SECONDARY STANDARD DOSIMETRY SYSTEM WITH AUTOMATIC DOSE/RATE CALCULATION

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INTRODUCTION

In view of the increasing requirements for standardization measurements in radiation dosimetry a versatile and automated secondary standard instrument*) has been designed for quick and accurate dose/rate measurement in a wide range of radiation intensity and quality for protection- and therapy level dosimetry. The system is based on a series of secondary standard ionization chambers /1/ connected to a precision digital current integrator /2/ with microprocessor circuitry for data evaluation and control. Input of measurement parameters and calibration factors stored in an exchangeable memory chip provide computation of dose/rate values in the desired units.

IONIZATION CHAMBERS

Secondary standard ionization chambers require excellent reproducibility and long-term stability of the sensitive volume. Therefore graphite is generally used as the wall material in combination with Al collecting electrodes to achieve a flat energy response. This compensation however is only valid for free-air measurement and may introduce significant errors when used in-phantom due to the inhomogeneous construction materials /3/.

In contrast the described chamber design uses walls and electrodes made from Polyacetal resins $(CH_2O)_x$. This material provides superior mechanical properties assuring the necessary long-term stability of dimensions and a most suitable chemical composition. By choosing the proper mixture of Polyacetal with Polytetrafluoroethylene (PTFE) and small additions of higher Z-material such as CaO, the chambers can be made virtually tissue-, water-, or air-equivalent as desired.

In order to achieve electronic equilibrium for photon energies above 1 MeV the wall thickness has to be at least 2 mm. For soft X-rays the absorption in the wall is compensated due to a thin vacuum-deposited layer of Al on the inner wall surface. In this way the energy response is within ± 2% between 0,02 - 1,2 MeV without any additional build-up caps etc.

*) International patents.

The ionization chambers (see fig. 1) are tailored to the different applications. For radiation protection measurements at low doserates a large spherical air-equivalent chamber of 10 l volume can be used down to environmental levels. An internal check-source of ^{241}Am can be introduced into the center of the chamber through a hollow axial tube protruding from the stem to the other pole of the spere. For high doserates in therapy level dosimetry a small water- or tissue-equivalent thimble chamber of 1 cm³ volume has been designed which can directly be put into a water phantom. For the intermediate doserate range a 100 cm³ spherical chamber can be used. In addition a backscatter chamber for soft X-ray therapy measurements is in preparation.

ELECTRONIC CIRCUITRY

The basic components of the electronicsystem are shown in the simplified block diagram fig. 2.

The ionization chambers are connected to a MOS/FET electrometer amplifier through a series of reed switches (R1-R3). The exchangeable measuring capacitor (100 pF - 100 nF) which determines the range of measurements is normally shorted and the input grounded. During a measurement cycle R2 is closed and R1/R3 opened. The ionization current generates an increasing voltage signal at C, which is measured by an automatic TOWNSEND-balance circuitry consisting of a 5 digit dual slope DVM integrator with compensation by a feedback amplifier system. With an offset current of less than 10^{-15}A ionization currents in the range of 10^{-12}A to 10^{-7}A can be measured within $\pm$ 1% error.

The system is controlled by a microprocessor central processing unit (CPU) chip containing a 1 K x 8 bit EPROM and 64 byte RAM with 6 MHz quartz clock and internal timer/counter. An additional arithmetic processing unit (APU) performes all calculations. A 320 byte RAM is used as a data buffer controlled by the CPU. Up to 100 chamber calibration factors (for 10 chambers at 10 qualities) and 10 capacitance values (C) are stored in an exchangeable memory chip (2 K x 8 bit EPROM). This reusable chip is loaded after calibration and exchanged with each new chamber.

The measurement parameters (atmospheric pressure, temperature, radiation quality and number of cycles) are manually set on BCD-thumb wheel switches on the front panel. Preset dose values and additional calibration factors not contained in the memory can be manually selected if required.

The LED-display contains the voltage signal (5 digits), integrating time (4 digits), dose/rate (4 digits) with 5 prefix-symbols and the unit of measurement (Gy, R,/h, /min,/s).

