An Automatic Isodose Plotter Using Film Dosimetry System

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フィルム法による線量分布自動解析装置

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ここに報告される装置は一種のフイルム濃度計であるが，最大の着眼点は解析に要する時間の節約とデーターの記録における誤差を少なくすることに置かれ，濃度を測光，走査して10段階の等線量曲線を5色に自動記録するものである．

1）装置の概要

a）走査記録装置：フィルム濃度を検出する測光部，設定した線量値の場所を記録する記録部，測光部と記録部を同時に走査させる走査部とからなる．

b）記録制御部：測光部からのフィルム濃度の信号を解析し，あらかじめ設定した10段階の濃度になつたとき，記録部に打点信号を送るための制御器である．

c）測定の手順

数段階の既知線量を与えた較正フィルムから線量出力較正曲線を作成し，それに基づいて10段階の弁別器を設定する．そこで被検フィルムを本装置に設定すると，フィルムと1対1の対応で等線量曲線のセットが打出される．

2）測定上の問題点

a）フィルムの選択について

上述の弁別器の利用によつて，線量濃度間の直線性は従前ほど critical な条件ではなくなつている．今回の実験には Sakura Konilitho Film PA が用いられたが，このフィルムは ^{60}Co で濃度3を与えるのに 800R という低感度と自動現像機で処理しうる特徴がある．

b）ファントームの厚さについて

ファントーム内でフィルムを平行線束で曝射する場合，フィルムの両側におかれるファントームの厚さが問題となるが，我々の用いた Mix-Dp ファントームでは 2.5cmあるいは5cmの厚みのものをフィルムの両側においた場合の実験値が，電離槽測定における深部率の値と良き対応を示した．

3）実用例

多門照射法の実際的な例として，上顎癌を対象とした現在の治療法の線量分布図を図示した．

A number of reports have appeared, dealing with the subject of film dosimetry in the field of supervoltage radiotherapy, in spite of the fact that photographic film has some disadvantages, such as lack of linearity in dose-density response, as well as existing dependence of response on radiation energy and developing conditions. High spatial resolution is its most distinctive advantage, and, from the practical point of view, its convenience and simplicity are also favorable.

Since the systems of clinical dosimetry in use vary greatly, depending on the particular organization of the field of radiotherapy, it is difficult to discuss the definite position of any particular system. However, it could be stressed, that the analogue dosimetry system is situated just between the digital and human computer system, and that the film method offers many more benefits than solid dosimeters are able to.

It has been almost impossible to get a sufficient number of physicists to solve the problems arising in clinical radiotherapy in Japan.

Although it has now been five years since the computer system was introduced into our department, it has not yet come into routine use, despite the fundamental problems in the dose calculation of radium technique having been solved[3]. This is due to some handicaps in the organization of the computer center and to problems existing in the praxis of radiotherapy. Most radiotherapy centers in the world, in our opinion, seem to require some analogue system in clinical dosimetry, although they would have a computerized system as a goal.

This is a report on an integrated system of film dosimetry, recently designed and built, and which consists of densitometer, analyzer, film scanner, and recording units. Some basic and clinical experiments are also reported in this paper.

Apparatus:

This apparatus is a type of film densitometer. However, the major effort was devoted to reducing the time required for interpretation, and the prevention of inaccuracies in recording the data obtained.

Once a film is processed following exposure in a suitable phantom, the automatic electronic film-reading and print-out system will devise and construct a complete isodose pattern. The block diagram of the circuits and the outlook of the machine are illustrated in Fig. 1, and Fig. 2.

The maximum area of film scanning range is 360 × 360 mm., and by changing the gear illustrated in Fig. 3, the size of the ratio between the print-out and the original film, may be changed.

The scanning speed is variable within the range of 100–500 mm/min., along one direction. There is a choice of five line spaces, namely 2, 4, 6, 8, and 10 mm. The area of film viewed, is 1 or 2 mm., in diameter.

The electronic circuitry consists of a densitometer, ten discriminators, five dot-pulse generators, and associated circuits for film read-out.

