A NEW kVp TOOL AND ITS SENSITIVITY TO SPECTRAL CHANGES

THOMAZ GHILARDI NETTO[1] and ELDEREIS DE PAULA[2]

ABSTRACT -- This paper describes an improvement on Stanton's original design. It combines an useful feature of the Ardran and Crooks method with the Stanton method. The device employs a polyethylene reference block alongside adjacent copper wedges. To determine the kVp, the kVp test tool is placed over a conventional X-ray cassette containing a fresh sheet of film and an appropriate exposure is made at the kVp which one wishes to measure. We used two thicknesses of brass to test the sensitivity of the wedge to spectral changes. The results indicate that the device is useful for measuring kVp over the diagnostic X-ray range (45-110 kVp).

INTRODUCTION

In 1966 Stanton described a simple penetrameter technique for measuring kVp in the diagnostic X-ray range. The device covered the region of 50 to 150 kVp with an accuracy of 2 percent. A modification of the basic technique was described by Ardran and Crooks in 1968. The latter technique was extended by Ardran and Crooks and others (Ardran and Crooks, 1971; Ardran and Crooks, 1972; Cameron at al., 1974; Jacobson at al., 1976). This paper describes an improvement on Stanton's original design. It combines an useful feature of the Ardran and Crooks method with the Stanton method. Ghilardi Netto and Cameron (1985) refer to this new instrument as the Stanton Wedge (Figure 1). This technique should be specially useful in developing contries because of its low cost and simplicity of construction.

DESCRIPTION

The Stanton Wedge consists of a lucite box containing a parallelepiped of polyethylene 6cmx1,5cmx22cm (Figure 1). The sides are covered with sheets of 0,6mm thick Pb to keep scattered radiation from leaving the block. Alongside the polyethylene block is a step wedge of Cu of 1,4cm wide. Each of the 12 steps is 1,4cm long by 0,1mm thick. The Ardran and Crooks (1968) feature of limiting the exposed area has been included in our design. Under both the block and the step wedge is a 3mm

---

1,2 - CENTRO DE INSTRUMENTAÇÃO, DOSIMETRIA E RADIOPROTEÇÃO (CIDRA) - FFCLRP-USP - Av. Bandeirantes, 3900 - 14.049 - Ribeirão Preto - SP

thick sheet of Pb containing 2 rows of holes, each 8mm diameter. One row of holes is under the polyethylene block and the other row is under the step wedge with a hole centered under each step. On top of the assembly is a sheet of Cu (or brass) to harden the beam. To determine the kVp, the device is placed over a conventional X-ray cassette containing a fresh sheet of film, an appropriate exposure is made at the kVp which one wishes to measure. The film is processed (Figure 2) and a densitometer is used to determine at which step the optical density is equal to the density under the polyethylene block. An approximate determination can be made visually (± 10 kV).

PRINCIPLE OF OPERATION

If two materials differ greatly in their average atomic number (Z) (e.g. polyethylene, Z = 6 and Cu, Z = 29), their absorption of X-rays will differ greatly over the kVp range used in diagnostic radiology (Figure 3). For a clinically useful X-ray beam, there will be a thickness of Cu which has the same attenuation as the 6cm of polyethylene. The thickness of Cu (i.e. step number) can be related to the kVp by calibrating the device on an X-ray unit known to be accurate. In principle, many materials can be used as the reference absorber, but polyethylene has excellent characteristics for this service because of its low Z, its uniformity and its ready availability at low cost.

Because filtration varies greatly from one X-ray unit to another, it is necessary to use additional filtration, or a beam hardener to minimize the effect of the filtration. The beam hardener is selected to permit reasonable exposures over the kVp range to be measured.

USE OF THE STANTON WEDGE

To use the test tool, it is placed over a standard X-ray cassette with intensifying screens, as fast screens reduce the exposure needed. The milliamperes-seconds (mAs) needed for a given kVp will depend on the speed of the screens and film used, as well as the exposure distance. Table 1 gives mAs values for our device using fast screens. Figure 2 shows a film made at 63 kVp. The circles on the left are the reference exposures under the polyethylene. Those on the right under the step wedge vary in

Table 1. - Typical mAs exposure values for various kVps. The focus-film distance (FFD) is 0,5m for 50 kVp and 1,0m for the other kVps.

kilovoltage (kV)	50	60	70	80	90	100	110
mAs	640	160	64	32	9	8	5

density the darkest being under the thinnest step. In this case the match step was at nº 5 and, from the calibration in Figure 4, this corresponds to 63 kVp. The calibration curve in Figure 4 was obtained by comparison with an Ardran and Crooks Cassette.

