Reference factor $F_{(CT)_Q}$ and X ray tube ionization yield $R_{(TUBE)_Q}$

Quaresma D.S.[1], Cardoso R.S.[2], Peixoto J.G.P.[2]

[1] Observatório Nacional; [2] Instituto de Radioproteção e Dosimetria

E-mail: dansq@on.br

Abstract: The operational facility procedures in diagnostic radiology standardization and calibration, through the relation between the X ray tube current and the ionization chamber current in a radiation quality Q, shown the reference factor $F_{(CT)_Q}$ as the reality estimate to the X ray tube ionization yield, $R_{(TUBE)_Q}$.

Keywords: Radiation quality; X ray tube; reference factor; ionization yield.

1. INTRODUCTION

The procedures application used in Diagnostic Radiology area passed through for various modifications and technology developments, that contributed decisively the scientific bases for the Technical Reports Series 457 [1] and the guide IEC 61267 [2].

The intrinsic relationship between the electric current generated by electrons X ray target tube, with the ionization current created by the ionization chamber through observations and realistic behavior were analyzed.

The relationship obtained by a reference factor, named chamber-tube factor at quality Q, $F_{(CT)_Q}$, enabling among a few applications, to Air kerma rate values estimate previously of the electric tube current, because the radiation quality Q is independent to the chamber-tube currents.

There is the objective to obtain the air kerma rate estimate of quickly way, for example, to calibrate the dosimeter, is dosimetry perform necessary in the point.

Generally, these procedures are cumber some and demands some time. After that, we have a operational tool to estimate easily with reference factor and ionization yield, an Air kerma rate in a varieties of radiation qualities Q, to any tube current in the range.

The tests were made solely in radiation qualities *RQR* [1, 2]to facility the verification for others laboratories.

2. X RAY TUBE IONIZATION YIELD $R_{(TUBE)_Q}$

The voltage result, U, through the X ray tube terminals is named electric potential. When the electrode filament is powered by an electric current and liable to thermionic effect, these electrons are attracted and accelerated in target material direction, T. Then, these electrons are decelerated; there are liberation of surplus energy in X ray.

Each X ray generate tube or housing will have maximum ionization capacity that may be defined how yield R. By Batista [3] the X ray tube *R* yield used in mammography was measuring in accordance with the "Manual de Precedimientos de Control de Calidad em Radiodiagnostico" [4], may be utilized to detect nominal value variations possible in the electric current tube, tube damage, as well as base estimates of the patient doses. Thus we have in equation 1:

$$R = \frac{mGy}{mAs} \qquad (1)$$

Where, the Kerma, current and time quantities are expressed in gray (Gy), ampere (A) and second (s), respectively, or reducing the equation in terms of the electric charge quantity, coulomb, *C*, equation 2:

$$R = \frac{Gy}{C} \qquad (2)$$

Defining the X ray tube ionization yield *R* in a radiation quality *Q*, we have equation 3:

$$R_{(TUBE)_Q} = \frac{Gy}{C} \qquad (3)$$

3. REFERENCE FACTOR $F_{(CT)_Q}$

The existent relationship between the X ray tube electric currents and X ray ionization generated by the interaction inside the ionization chamber volume V_{IC}, we can establish the reference factor $F_{(CT)_Q}$ for each quality *Q*, where X ray tube electric current will be normalize, equation 4.

The $F_{(CT)_Q}$ represent the radiation beam intensity of the total filtration, f_T, of the radiation quality, *Q*, that is obtained during the ionization chamber traceability.

$$F_{(CT)_Q} = \frac{I_{chamber}}{I_{tube}} \qquad (4)$$

In the *RQR* radiation qualities determination of the standard beams, are used Air kerma rate measurements of the aluminum filtration attenuation function, for each radiation condition *Q*, denominated so radiation qualities or just qualities [1, 2].

Table 1 shown the relationship behavior between electric currents variations to *RQR6* radiation condition [1, 2].

