystal doped with tellurium or thallium. When the crystal is subjected to X-rays it gives off flashes of light which are amplified and detected by a photomultiplier tube. The dead time on this type of instrument can be around 40 micro second. This type of detector is very sensitive but some types lack a good low energy response. Both the GM tube counter instrument and the scintillation counter, when suitably chosen for the purpose, are particularly good for the initial part of a survey where they act as 'sniffers' (search instruments to locate leakage beams). They do not need to be calibrated for this purpose since they are only used to identify places where measurement is needed.

Reference: *Ronald Kitchen - RF and Microwave radiation safety handbook.*