The densitometer detects light intensity with a small tungsten lamp, and a photomultiplier tube, and utilizes a dinode feedback circuit in order to accomplish a logarithmic response over a wide range of light values, without feedback, the output current of the photomultiplier is proportional to the light value through the film. When it is used on feedback, the densitometer output voltage is approximately proportional to the film density, because the feedback circuit reduces dinode supply voltage as the output current increases.

Each channel of ten discriminators has two input terminals, one of which is connected with the densitometer output line, and the other with one of the potentiometers, i.e. dot-line adjustors. There are

Fig. 1. Block diagram of electronic circuitry for film densitometer, isodose plotter, and print-out circuit.

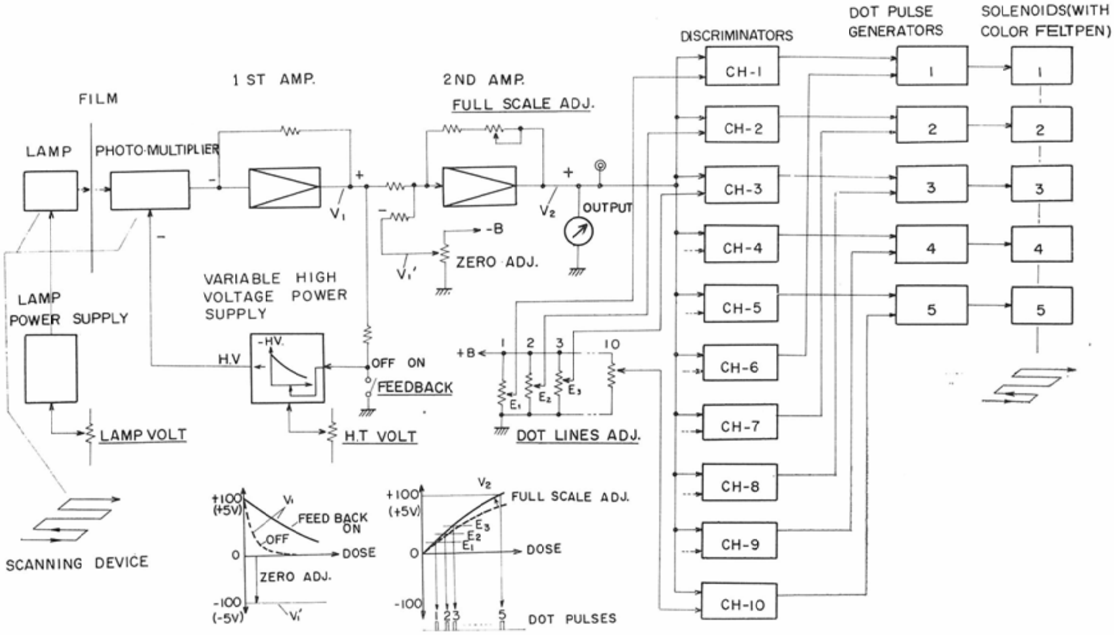


Fig. 2

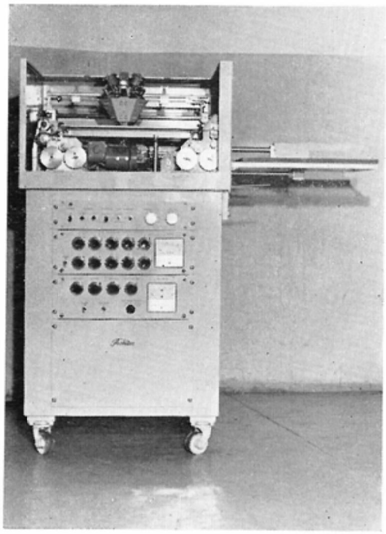
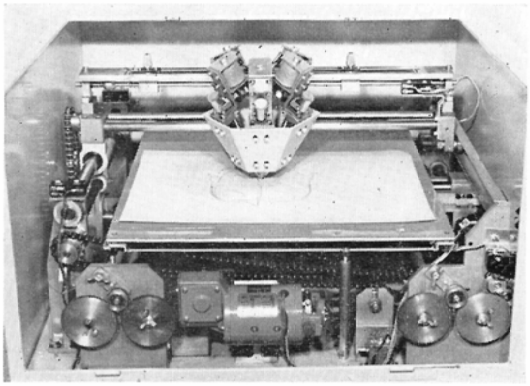


Fig. 3



designed to give a signal to generate the print-out system, when the densitometer output voltage reaches the same level as the pre-set voltage of the potentiometer, which has been pre-set in advance.