Table 1 – Factor $F_{(CT)_Q}$ to the quality *RQR6*

$I_{chamber}$ (A)	I_{tube} (A)	$F_{(CT)_Q}$
$1.380 \cdot 10^{-11}$	$1.994 \cdot 10^{-3}$	$6.920 \cdot 10^{-9}$
$6.275 \cdot 10^{-11}$	$8.999 \cdot 10^{-3}$	$6.973 \cdot 10^{-9}$
$10.41 \cdot 10^{-11}$	$15.00 \cdot 10^{-3}$	$6.937 \cdot 10^{-9}$
$13.05 \cdot 10^{-11}$	$19.01 \cdot 10^{-3}$	$6.865 \cdot 10^{-9}$
$15.09 \cdot 10^{-11}$	$22.01 \cdot 10^{-3}$	$6.857 \cdot 10^{-9}$

Taking the average measurement and standard uncertainty to the *RQR6* quality, as the first value approximation, $F_{(CT)_{RQR6}} = (6.910 \pm 0.049) \cdot 10^{-9}$

4. MATERIALS

For tests and reference factor determination were used the constant potential X ray unit, made by Pantak, model HF160, with a X ray tube MXR160, manufactured by COMET, with 20° anode angle. The RADCAL ionization chamber model 20X5-3 of 3cm^3, calibrated in PTB (Germany), the KEITHEY electrometer model 6517A, the temperature measure unit model 1529R, HART SCIENTIFIC, the barometer model DPI141 manufactured DRUCK, and two HEWLEWT PACKARD multimeters, model 14401A, that are used to invasive X ray tube readings of the high voltage and electric current, and the *RQR* radiation quality in aluminum with 99,999% purity degree.

Figure 1 can behold the setup for the reference factor implementation, $F_{(CT)_Q}$.

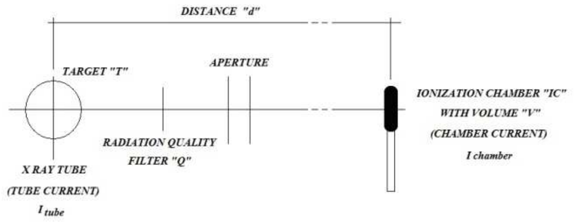

Figure 1 – Setup of test to obtained the factor $F_{(CT)_Q}$

This setup we have some fixed parameters, as well as distance d = 100 cm, total filtration f_T for each radiation quality "*Q*" or *RQR* quality, field size 10 cm determined by aperture and the target "*T*" that is characteristics of the X ray tube and, an ionization chamber with a 3cm^3 fixed volume, V_{IC}.

5. RESULTS

The determination of the values to the reference factor, $F_{(CT)_Q}$, for *RQR* each radiation qualities, according equation 5:

$$F_{(CT)_Q} = \frac{dQ_{corrected}}{dt \cdot I_{tube}} \qquad (5)$$

Where $dQ_{corrected}$ is the ionization chamber charge measurement, corrected to the environmental conditions of the temperature and pressure, dt is the time interval integration and I_{tube} is the X ray tube electric current measured with the invasive method.

The method can be I_{tube} display value used of the X ray unit system. These values were collected with the data acquisition system assistance.

Figure 2 shown the polynomial adjust related to reference factor $F_{(CT)_Q}$ for each *RQR* radiation quality.

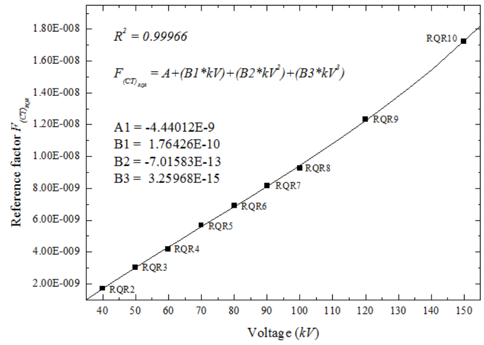

Figure 2 – Reference factor $F_{(CT)_Q}$ versus voltage tube *kV*

Each *RQR* quality was defined in an electric current range according the X ray generator limit and reference factor determined in this range.

Table 2 shown at the first column the *RQR* qualities, the second the tube current range, that is the width of test, third the reference factor $F_{(CT)_Q}$ tube current to generate an Air kerma rate of 22 mGy/min in the *RQR* quality, and fourth the correction factor $k_{(TUBE)_{RQR}}$ that is the value times $R_{(TUBE)_{RQR5}}$ normalized in *RQR5*, to give the others values of ionization yield.