With a built-in miniaturized alphanumeric printer (16 characters/line) dose/rate, meanvalue, standard deviation, time, calibration factor and capacitance value are recorded.

The ionization chambers and measurement capacitors are identified by encoding resistors contained in the connectors. The programmable high voltage supply (0 - 2 kV,2 mA) is automatically set to the correct chamber high voltage by the CPU as a function of the decoded chamber number.

DISCUSSION

The system described is designed for secondary standard measurements in protection- and therapy level dosimetry. It covers a wide range of measurement between 1 µR and 100 kR (0,2 nC/kg - 20C/kg) with proper chamber and capacitance and automatically calculates dose/rate due to its microprocessor circuitry. The ionization chambers provide excellent long-term stability and energy response and can be used with internal check sources to test validity of calibration. The system is a useful tool particularely for daily measurements in a secondary standard dosimetry laboratory or radiation therapy center.

REFERENCES

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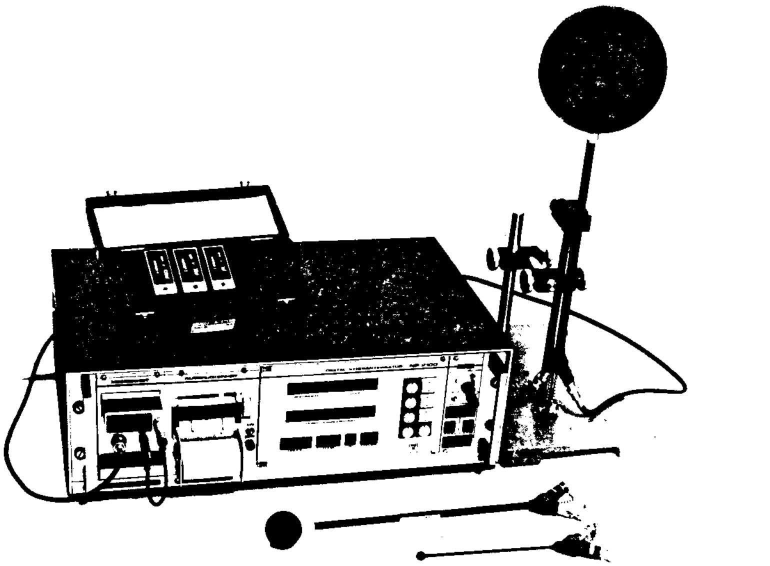

Fig.1 PHOTOGRAPH OF THE SECONDARY STANDARD SYSTEM

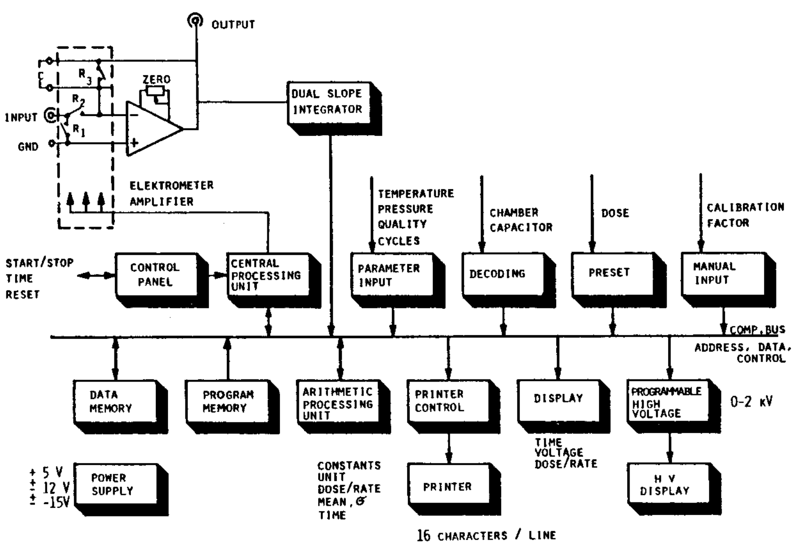

Fig.2 SIMPLIFIED BLOCK-DIAGRAM OF THE ELECTRONIC SYSTEM