The recording system is composed of a scanning device, five dot-pulse generators, and five solenoids with felt pens. Each of the dot-pulse generators gives an approximately 15 mSec wide pulse to the solenoid, which in turn prints a dot with its felt pen, corresponding to the signal to the discriminator, 1 &

6, 2 & 7, 3 & 8, 4 & 9, and 5 & 10.

To make a standard dose-density response curve, a processed film, which has various steps of known exposure, is placed between a light spot and a photomultiplier for detection. Then the output meter is adjusted to "O" at the density of film base, and to full scale at the density of maximum exposure in the film. A dose-output response curve can be drawn from the reading of the output meter corresponding to each of the intermediate steps.

Using this dose-output response curve, any film in which it is required to know the exposed dose or dose distribution, can be easily examined by reading the output meter or reading the print-out directly, provided the density remains in the range of standard film, and the processing conditions remain unchanged. The dot-line adjustors, i.e. potentiometers, can be set to any output voltage wanted in the range corresponding to ten dose values, and make it easy to obtain a set of iso-dose patterns.

Experiments:

A study was made to evaluate the accuracy and practicality of the densitometer, and to examine the problems in film dosimetry. The factors in measuring devices are as follows:

Phantom: Mix Dp Phantom

plate form—25 mm thick, 10 mm thick, 370 mm × 300 mm in size

human shaped[4)]—25 mm thick in each transverse section. Fig. 4

Ionization Chamber:

Victoreen condenser R meter No. 621.

PTW simplex normal chamber.

Photographic Film:

Sakura Konilitho Contact Film PA.

Processing:

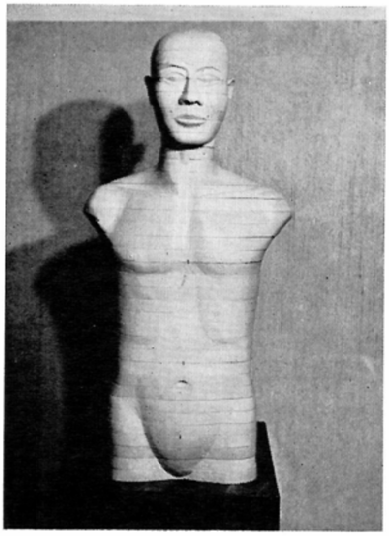
Kodak X-O-Mat Processor.

Developers: Sakura Konidol XM 101 R.

Radiation Source:

Cobalt-60 2,000 Ci Unit (Model RI 107-1 Tokyo Shibaura Electric Co., Ltd.)

Fig. 4



1) Dose-Output Calibration Curve:

Steps of known exposure were given on a single film for dose-output calibration. The exposure was calculated by measuring a free air dose, at the same point of 5 mm depth of the phantom along the central axis of the beam, followed by multiplying the back scatter factor. A calibration film was obtained for each series of experiments, with a perpendicular set-up to the beam axis, as illustrated in Fig. 5.

A dose-output calibration curve is shown in Fig. 6, which was obtained by using the method described in the preceding paragraph.

Fig. 5. Illustration of exposing calibration film in a phantom.

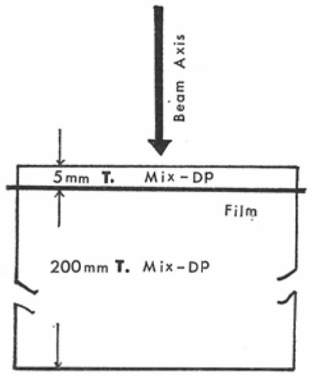
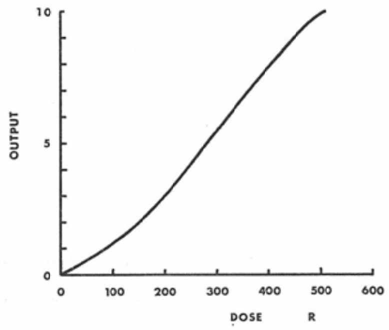


Fig. 6. Dose-output calibration curve.