Table 2 – X ray tube MXR160, ionization chamber Radcal model 20X5-3, 22 *mGy/min*, ionization yield $R_{(TUBE)_{RQR5}} = 5.939 \cdot 10^{-2} \frac{Gy}{C}$

RQR	*Tube Current range (mA)*	$F_{(CT)_{RQR}}$	$k_{(TUBE)_{RQR}}$
2	2 to 26	$1.718 \cdot 10^{-9}$	0.304
3	2 to 24	$3.051 \cdot 10^{-9}$	0.536
4	2 to 24	$4.216 \cdot 10^{-9}$	0.736
5	2 to 22	$5.754 \cdot 10^{-9}$	1.000
6	2 to 22	$6.933 \cdot 10^{-9}$	1.200
7	2 to 20	$8.245 \cdot 10^{-9}$	1.421
8	2 to 20	$9.339 \cdot 10^{-9}$	1.605
9	2 to 15	$12.361 \cdot 10^{-9}$	2.114
10	2 to 14	$16.887 \cdot 10^{-9}$	2.867

Then, the values of table 2, we can calculate the Air kerma rate, substituting in equation6:

$$I_{chamber} = F_{(CT)_{RQR}} \cdot I_{tube} \qquad (6)$$

The Air kerma rate can be estimate changing equation 6 in 7, thus:

$$\dot{K}_{air} = (F_{(CT)_{RQR}} \cdot I_{tube}) \cdot N_k \cdot k_Q \cdot \prod k_i \qquad (7)$$

Or calculate through the tube parameters, we can estimate too at equation 8:

$$\dot{K}_{air} = I_{tube} \cdot R_{(TUBE)_{RQR5}} \cdot k_{(TUBE)_{RQR}} \qquad (8)$$

The table 3, using equations7 and 8, was each *RQR* radiation quality estimated for the X ray tube current for an Air kerma rate of 22 mGy/min.

Table 3 – Factor $F_{(CT)_Q}$ to the quality *RQR6*

RQR	*Air Kerma rate (mGy/min) (7)*	*Air Kerma rate (mGy/min) (8)*
2	22.002	22.003
3	22.002	22.003
4	22.004	22.006
5	22.003	22.004
6	22.004	22.005
7	22.002	22.002
8	22.002	22.002
9	22.000	22.001
10	22.005	22.006

Table 3 shown Air kerma rate diference maximum as 0,01% in the *RQR4* radiation quality between in the calculation of equations (7) and (8).

6. CONCLUSIONS

The estimative of the reference factor, $F_{(CT)_Q}$ can be a good operational tool, because defines an identity for each reference radiation quality *Q* and makes the interface between X ray tube and ionization chamber, providing, how an application, an Air kerma rate prior method of the X ray tube current and their confirmation with the dosimetry in this point utilizing an ionization chamber.

The ionization yield $R_{(TUBE)_Q}$ is related the specific test conditions, being the material target *T* of the X ray tube, the high voltage between anode and cathode, the total filtration f_T, the distance focus-chamber *d*, and the ionization chamber volume V_{IC}, respect to the volume *V*, there an attention point, since the ionization chamber current will go change according volume variation for the same X ray tube current.

Them, the ionization yield of X ray tube estimated is valid for the volume *V* to 3cm^3 national standard ionization chamber.

The final conclusion was showed the implementation in *RQR* reference radiation qualities, in detail, for others laboratories may experiment, test, recommend adjustments and disseminate the method if applicable.

7. REFERENCES

[1] IAEA, “Technical Reports Series 457 - Dosimetry in diagnostic radiology: An international code of practice,” Vienna, Austria, 2007.

[2] IEC, “IEC 61267 - Medical diagnostic X-ray equipment - Radiation conditions for use in the determination of characteristic,” 2005.

[3] M. C. Batista, “Dose glandular média em mamografia, usando interpolação polinomial e bicúbica,” vol. 15ª Confer, 2006.

[4] SSVR, “Manual de control de calidad em radiodiagnóstico,” 2002.