EXPERIMENTAL RESULTS

Measurements were made on a conventional clinical X-ray unit, Philips Model DL42, with 2mm Al added filtration.

Figure 5 show the results of two calibrations with different amounts of added filtration. The harder beam has slightly greater kVp/step ratio. Note the correlation coefficients are greater than 0,99 in both cases.

It is known that any penetrameter type of kVp test tol must use additional filtration to minimize the effect of variations in tube filtration (The physics of Radiodiagnosis, Report Series nº 12, 1974; Cruty and Ghilardi Netto, 1980). Most diagnostic X-ray units use a total filtration with 3 or more mm Al. We used two thicknesses of brass (0,55mm and 1,27mm) to test the sensitivity of the Stanton wedge to spectral changes. Figures 5 and 6 show the results with these filters for different tube filtrations. With 0,55mm of brass (Figure 4) there is little variation at 50 kVp but about $\pm$ 2,6% variation at 100 kVp. The heavier 1,27mm of brass reduces this variation (Figure 6).

DISCUSSION AND CONCLUSIONS

The linear regression analysis of the match step vs kVp indicates that the Stanton wedge is a useful device for measuring kVp over the diagnostic X-ray range (45 - 110kVp). The standard deviation is typically 2 percent which is adequate for normal clinical use.

The components costs are only a few dollars and the unit can be constructed with only a few tools. It is suggested to be a useful method for developing countries. A calibrated Ardran and Crooks cassette could be loaned to the laboratory for the calibration or the World Health Organization (WHO) could provide kits of materials for the construction of Stanton wedges, were the calibration curve would be standard for the materials used.

ACKNOWLEDGEMENTS

This work was supported by FINEP/PADCT, FAPESP and CNPq.

The authors would like to thank June Tadeu de Moraes for their technical assistance, Sonia Aparecida Nali and Teresa Cristina Fernandes de Andrade Silva for typing the manuscript and Marcos Ribeiro de Souza for art work. Thanks are also due to Dr. John R. Cameron for helpful comments, suggestions and revision of this paper.

REFERENCES

ARDRAN, G.M. and CROOKS, H.E.(1968), "Checking Diagnostic X-Ray Beam Quality", British Journal of Radiology , Volume 41, Number 483, pages 193-198.

ARDRAN, G.M. and CROOKS, H.E. (1971), "Some Technical Problems with Diagnostic Radiography at 20 to 40 kVp", British Journal of Radiology, Volume 44, Number 524, pages 625-630.

ARDRAN, G.M. and CROOKS, H.E. (1972), "The Measurement of Inherent Filtration in Diagnostic X-Ray Tubes and the Effect of Target Angle on X-Ray Quality", British Journal of Radiology , Volume 45, Number 536, pages 599-602.

CAMERON, J.R.; SIEDBAND, M.P.; WAGNER, J. and JACOBSON, A. (1974), "X-Ray Test Cassette for Routine Evaluation of kVp and Added Filtration", Phys. Med. Biol. , Volume 19, Number 2, page 256.

CRUTY, M.R. and GHILARDI NETTO, T. (1980), "Evaluation of the Spectral Response of the Wisconsin Mammographic", Medical Physics, Volume 7, Number 2, pages 151-156.

GHILARDI NETTO, T. and CAMERON, J.R., (1985) "An Inexpensive kVp Penetrameter", Medical Physics, Volume 12, Number 2, pages 259-260

JACOBSON, A.F.; CAMERON, J.R.; SIEDBAND, M.P. and WAGNER, J., (1976) "A Test Cassette for Measuring Peak Tube Potencial of Diagnostic X-Ray Machines", Medical Physics, Volume 3, Number 1, pages 19-25.

STANTON, L.; LIGHTFOOT, D.A.; MANN, S., (1966) "A Penetrameter Method for Field kV Calibration of Diagnostic X-Ray Machines", Radiology 87, pages 87-98.

The Physics of Radiodiagnosis, Report Series Number 12, (1974), Hospital Physicists Association, 47 Belgrave Square, London SWIX 8QX.