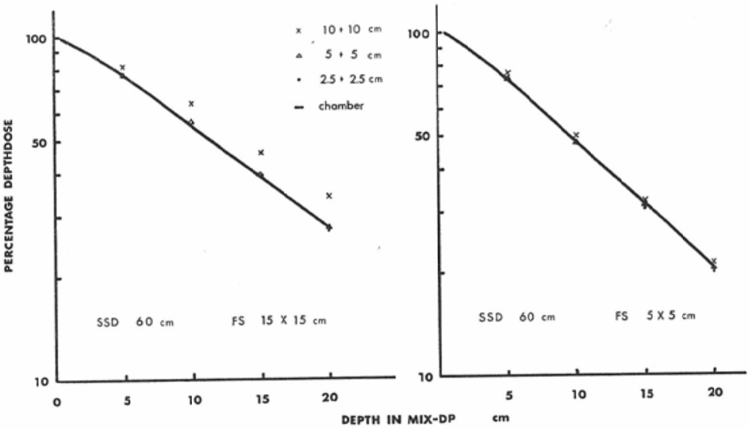
2) Phantom Measurement:

In order to examine the problem of film dosimetry in various depths, and in various field sizes, measurements were taken in a Mix-Dp phantom. Experiments were performed on field sizes of 15 × 15 cm; 10 × 10 cm; and 5 × 5 cm respectively, using a Cobalt 60 unit and 60 cm SSD, in which isodose curves obtained by film methods were compared with those obtained by ionization chamber measurement. The film was inserted between phantom plates of 37 × 30 cm size, with a thickness of 2.5 cm; 5 cm; and 10 cm, on both sides. It was exposed with Cobalt 60 gamma rays parallel to the beam direction. As in the reports of Stanton[7] and Tsunemoto[8], the percentage depth dose obtained from film dosimetry varies, depending on the thickness of the phantom plate placed on both sides of the film. In our experiments, phantom thickness of 2.5 cm, or 5 cm on both sides of the film has appeared to give the closest correspondence to the data of ionization chamber dosimetry. Percentage depth dose curves along the central beam axis, are illustrated in Fig. 7, refering to the thickness of the phantom. A set of isodose curves of the central axis which were obtained with the film method, using Cobalt 60 gamma rays, 60 cm SSD and Mix-Dp phantom as mentioned above, are illustrated in Fig. 8, compared with those of the ionization chamber method using a water phantom.

3) Examples of Isodose Patterns in Multiple Beam Technique:

A variety of isodose patterns has been made using this film dosimetry system. Because it is not the main purpose of this paper to illustrate this practical data, some techniques now in use for the treatment of maxillary antrum carcinoma are shown as an example in Fig. 10.

Fig. 7. Percentage depth dose curves obtained by film method, refering to the thinkness of the Mix-Dp phantom plate on both sides of the film.



Discussions:

Film dosimetry is coming into increasingly widespread usage for phantom dosimetry. Although it seems to have gained an established position, there remain a number of problems from the technical point of view. Since this densitometer has been developed for practical radiotherapy, discussions will be given from a practical point of view, firstly in the choice of film, and secondly, in the problem of calibration.

