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AUTOMATED CORRECTION ON X-RAYS CALIBRATION USING TRANSMISSION CHAMBER AND LABVIEW ™

Flávio Betti and Maria da Penha Albuquerque Potiens

Instituto de Pesquisas Energéticas e Nucleares - IPEN* - CNEN/SP
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
fbetti@ipen.br
mppalbu@ipen.br

* Autarchy associated to the University of São Paulo - USP

ABSTRACT

Uncertainties during prolonged exposure times on X-rays calibration procedures at the Instruments Calibration facilities at IPEN may suffer from efficiency (and therefore intensity) variations on the industrial X-Ray generator used. Using a transmission chamber as an online reference chamber during the whole irradiation process is proposed in order to compensate for such error source. Also temperature (and pressure) fluctuations may arise from the performance limited calibration room air conditioning system. As an open ionization chamber, that monitor chamber does require calculation of a correction factor due to the temperature and pressure effects on air density. Sending and processing data from all related instruments (electrometer, thermometer and barometer) can be more easily achieved by interfacing them to a host computer running an especially developed algorithm using LabVIEW ™ environment which will not only apply the proper correction factors during runtime, but also determine the exact length of time to reach a desired condition, which can be: time period, charge collected, or air kerma, based on the previous calibration of the whole system using a reference chamber traceable to primary standard dosimetry laboratories. When performing such calibration, two temperature sensors (secondary standard thermistors) are simultaneously used, one for the transmission chamber, and other for the reference chamber. As the substitution method is used during actual customer's calibration, the readings from the second thermistor can also be used when desired for further corrections. Use of LabVIEW ™ programming language allowed for a shorter development time, and it is also extremely convenient to make things easier when improvements and modifications are called for.

1. INTRODUCTION

Automation of the duties which are called for during the tasks of radiation monitor instruments calibration using open ionization chambers have been sought after since long [1]. Every year the LCI (Instruments Calibration Laboratory) at IPEN performs 200+ calibrations using its X-ray calibration facilities, plus around 50 test irradiations for research purposes [2]. Part of the time traditionally expended by the crew members involves manual registration and determination of the correction factor for temperature and pressure for each calibration essay. Considering that the exact irradiation time for a desired air kerma value can hardly be achieved because the influence factors (temperature, pressure and especially X-rays intensity which relates to the efficiency of the generating system) cannot be exactly predicted in prior, it becomes difficult for the instrument under calibration to receive an exact amount of air kerma, a desirable feature when it is of the integrating type, or when it cannot be turned on and off after a well determined period of time. In such cases, the technician is challenged to simultaneously start and stop both the X-rays shutter control and integrating device (typically an electrometer), resulting in increased overall expanded uncertainties level.

Automatic control of the shutter calls for special compensation techniques in order to minimize time lag errors [3]. Moreover, it has to be considered that, especially during longer exposure times, variations on any of the relevant parameters (temperature, pressure and especially X-rays intensity) are expected to directly impair the overall precision that could otherwise be achieved.

2. MATERIALS AND METHODS

As all related instruments used for such X-rays calibration tasks (electrometer, thermometer and barometer) could be easily linked to receive and send data to a local computer using their standard RS-232C interface, an automatic control system was devised so as to overcome and reduce known uncertainties sources as described above. As a multifunction card (PCI-6040E from National Instruments®) was readily available thanks to a supporting project [4], providing for digital output control became easy and the only hardware which had to be designed and constructed was the shutter interface controller, as it was a part from the X-rays generating system (Agfa NDT Pantak Seifert GmbH ISOVOLT HS 160).

A precision 4-channel thermometer (Hart Scientific 1529 Chub E-4) coupled to a pair of secondary standard thermistors (Hart Scientific 5611-X) was used in conjunction with an absolute barometer (Drück DPI 142). The electrometer for the transmission chamber (PTW 34014) was one UNIDOS E (also from PTW). Calibration traceability could be achieved by substitution method using a secondary standard ionization chamber PTW 77334, calibrated by the Primary Standard Dosimetry Laboratory Physikalisch-Technische Bundesanstalt, PTB, Germany, coupled to a true integrating PTW UNIDOS electrometer suitable also suitable as secondary standard.