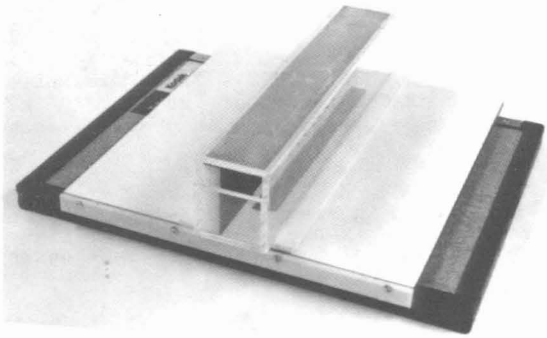

Figure 1. Photograph of the kVp Test Tool.

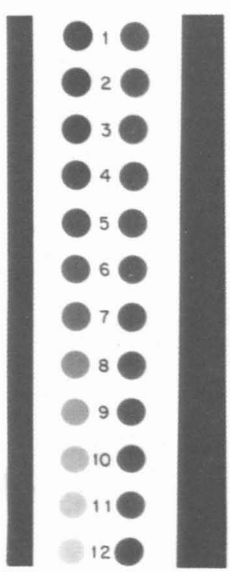

Figure 2. Typical Test Film for the Stanton Wedge.

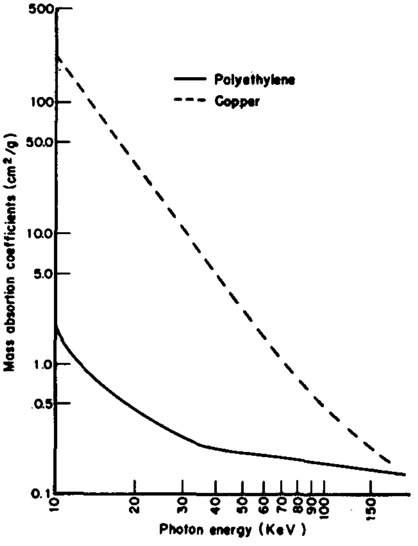

Figure 3. Mass Absorption Coefficients for Polyethylene (Solid Line) and Copper (dashed line) vs Photon Energy (keV).

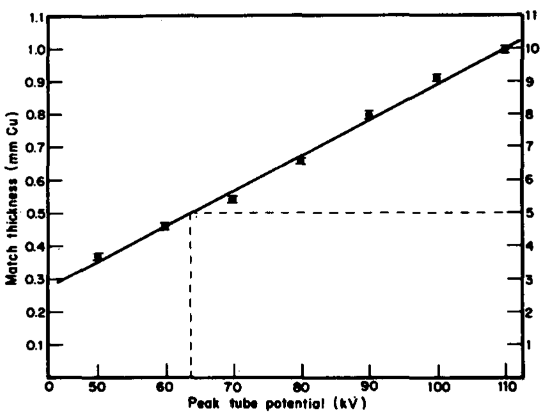

Figure 4. Calibration Curve of Prototype Stanton Wedge.

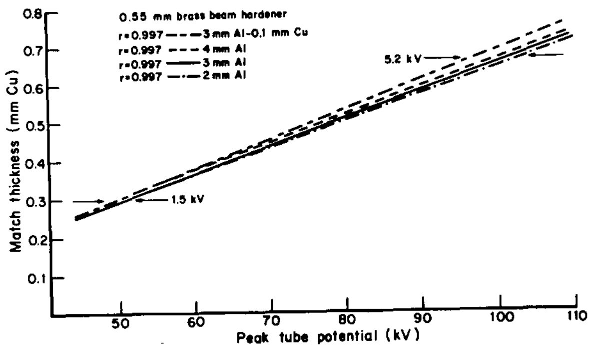

Figure 5. Spectral Response of Stanton Wedge with Thickness of 0,55mm Brass Filter Hardener.

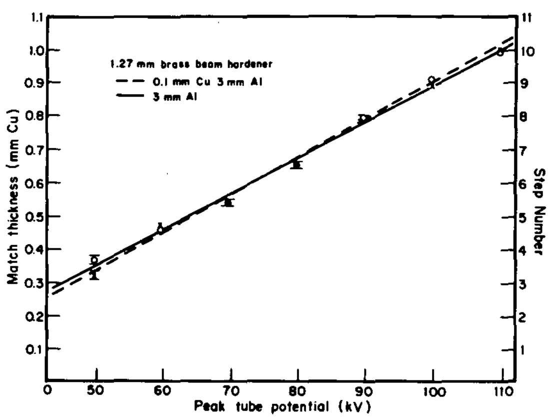

Figure 6. Spectral Response of Stanton Wedge with Thickness of 1,27mm Brass Filter Hardener.