OBJECTS OF A STABLE BEAM CALIBRATION SYSTEM BASED ON PHYSICAL CONSTANTS

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Calibration of protection-level dosemeters is a legal requirement in many countries[1] and in the UK is required by Regulation 24 of the Ionising Radiations Regulations 1985[2]. Two important features of the testing required under this regulation are that 1) the calibration is traceable to a national standard and 2) the accuracy of the calibration is known.

A major difference between the requirements for the calibration of clinical dosemeters for use in radiotherapy and of protection-level dosemeters is that in the former case there are a few dosemeters requiring calibration to a high standard of accuracy while in the case of protection-level dosemeters, there are a great number of dosemeters requiring calibration to a lower, but known standard of accuracy. The performance of dosemeters used for protection purposes must be verified on a regular basis, and in view of the numbers of dosemeters and doserate meters involved, a robotic system presents many advantages, as it is no longer permissible to use dosemeters the characteristics of which have not been verified.

In the system described, dosemeters are placed in known positions on measuring platforms (fig 1). On leaving the calibration cell, the operator initiates the calibration procedure, which can be wholly or partly robotic. Measuring sequences can be chosen so that each of two detectors can be placed at each position and exposed in turn, or alternatively a single detector can be exposed at each chosen position along the axis of the beam.

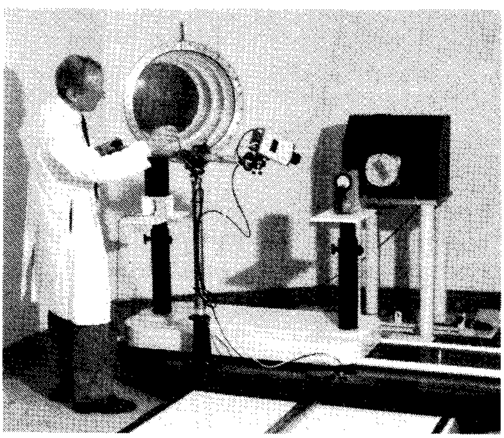

fig 1 GENERAL VIEW SHOWING MEASURING PLATFORMS

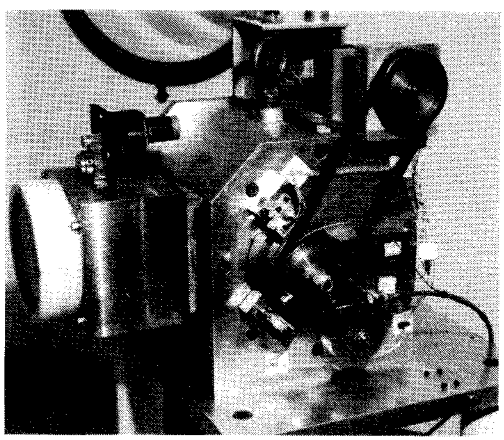

fig 2 SOURCE HOUSING AND CONTROL MECHANISM

Conventional dosemeter calibration is based on the transfer of calibration factors from a calibrated secondary standard dosemeter which itself requires to be calibrated regularly against a national standard, so that the calibration of the instruments calibrated against it are also traceable. The secondary standard dosemeter itself is subject to possible loss of its calibrated status due to severe environmental conditions, damage or component failure. It is necessary to maintain a reference source to check the calibration of the secondary standard dosemeter.

The philosophy of a stable-beam calibration system is to use for calibration purposes the output from a radioactive source the air kerma rate from which at a given distance, once determined, can be predicted by the use of physical constants, so as to eliminate the intermediate secondary standard dosemeter interposed between the primary standard and the dosemeter under calibration by using the radiation beam from the source as the actual calibration standard. While this eliminates the need for the use for the secondary standard dosemeter for each calibration, there may however remain the need to validate the accuracy of the system at regular intervals of say a week or a month by checking the air kerma rate at a fixed point in the beam using a calibrated secondary standard dosemeter. These measurements will ensure that that changes have not arisen due to mechanical inconsistencies arising from shocks to the system or wear and tear, or to unpredicted changes in air kerma rate arising from the decay of the radioactive source not following the predicted values due to the presence of source impurities, and are required in the UK to satisfy the requirements of NATLAS and NAMAS.

Inaccuracies occurring in calibration against secondary standard dosemeters of known accuracy can arise due to uncertainties regarding the source in the case of X-ray generators, to errors in the secondary standard itself, and to positional inaccuracy, arising from uncertainties in the determination of the exact postion in the photon beam where the air-kerma rate is determined, together with the need to position the dosemeter under calibration with comparable accuracy. If an X-ray source is used, there is the further requirement to position a reference dosemeter, to allow the air-kerma rate to be normalised between dosemeter readings.