The beam qualities used during the tests had been previously established according to the IEC 61627:2005 [5] requirements: RQR-2 through RQR-10 and RQA-2 through RQA-10, both useful for diagnostic radiology. Intended for radiological protection instruments calibration, the N-60 through N-150 qualities were reproduced according to ISO 4037-2 standards [6].

Most ionization chambers used require correction for the air density against the reference conditions:

$$T_{ref} = 20\ C \qquad \text{and} \qquad P_{ref} = 101{,}325\ kPa \tag{1}$$

The most widely used expression for the correction factor [7] for the calibration room conditions is:

$$k_{room} = \frac{T_{room} + 273.15}{293.15} \cdot \frac{101.325}{p_{room}} \tag{2}$$

Among the instruments interfaced to the arrangement, the slowest are the UNIDOS electrometers connected to the ionization chambers. When set to the so called “streaming mode”, they keep a rate of flowing data updated every 0.5 s. It was then decided that the computer program was fast enough to perform all needed calculations between two successive readings, so the resulting correction factors are updated and applied twice per second, lessening the importance of variations on both temperature and pressure that might occur during long term irradiations.

Time uncertainties associated with the computer-generated command for the shutter were experimentally found to stay under 16ms, allowing for a more accurate exposure time control than could have been achieved by manual methods, and making it possible to devise a compensation algorithm for the time lag inherent to the mechanical operation of the shutter. Such algorithm is based on both extrapolation methods and empirical results, as described on an academic work conducted by the technical staff of the LCI [8].

3. RESULTS

A main program was developed in LabVIEW ™ strictly aiming to achieve a precise control of the charge collected by the electrometer connected to the monitor (transmission) chamber. The dynamic correction factor calculator subroutine is disabled when extrapolation reveals that the intended charge is expected to be reached within less than 1.5 s, and the predicted time to close the shutter is delivered after subtraction of the estimated time lag of the shutter. Fig. 1 shows the front panel of the application where intended and actual values can be compared for good matching.