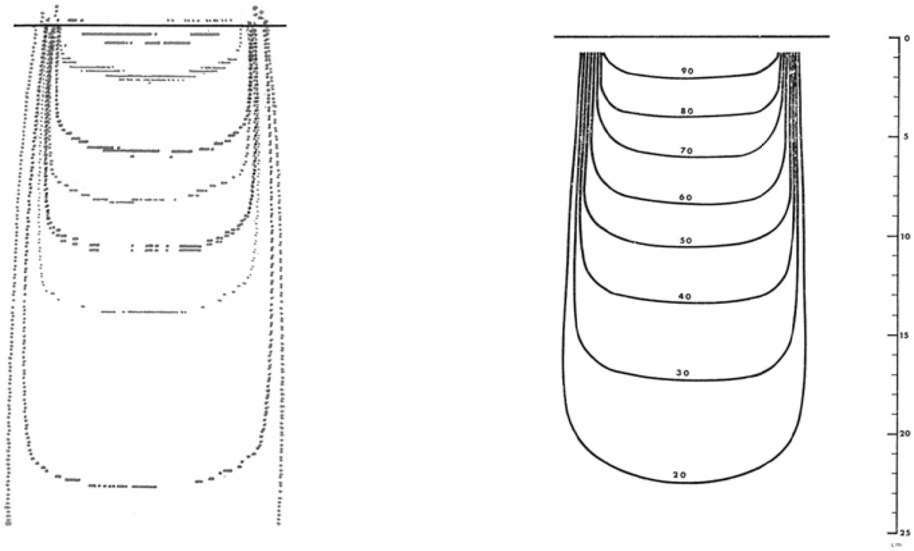
1) Choice of Film:

Although some institutions use standard X-ray films, most prefer films used primarily in such fields as lithography, because of their considerably higher dose capacity. Sakura Konilitho Contact Film PA was used in this study. In this country, (Japan), industrial films have been widely used for this purpose, because of their considerably higher dose capacity, and thier good dose-density lineality. However, industrial film is difficult to process with an automatic processor, and a dose of 30-50 R to give optical densities of 3.0, seems to be a little too limited for practical purposes, as far as high output machines, such as linear accelerators or Cobalt 60 Kilocurie machines, are concerned. Konilitho Film can be easily and without trouble processed by an automatic processor, and it requires approximately 800 R, to reach optical densities of 3.0. It is our opinion that special processing systems should be avoided for this kind of dosimetry of routine use, because specially prepared processing systems are difficult to keep in good condition.

Up to the present time, we have encountered no trouble using an ordinary automatic processor. The slow speed of this film has apparently given a lot of benefits, because all of the experiments have been carried out in just the same conditions as the daily treatment of a patient, and shutter-timing errors[6] have been a negligible factor.

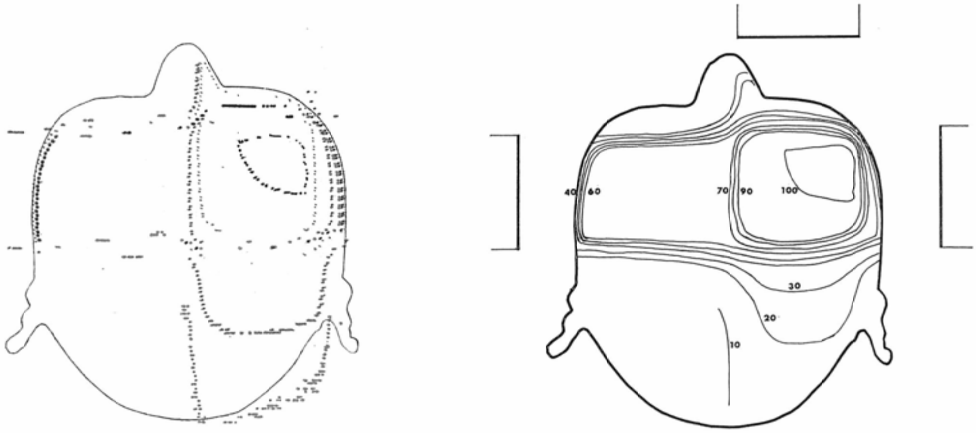
Until now, the lineality in dose-density response has been a factor of extreme importance in the choice of film for dosimetry. In this integrated system of densitometer, however, the dose density lineality requirment is not such a critical factor as previously, because dose levels of print-out can be easily set with potentiometers based on a dose-output calibration curve prepared in advance.

Fig. 8. Isodose curves for Co-60, SSD 60 cm, Field Size 10 × 10 cm.



