AN AUTOMATIC INSTRUMENT FOR MEASURING
THE LIGHT TRANSMISSION OF PERSONNEL MONITORING FILMS

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ABSTRACT

A densitometer has been constructed which automatically measures the transmission of light through seven points, or through only one point, on gamma films used for personnel monitoring. The data is automatically punched out on cards. Of particular interest in this construction is the use of flexible light guides which offers a simplified mechanical construction and more favourable optical conditions. A printing summary punch with two programme drums is used. The second drum controls the position of a light distributor which, via light guides, illuminates different points on the film. This offers the advantage that the scanning programme can easily be changed, and the second drum makes it easy to synchronize the automatic operation, which results in a minimum of electronics.

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1. INTRODUCTION

The development of film-badge holders for personnel monitoring of γ rays has resulted in the use of several filters in order to increase the precision in the dose evaluation^{*)}. Films used in such holders have to be measured separately at each filter and therefore present a particular problem concerning the use of a densitometer. In order to overcome the practical difficulties in this respect, an automatic system for a film carried in a seven-filter film badge holder has been developed.

Light from the light source is passed consecutively through a set of light guides by the light distributor which illuminates different points on the film, corresponding with the centre of each filter in the film holder. On the other side of the film, a corresponding set of light guides collects the light and channels it to the cathode of a photomultiplier tube. The current from the anode of the photomultiplier is passed through a resistor and the drop in voltage over the resistor is measured by a digital voltmeter. The data from the digital voltmeter is automatically punched onto cards. A light control is introduced in each channel in order to compensate for irregularities in the light source, light guides, and photocathode.

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The block diagram of the system in Fig. 1 shows the principle of the film dosimeter.

2. OPTICAL SYSTEM (see Figs. 2 and 3)

The light source and its housing from a conventional slide projector are used, where the lens has been replaced by the light distributor. The light distributor passes light into one light guide channel at a time. It consists of a circular rotating disc having approximately the same diameter as the condenser lenses. The disc is mounted in a housing and rotates in steps of 30 degrees by a step relay. On one side of the light distributor, twelve holes are arranged in a circle for the light guide connections. This disc has an aperture located on a radius corresponding to the location of the light guides on the light distributor. When the disc rotates, only one light guide at a time will be exposed to the light. The step relay has three sets of wafers which indicate the location.

The light guides used are 6 inches long and have a diameter of $1/16$ of an inch. The light transmission varies considerably from one light guide to another. Selected light guides with a variation of the light transmission within $\pm 5\%$ are obtainable.

With the light control the light intensity can be regulated in each light guide channel individually. It consists of a rectangular block in which light guides coming from the light distributor are connected in series with another set of light guides going to the film scanning block. In each channel there is a distance of a few millimetres between incoming and outgoing light guides. A screw with a conical tip can be screwed into the space between the two light guides. A fraction

of the light beam is cut by the screw. By adjusting the depth of the screw, the amount of light in each channel can be regulated.

The film scanning block. The film to be measured is pushed into a slot made in a rectangular block. On either side of the slot, holes are made for connecting light guides. The position of the holes corresponds with the centre of each of the filters in the film-badge holder. The distance between the film and the light guides is only some tenths of a millimetre in order to achieve the most favourable optical conditions. For scanning of personal film badges requiring only one density measurement, a second film scanning block is made with only one scanning point corresponding to the centre of the film.

The photomultiplier housing. The photomultiplier is mounted in a steel tube. A circular holder accepting ten light guides is placed about 20 mm in front of the cathode.

3. ELECTRICAL ASSEMBLY

The block diagram in Fig. 4 demonstrates the principle of the electrical assembly. The cathode of the photomultiplier tube is connected to a variable negative voltage. The bleeder is of conventional type using a current of about 3 mA. The voltage drop over the resistor is measured by a digital voltmeter (Hewlett Packard 3440). The range is fixed to 9.999 V which corresponds to a sensitivity of 10^{-9} A per mV. The data from the digital voltmeter is fed via a coupler unit (Dymec type 2526 and 2526 B) to an IBM 526 Printing Summary Punch. Two modes of operation can be achieved by the coupler unit: manual or automatic punching. In the latter, the punching interval is controlled by the sampling rate of the

digital voltmeter. The step relay which drives the light distributor is connected in a self-hunting transistorized circuit. When one wafer contact is earthed, the step relay will find this position and stop until the earth connection is shifted to another wafer contact; the relay will then find the new position. In this instrument the position of the step relay and light distributor is controlled either manually by push-buttons or automatically by a second programme drum on the IBM 526 Printing Summary Punch.

The first programme drum can control skipping, automatic duplication, shifting from numerical to alphabetic punching, printing zeros to the left of significant digits in a field, and suppression. On the same programme card, two different programmes can be made. The second programme comes into operation when the key "ALT PROG" on the keyboard is pushed. A relay contact has been introduced working parallel with the key contact. The relay is energized when push-button 1 (Fig. 4) is operated. This button should be used when only one scanning point is required.