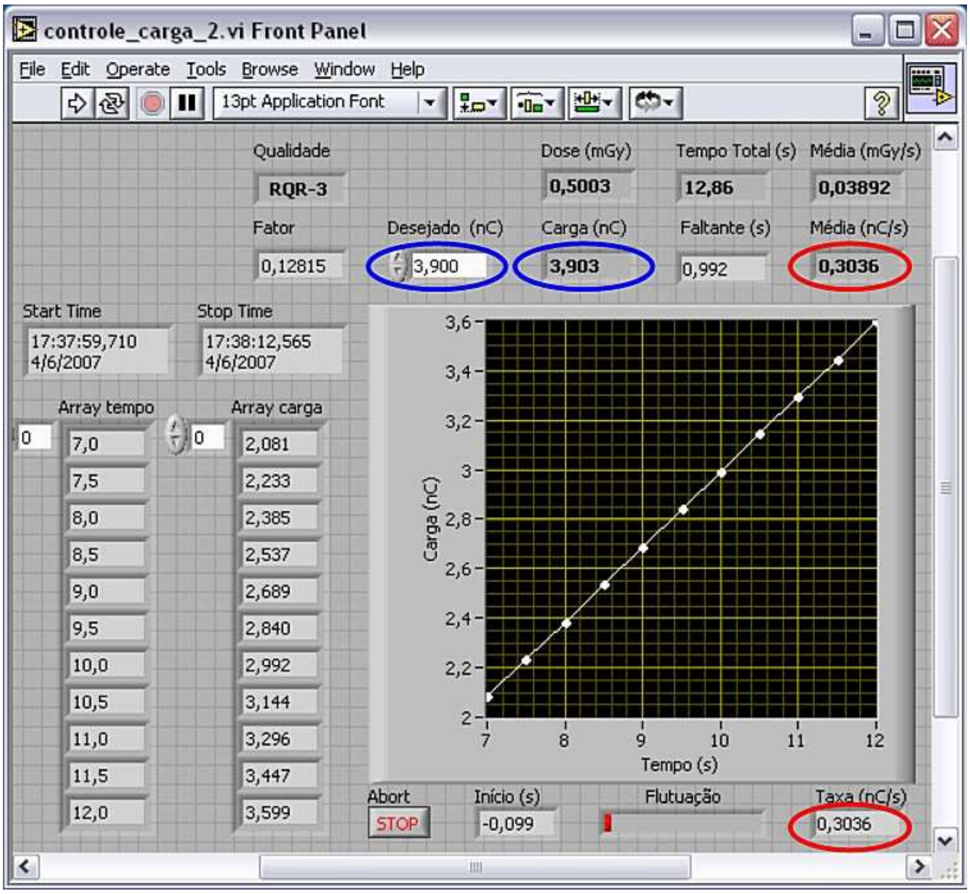

Figure 1. Front panel of the charge control LabVIEW ™ routine developed for test proofing the accuracy of the automatic shutter controller.

A second routine was directly developed starting from this one, aiming to achieve a desired air kerma value based on calibration factors that must have been previously determined. As new correction factors are generated every 0.5 s, better results are obtained than if using a single one (for the initial, final or average condition), in case of variation of the room temperature (or even pressure) during the irradiation.

A program for periodically refreshing such calibration factors has also been developed (see Fig. 2). It incorporates an auto-ranging feature for older type UNIDOS electrometer connected to the reference chamber, as well as an automatic decision for using either the true (capacitive) integrator (which lends to a better accuracy), or the ∫i.dt option. The UNIDOS E connected to the monitor chamber always work in current integration mode.