While at this stage of its development, a stable-beam system cannot itself be regarded as a secondary reference standard, the performance of such a system is substantially better than that of a tertiary standard, and the degree of consistency of measurement which can be achieved is such that only occasional reference to a secondary standard is required. The calibration standard in a stable-beam system consists of the photon beam itself, emitted by a radioactive source or sources of photons of suitable energy or energies, the characteristics of the source and of the beam itself being known to a high degree of accuracy. Once the air-kerma rate at a given point on the axis of the beam has been established, the air-kerma rate at that point can be predicted at a future date by means of the decay constant of the given radionuclide and the reading of the instrument under calibration compared with this value.

The use of the air kerma rate at a point in the beam from a radionuclide source as a reference standard presupposes the availability of a stable scatter-free beam, the characteristics of which have been verified by a national standardising laboratory.

CALIBRATION USING A STABLE BEAM SYSTEM

The use of a stable beam system for calibration consists therefore of the following initial steps:

The system is set up with one or more radionuclide sources.
The beam is checked for electron contamination and the photon energy checked.
The air-kerma rate on the axis of the beam is measured to check for any deviation from the inverse square law prediction and entered into the system computer, together with the date and decay constant of the source (fig 3).
The air-kerma rate is measured across the beam at various positions along the axis to ascertain uniformity of air-kerma rate over given measuring volumes, in order to establish accuracy limits for radiation transducers of different sizes (fig 4).

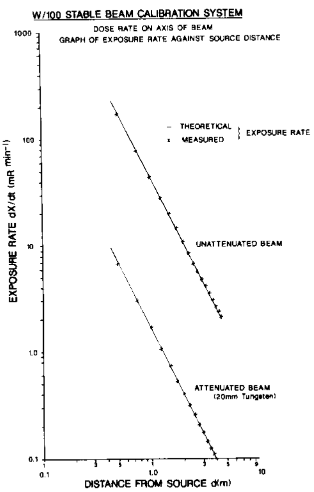

fig 3

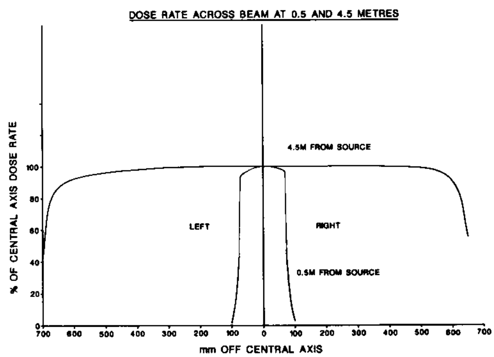

fig 4

CALIBRATION PROCEDURES

Dosemeters under calibration are then set up on one of the two measuring platforms and moved to the limit of distance along the axis of the beam (Z-axis). The reading of the instrument is then observed and entered into the computer, and the detector moved to another position.

The time required for each observation is limited by the response time of the instrument, and is pre-programmed before the measurement, the detector being driven automatically to the next position after a given time. When the series of measurements is completed, the computer produces a calibration certificate for the instrument which includes all relevant information: the measurement data entered by the computer and the details of the instrument entered by the operator. In the case of ionisation chambers under calibration, details of temperature and pressure are also entered automatically by the computer, and the correction factor applied so that the calibration produced is correct at 20°C and 1013 mbar (1.013×10^5 Pa).

Source housings (fig 2) are available to permit the use of two sources of high photon energy; for sources of lower photon energy, an alternative source housing is being developed. The lower energy sources are intended to fit on to the axis of the calibration system in front of the main source housing. Examples of nuclides evaluation of which it is proposed to carry out to assess their suitability for calibration purposes include ^{241}Am, ^{57}Co and ^{125}I.

A wide range of tests may be required for complete calibration. Some, such as those relating to warm-up times and the response time of the instrument are important for measurement of rapidly changing radiation intensities. It is also important to validate instrumental integrity over the range of physical conditions under which the instrument is likely to be used, and over the full range of intensity and photon energies to which the instrument may be exposed. The calibration process consists of a range of pre-programmed measurements, which are compared with the standard data stored in the computer. A summary of the results from a full calibration of a range of instruments can then be used to evaluate their suitability for use for a particular purpose.

The purpose of developing this system is to attempt to set up a calibration facility which satisfies the NAMAS and NATLAS requirements as set out in publications M1S1, M1S2 and M1S3, B0021, B0102 and M1 to M5[3]. The first system was installed at Bristol General Hospital in what was previously the Cobalt Teletherapy Suite in the old Radiotherapy Department in October 1987.

These calibration systems are being developed in collaboration with Messrs Pantatron Engineering Limited, Gillingham, Kent.

References

1 IAEA, 1971. Technical Reports Series No 133. Handbook on Calibration of Radiation Protection Monitoring Instruments.

2 HMSO, 1985. Ionising Radiations Regulations 1985, 24.

3 HMSO, 1985-6. NAMAS Executive, National Physical Laboratory, Teddington.