

## AUTOMATIC PRODUCTION OF ISODOSE CURVES

by

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An automatic system for producing isodose curves and data for automatic treatment planning was needed in connection with the installation of a 6 MeV linear accelerator (Varian Clinac 6). A system that measured depth dose curves and dose profiles of radiation fields and stored the results on punched paper tape was therefore designed. From these data isodose curves are produced ready for use by means of a plotter coupled on-line to an IBM 1130 computer. Depth dose tables are also evolved and when a larger computer becomes available at the hospital, automatic treatment planning may be based on the field data stored on paper tape.

*Measuring equipment.* A block diagram of the measuring system appears in Fig. 1. The measurements are carried out in the water phantom by means of an ionization chamber with an inner diameter of 6 mm. The chamber is run automatically between two end stops at a speed of 2 mm per 4 seconds. As the absorbed dose is proportional to the ionization, a depth dose curve along the axis of the field or a dose profile perpendicular to the axis may be measured. The ionization current is determined by means of an electrometer (Keithley), and the output potential of this instrument is converted to a number of pulses

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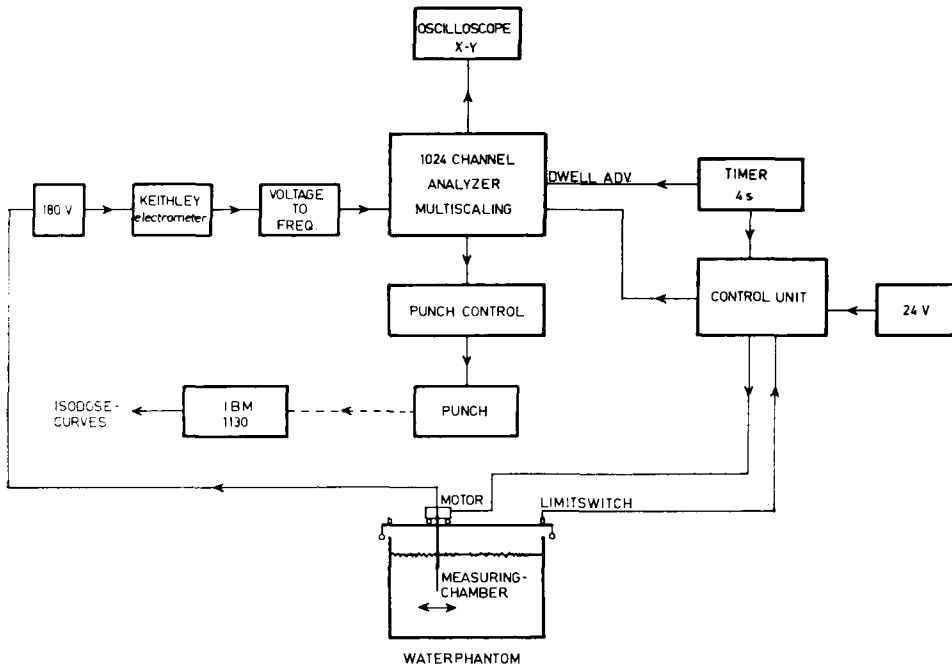


Fig. 1. Measuring system for automatic registration of depth dose data and profile data of radiation fields.

proportional to the measured ionization by means of a voltage-to-frequency converter (Hewlett Packard). The number of pulses in 4 seconds is counted with a 1 024 channel analyzer (TMC) run in the multiscaler mode. The analyzer's memory is divided into four parts each consisting of 256 channels so as to store information of more curves; this means that the curves may be extended to a length of more than 50 cm. The stored information may be displayed on an oscilloscope and if no faults are evident may be punched out on perforated paper tape. About 200 000 pulses are obtained, corresponding to the maximum dose of a field with the applied potential-to-frequency conversion; thus about 2 000 pulses represent a one per cent dose.

Due to the dimension of the chamber and its protecting cap as well as to the wall thickness of the water phantom, the effective measuring point (i.e. a point placed at a distance of  $0.75 \times$  inner radius of the cylindrical chamber from the centre line towards the radiation source) cannot come closer than 2.0 cm from the surface of the phantom. As no measurement is made during the first 2 mm so as to avoid false counts due to the operation of several electric relays etc., the

first measurement is obtained at from 2.2 cm to 2.4 cm, which means that the first measuring point is assumed to be 2.3 cm. The measurements are then carried out to a depth of 37 cm.

Dose profiles are normally measured at 4 depths, namely 2.1 cm, 12.1 cm, 22.1 cm, and 32.1 cm. The end stops for these measurements are symmetrically sited in relation to the central axis, and at a distance of an odd number of mm from the axis; all 4 profiles are measured under the same conditions. Again the results are inspected on an oscilloscope after each profile measurement and, the 4 profile measurements for a field having been carried out, the complete set of data of the 1 024 channel analyzer is punched out.