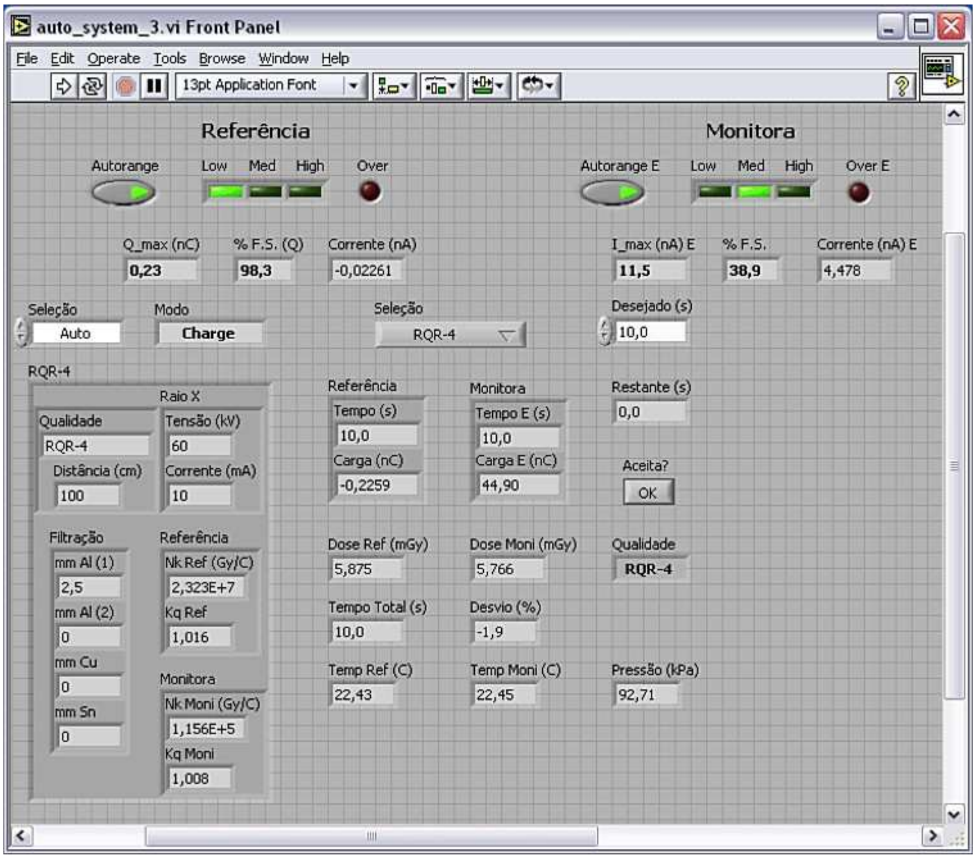

Figure 2. Front panel of LabVIEW ™ program developed for periodical generation of new calibration factors for the monitor chamber.

4. CONCLUSIONS

The choice of LabVIEW ™ as programming tool proved to be a quick and effective method to achieve the desired results, with the advantage of being easily customizable for the needs of the laboratory crew, dispensing the need for third part developers.

The results obtained were found to be more reliable and accurate than those from the previous manual methods employed, particularly in extreme conditions of very short time exposures of only a few seconds, or else during long irradiations were the temperature cannot be held constant. The importance of such corrections has been often emphasized [9]. Using two independent temperature sensors placed in close vicinity of each ion chamber led to calculation of individual correction factors which allowed for a better compensation of the temperature gradient caused by the heat emanated from the X-ray generator.

Further improvements could still be obtained by incorporating the periodically generated calibration factors into a database file which would allow for a closer quality control of the calibrating system stability over time.

Computer communication with the X-ray generator control panel is another feature that could not be implemented up to now, due to lack of information from the manufacturer (Seifert). It would be obviously advantageous (and easy, from the programming point of view, not to say safer against operation error) to permit that the main program set the voltage and current at the beam generator. It is still possible and desirable as a future improvement to include a checking feature on the current program that would compare the air kerma rate with a previously stored expected value, and sign up with a warning flag in case the difference exceeds a predetermined value.

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REFERENCES

1. Bylander, E. G. and Gardner, J. R., "Automatic Ion Chamber Correction for Temperature and Pressure", *Review of Scientific Instruments*, **Volume 31**, pp.778-779 (1960).
2. Correa, Eduardo de L.; Potiens, M. P. A.; Caldas, Linda V. E.; "Evaluation of Ionization Chambers in X-Rays Beams Used for Instruments Calibration", *Proceedings of the 12th International Congress of the International Radiation Protection Association (IRPA)*, Buenos Aires, Argentina (October 19-24, 2008).
3. Betti, F. and Potiens, M. P. A., "X-rays Short Exposure Errors Evaluation", *IV Congreso Latinoamericano de Física Médica*, Cartagena das Índias, Colombia (2007).
4. IAEA Technical Co-Operation Project: BRA/1/034, "Calibration Network for Dosimeter and Quality Control Equipment Used in Diagnostic Radiology" (2006).
5. International Electrotechnical Commission, "*Instruments as used in the non-invasive measurement of X ray tube potential in diagnostic radiology*", **IEC 61627** (2005).
6. International Organization of Standardization, "*X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy*", Part 2: "*Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV*", **ISO 4037-2** (1997).
7. Knoll, G. F., "*Radiation Detection and Measurement*", 2nd ed., John Wiley & Sons, New York, NY (1989)
8. Betti, F., "*Desenvolvimento e Implantação de um Programa de Controle e Aquisição de Dados na Calibração de Instrumentos em Radiodiagnóstico*", MSc Dissertation, IPEN-USP (2007).
9. Indra J. Das and Timothy C. Zhu, "Thermal and temporal response of ionization chambers in radiation dosimetry", *Medical Physics*, **Volume 31**, **Issue 3**, pp. 573-578 (March, 2004).