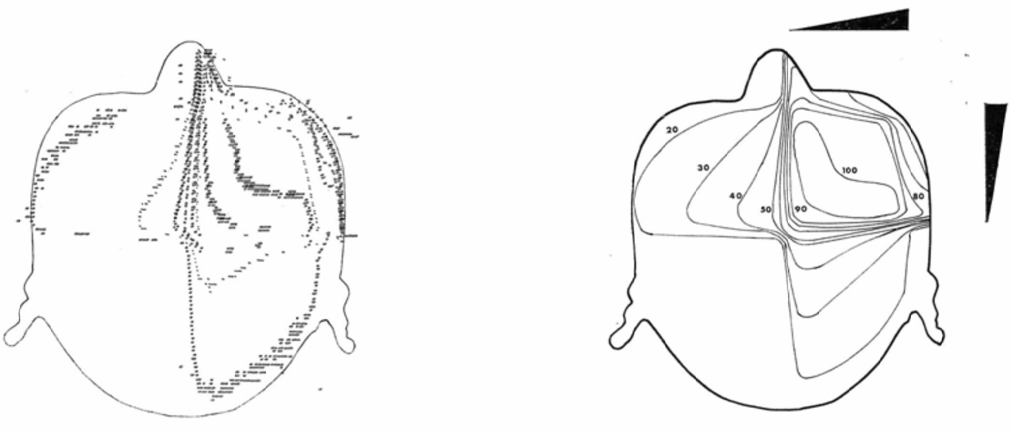
(a) by film method (b) by ionization chamber method

Fig. 9. Isodose distribution for three 6×8 cm Co-60 fields at SSD 50 cm directed towards a maxillary antrum carcinoma.



(a) original print-out (b) Isodose chart

Fig. 10. Isodose distribution for two 6 × 8 cm Co-60 fields using 45 wedge filter, at SSD 50 cm directed towards a maxillary antrum carcinoma.



(a) original print-out (b) Isodose chart

2) Other Problems:

One of the most distinctive advantages of film dosimetry is found in its excellent spatial resolution power. Resolution power is influenced by the thickness of the emulsion on the film and by the spot size of the detector. There are still some experimental errors in the area of changing densities using 1.5 mm slit, according to Stanton[6]. In this densitometer, the area of film viewed can be set to 1 or 2 mm in diameter. The resolution power will be examined in time, by means of a modulation transfer function. Although there could be more room to improve the resolution power in the detector, it might be of little importance for practical use.

Another problem which has been discussed rather frequently, is that the film has a dependence of response on radiation energy. The range of radiation energy in which photographic film can be used for dosimetry purposes, is reported to be 400-2,000 kVp X-rays by Hine[2], and 1-20 MeV X-rays or gamma-rays by Granke[1]. Considerable care is required to ensure that portions of the film do not actually contain regions of excess response to low-energy radiation. This may occur at some depth in the phantom, due to degraded secondary radiation, or within the penumbra regions.

Comparing the isodose curves obtained by the film method with those obtained by the ionization chamber method, the data of the film methods correspond well to those of the chamber methods, as far as the depths for clinical radiotherapy are concerned. Therefore, the film method can be said to be the most reliable one for use in clinical dosimetry, especially in a rather small body section such as the head and neck region.

The dependence of response on incidental beam direction is another problem to be considered. This has been reported as less than 10% in supervoltage radiation, by Granke[1]; and as less than 20% in 350 keV X-rays, by Casnati[5]. Experiments have been under way in the use of a dose-output calibration curve obtained with a film of parallel exposure to the beam, in order to examine the possibility of minimizing the experimental error due to the incidental beam direction factor.

In fact, it seems almost impossible to prepare a detailed correction factor for each individual problem in the film method of dosimetry, and it is wiser to calibrate all the information from the film, as closely as the data obtained by the ionization chamber dosimetry method.

Summary:

1) An automatic densitometer was recently designed and built for practical radiotherapy, in Osaka University Hospital, in collaboration with the Tokyo Shibaura Electric Co., Ltd. The densitometer has an integrated system composed of densitometer, film scanner, and color print-out system.

2) A study was made to evaluate the accuracy and practicality of the densitometer and to examine the problems in film dosimetry.

3) Discussions were made from the practical point of view, i.e., in the choice of film, and in the problems of calibration, etc.

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