*Calculation of isodose curves.* The isodose curves are calculated by the decrement line principle as suggested by ORCHARD (1964). The assumption is that all points in which a dose is a certain percentage of that on the central axis at the same depth are on a straight line. ORCHARD demonstrated that this is true in a cobalt field and the method was used by several authors to draw isodose curves by hand (NAYLOR & ORMSBY 1968, FELDMAN et coll. 1968); it has been used for some time in Odense. ORR et coll. (1964) employed the same method for a linear accelerator.

The above principle is not assumed to hold for a whole field in the computer program ISOSE in which isodose curves are calculated from the measurements described, but rather for the area between two profiles, i.e. over a depth variation of 10 cm. This assumption will probably be close to reality at all depths greater than 10 cm as the manufacturers of the Varian 6 MeV accelerator have at-

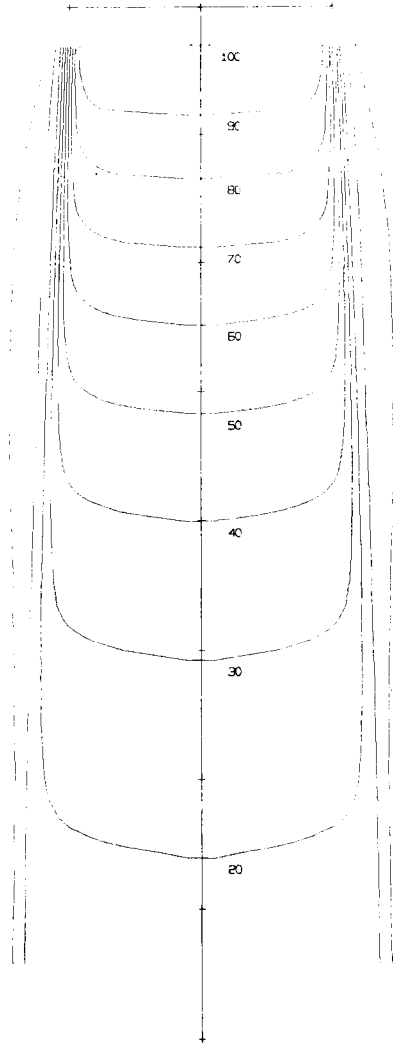


Fig. 2. Isodose curves for a 10 cm  $\times$  15 cm field, as drawn by the computer. The unit on the central axis of the field is 5 cm. (Scaled down from normal size.)

tempted to have a uniform dose over the field at a depth of 10 cm. A certain amount of overcompensation is obtained with a flatness compensator; this gives a uniform dose over the field at 10 cm depth. At depths less than 10 cm the dose at the edge of a broad field may therefore be as much as 5 per cent higher than at the central axis. The assumption of straight decrement lines does not hold in these areas which means that the higher dose at the edges of broad fields do not appear on the isodose curve diagrams.

The depth dose curve is always measured twice to ensure that it is capable of being reproduced, an attempt is made to run the linear accelerator at the same dose rate during the two measurements (see Discussion).

The depth dose curve used in the calculation is a mean value of the two curves. The ratio of the dose at the first measuring point to the dose at the maximum point is given as an input variable and is obtained from the data of HORSBY et coll. (1967). Four dose profiles across the entire field are measured. Any possible lack of symmetry is however ignored in the treatment planning; therefore the profile in the calculation is the mean value of the two halves.

Isodose curves are drawn by means of decrement line calculations for every one per cent dose change on the central axis. This means for example that the 90 per cent isodose curve will be drawn by means of 10 points in each field half, whereas the 30 per cent curve will be depicted by 70 points in each field half. The points will be connected by straight lines, excepting that the central 10 mm of all isodose curves are drawn perpendicular to the central axis.

*Calculation of isodose curves for fields not measured directly.* The depth dose curves and dose profiles for all usable square fields having been measured, it becomes possible to calculate approximate isodose curves for all suitable rectangular fields. An equivalent square field with the same depth dose curve may be found for any rectangular field (Brit. J. Radiol. (1961) Suppl. No. 10). It is then assumed that the dose profiles for the rectangular field are identical with those for a square field of the same width, and the isodose curves for the rectangular field may thus be calculated. Any discrepancy between these calculated curves and the true measured ones are due to the contribution from the scattered radiation. This will be discussed later.

*The computer program ISOSE, data, and results.* The input data necessary for ISOSE consist of a punched card and two punched paper tapes. The card must contain information, such as name of the radiation source, skin-source distance and field width and height. The starting and end points of the depth dose curve measurement must be given and the dose at the point of the first measurement divided by the maximum dose. The depth of four profiles and the distance from the central axis to the starting position of the measuring point on

these, the depth of the dose maximum and a code number determining the amount of plotting to be done are all quantities that are needed. All distances must be in cm. One paper tape must give two depth dose curves, and the other paper tape the four dose profiles. The detailed format of the punched card and the paper tapes appear in an internal report.