When the coupler unit 2526 is connected to the IBM 526, the keyboard of the punch is blocked. This is to avoid unwanted information being punched through accidental touching of the keys during automatic operation. The identification number of the film, however, must be punched manually. It is therefore necessary to de-block the keyboard in those columns where the identification number is going to be punched. This is done by a relay which is operated by the second programme drum.

4. THE INSTRUMENT IN OPERATION (Fig. 5)

Light transmission can be measured either at seven different points successively, or at one point only corresponding to the centre of the film. The upper slot is used for seven-point measurements and the lower slot for one-point measurements (Fig. 3). Accordingly, button 7 or button 1 is pushed for automatic operation (Fig.4). Button M is used for manual operation.

When the instrument is not in operation, the cathode of the photomultiplier should not be exposed to light from any of the light guide channels. A zero position on the light distributor has therefore been introduced. From the eight following positions, light guide channels go via the light control to the film scanning blocks and continue to the cathode of the photomultiplier. The first seven channels lead to the upper block and the eighth to the lower block. A reference channel goes from the light control directly to the cathode of the photomultiplier.

When the data reaches the IBM Printing Summary Punch, the distribution of data is handled by the Control Panel. This panel is programmed by means of plug-terminated jumper wires. Modes of starting column skipping, omitting characters, and the arrangement of the sequence of the punched characters can all be controlled by the manner in which this board is wired. The wiring of the control panel is shown in Fig. 6.

The movement of the card to be punched, here known as the data card, is synchronized with the movement of the two programme drums. This means that the position of the scanning contacts on the programme drums always corresponds to the column to be punched on the data card.

The data from the digital voltmeter is distributed on the data card in the following way:

<u>Column</u>	<u>Function</u>	<u>Mode</u>
1- 6	Code	Manual
7-20	Spare	Automatic
21-24	Data, Point 1	"
26-29	Data, Point 2	"
31-34	Data, Point 3	"
36-39	Data, Point 4	"
41-44	Data, Point 5	"
46-49	Data, Point 6	"
51-54	Data, Point 7	"
56-59	Data, Point 8	"
61-64	Data, reference	"
65-80	Spare	"

Figure 7 shows the two programme cards used. The following code is used for the programme card on drum 1:

<u>Code for programme 1</u>	<u>Function</u>	<u>Code for programme 2</u>
12	Field definition	4
11	Start automatic skip	5

The programme card for drum 2 is used for controlling the position of the light distributor and for de-blocking the keyboard during manual operation. The position number of the light distributor corresponds with the code number on the card. Code 12 is used for de-blocking the keyboard.

For a seven-point measurement a film is inserted in the upper slot and button 7 is pushed. The door in front of the scanning block should be closed before starting measurements in order to prevent stray light from influencing the results. By means of the keyboard, the operator punches the film identification number on the first 6 columns of the data card. When this card comes to column 7 it will be moved automatically to column 21 by the automatic skip, triggered off by the first programme on drum 1. At the same time, the programme card on drum 2 moves the light distributor from zero position to position 1. Light now flows through point 1 on the film to the cathode of the photomultiplier. After a given time, set by the sampling-rate knob on the digital voltmeter, the voltmeter reads the voltage drop over the anode resistor of the photomultiplier and sends the information via the coupler unit to the punch which punches the data in columns 21-24. Column 25 is skipped automatically in order to get a space between data. At the same time as the data is punched, the second drum moves the light distributor to position 2. In column 26, the data card waits for information from point 2 on the film. The whole sequence is repeated until all seven points have been measured. The data card will then be moved to column 61 by the automatic skip. It waits here for information to be punched from the reference position, to which the programme card has now moved the light distributor. Columns 65-80 are then skipped and the card released. The next card then drops into position.

Should a one-point measurement only be required, the lower slot on the film is used and button 1 is pushed. A relay will connect the second programme on drum 1. After the manual data has been punched, columns 7-55 will be skipped and the data card will wait in column 56 for data to be punched from point 8. Following this, information

from the reference position is read and punched. The data card is then released, and a new card is ready for the next film.

The instrument has proved to work satisfactorily during a test period. A measuring time of about 30 seconds is required for each film when seven-point measurements are made. Possibilities exist for reducing this time. The calibration of the instrument has been made by film strips with a known degree of blackening.

Figure captions

- Fig. 1 : The optical system of the densitometer.
Light from the light source is distributed into different light guide channels by the light distributor. Each light channel is used for the measurements of the optical density of predetermined points of the personal monitoring film.
- Fig. 2 : The principle of the light distribution system.
- Fig. 3 : Film scanning block with photomultiplier tube connections.
- Fig. 4 : Block diagram for the operation of the automatic densitometer.
- Fig. 5 : Picture showing the densitometer with the punch card machine.
- Fig. 6 : Connections of the control panel of the IBM 526 Printing Summary Punch.
- Fig. 7 : Programme cards for the automatic operating densitometer.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

PROGRAMME CARD FOR DRUM 1

[illegible]

PROGRAMME CARD FOR DRUM 2

[illegible]

Fig. 7