The results obtained consist of a control print-out on a line printer and an automatic drawing on the plotter. The plotting is governed by the code number. If this is zero, then first of all the two original depth dose curves are plotted as dotted lines whereas the mean depth dose curve appears as a full line. The two halves of the profiles are also drawn as dotted lines whereas the mean value is depicted by a full line. The isodose curves are presented in Fig. 2. Only the isodose curves are plotted if the code number 1 or 2 and in the latter case the 5 per cent curve is omitted.

### Discussion

The measuring equipment described has proved extremely useful in the measurement of radiation fields for radiation therapy. Nevertheless several alterations in the equipment would improve the performance. First of all the ionization chamber with an inner diameter of 6 mm ought to be somewhat smaller. This is only of importance near the edges of the fields. The penumbra of the fields will appear somewhat greater than is actually the case. It would also be convenient if the ionization chamber were to travel at a higher speed so as to make the measurements more quickly. By a change in the gearing, the travelling speed of the probe might well be increased by a factor of two combined with a decrease in the measuring interval by the same factor to two seconds. No loss in accuracy due to this would occur.

A most important condition for the successful outcome of the measurements is the constant dose rate from the radiation source during a complete measurement. That this assumption is fulfilled may easily be checked as any change in dose rate would appear as a difference between the two dotted depth dose curves and the two dotted profile half parts; this has been done for all measurements. If the dose rate cannot be kept constant, a reference chamber must be used in connection with a ratio circuit or print-out of the measurements from the two chambers.

As far as the use of the decrement line principle is concerned, this has been proved valid in the two papers previously quoted. The condition is that no overcompensation is used as mentioned earlier. In the case of overcompensation no decrement lines can be drawn, which means that the use of the decrement line system is not entirely satisfactory. This limitation is however not serious from a practical point of view.

A great advantage of the method is that any skew in the set-up of the measuring system is easily detected by visual inspection of the computer plotted transverse curves. The two half parts of a curve are plotted in the same coordinate system and therefore any discrepancy between the planned and the actual radiation axis appears at twice the true size on the computer plot.

The possibility of having to measure only square fields and being able to calculate sufficiently accurate isodose curves for all rectangular fields is most important. Regarding the equivalency of the depth dose curves for square fields with rectangular fields as given in Suppl. No. 10 (Brit. J. Radiol.), it has been proved that agreement with the cobalt 60 table exists for 6 MeV roentgen rays for field dimensions 10 cm  $\times$  15 cm and 6 cm  $\times$  20 cm.

The error due to the scattered radiation is small in the most important parts of the isodose curves when dose profiles measured on square fields are used for rectangular fields. The five per cent isodose curve is drawn only on fields measured directly as this curve is displaced considerably when the rectangular fields are far from square geometry. Apart from this, discrepancies of any importance occur only at the corners of the isodose curves at fair depths. The maximum discrepancy for a 10 cm  $\times$  15 cm field measured at right angles to the isodose curves is 1 mm which occurs only at the 10 per cent curve. The maximum discrepancy for a 6 cm  $\times$  20 cm field measured as above is 8 mm at the corner of the 20 per cent isodose curve corresponding to about 1 per cent of the maximum dose and 5 per cent of the actual dose. The maximum discrepancy for the 50 per cent curve at the corners is 4 mm corresponding to about 1 per cent of the maximum dose and 2 to 3 per cent of the actual dose; the 10 per cent curve for this elongated field is also displaced up to 4 mm measured at right angles to the central axis.

## SUMMARY

The measuring equipment, the principles and the computer program for the automatic production of isodose curves are described. This method necessitates measurements only of square fields and the computer plotted curves may be used directly in treatment planning. The accuracy obtainable is discussed.

## ZUSAMMENFASSUNG

Die Messausrüstung, die Prinzipien und das Komputerverprogramm für die automatische Herstellung von Isodosiskurven werden beschrieben. Diese Methode benötigt lediglich Messungen der Quadratfelder, und die vom Komputerdargestellten Kurven können direkt für den Bestrahlungsplan verwendet werden. Die zu erreichende Genauigkeit wird besprochen.

## RÉSUMÉ

Les auteurs décrivent l'appareillage de mesure, les principes et le programme d'ordinateur pour la production automatique de courbes isodoses. Cette méthode ne nécessite de mesures que pour des champs carrés et les courbes établies par l'ordinateur peuvent être utilisées directement pour établir le plan de traitement. Les auteurs examinent la précision que l'on peut obtenir par cette méthode.

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