

## Calibration System for Electric Charge at the Centro Español de Metrología

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**Abstract** - In this paper, the new system developed at CEM for the calibration of electric charge meters is presented. Two different approaches are adopted. The first one is based on the charge of a standard capacitor, the other one in the generation of a known current during a specific time.

### I. Introduction

Measurement of electric charge is increasingly important in several technical fields, especially in ionising radiation dosimetry. Furthermore, many electrometers and picoammeters include an electric charge measuring function or could be configured to measure charge by using a capacitor in external feedback. Until now, a calibration service for this magnitude didn't exist in Spain. Responding to a calibration request of CIEMAT, the Spanish designated laboratory in Ionising Radiation Metrology, CEM has begun to develop a calibration system for charge meters which is traceable to national standards.

Two methods to create a known charge have been tried. Charging a standard capacitor to a specific voltage gets the best accuracy but this method is only applicable to the lowest charges (because of the limitation on the applied voltage) and requires matching between electrometer input and capacitor terminals to avoid errors due to cable capacitance. Besides, standard capacitors are usually calibrated in AC at 1 kHz, and this method uses them in DC so that it could show significant differences.

The second method is based on the application of a known current to the electrometer during the time necessary to get the required charge. This method is more fitted for higher charges.

### II. Description / Development

#### A. Charged Capacitor Method

If a standard capacitor of capacitance  $C$  is charged to a voltage  $V$ , then by definition its charge is:

$$q = CV \quad (1)$$

Both capacitance and voltage are measured with relative accuracy of  $10^{-6}$  or better, so initially high accuracy is possible. However, several problems arise with this method:

Best accuracy is only achieved in standard capacitors with values in the range 1 pF-1000 pF. Furthermore, many higher value capacitors have a relevant loss factor. This, joint to limited voltage in the standard capacitors to avoid damage them reduce the application range of the method to lowest values of charge.

Capacitors are usually calibrated in AC at about 1 kHz-1.592 kHz frequency. However, for this application, they are used in DC. Many standards have shown a relevant AC-DC difference and this is a source of uncertainty, at least when highest accuracy is required.

The standards of capacitance or, impedance in general, are built according to well specified definitions (three terminals or two or four terminal pairs, normally) [1]. They are defined in that way in order to avoid errors due to parasitic impedances in cabling and insulation. However, electrometers usually have coaxial or triaxial inputs, requiring adapters to connect them to the capacitors. At the moment, we have only tried coaxial electrometers and we have found impossible to make accurate charge measurements, due to parasitic capacitance of cables.

Errors higher than 50% have been found. We expect better results for triaxial electrometers but we haven't made measurements yet.

Not being possible to service coaxial electrometers and not being sure the application of the charged capacitor method to the triaxial ones, we have developed an alternative method.

### B. Time-Current Method

Our second method is based on the application of a current during well-defined time intervals. For the case of ionising radiation dosimeters, this method is really better adapted to real behaviour of the instrument, charge accumulation during long time periods rather than single shot charge. In our case we generate the required current applying voltage to a high value resistor, according to figure 1.

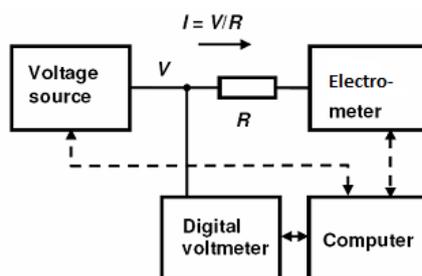


Figure 1. Scheme of measuring system.

To assure an accurate timing we use an Arbitrary Waveform Generator (AWG) connected to a GPS frequency standard as voltage source, generating a squared pulse of amplitude  $V$  and duration  $t$ . It is very accurate as a frequency/time interval generator but not as a voltage source and, because of this, its output is measured with a calibrated digital voltmeter during charge cycle.

With this system, the resulting charge is:

$$q = It = \frac{V}{R}t \quad (2)$$

Preliminary measurements on a BIPM calibrated electrometer lent to us by CIEMAT showed an agreement to the level of 0.1%, very appropriate to calibrate dosimeters.

### III. Results and discussion

We first made measurements with the time-current method on an electrometer and ionising radiation dosimeter Wellhofer model DOSE1 with serial number 10908, lent to us by the Gamma Reference in Therapy Levels Laboratory belonging to CIEMAT. Results are shown in table 1.

The calibration coefficient is defined as the relation between the actual charge value and the charge value measured by the electrometer. As it can be checked, in this case the value of this coefficient is about 0'1% in all the different values of measured charge.

Charge	Applied value	Measured value	Uncertainty	Calibration coefficient
<b>1000 nC</b>	995,0 nC	996,2 nC	65 pC	0,998 798
<b>500 nC</b>	497,5 nC	498,1 nC	59 pC	0,998 838
<b>250 nC</b>	248,8 nC	249,0 nC	59 pC	0,998 946
<b>150 nC</b>	149,2 nC	149,4 nC	59 pC	0,999 079
<b>100 nC</b>	99,49 nC	99,59 nC	10,3 pC	0,999 033
<b>80 nC</b>	79,59 nC	79,66 nC	9,1 pC	0,999 023
<b>60 nC</b>	59,69 nC	59,74 nC	8,7 pC	0,999 128
<b>40 nC</b>	39,82 nC	39,86 nC	6,2 pC	0,999 007
<b>30 nC</b>	29,87 nC	29,90 nC	6,3 pC	0,999 006
<b>20 nC</b>	19,91 nC	19,93 nC	6,0 pC	0,998 962
<b>10 nC</b>	9,966 nC	9,977 nC	1,2 pC	0,998 937
<b>5 nC</b>	4,985 nC	4,988 nC	0,7 pC	0,999 322
<b>1 nC</b>	1,001 nC	1,001 nC	0,6 pC	0,999 818

**Table 1.** Wellhofer DOSE1 electrometer results

Afterwards, we try the same measurement method on an electrometer PTW UNIDOS model T10002, with serial number 20495, also lent to us by the Gamma Reference in Therapy Levels Laboratory belonging to CIEMAT. This device has two ranges in electric charge measurement, the high one is up to 23 nC, and the low one until 230 pC.

Charge	Applied value	Measured value	Uncertainty	Calibration coefficient
<b>23 nC</b>	22,91 nC	22,89 nC	6 pC	1,000 718
<b>22 nC</b>	21,91 nC	21,90 nC	6 pC	1,000 514
<b>21 nC</b>	20,92 nC	20,90 nC	6 pC	1,000 849
<b>20 nC</b>	19,92 nC	19,91 nC	6 pC	1,000 403
<b>19 nC</b>	18,93 nC	18,92 nC	6 pC	1,000 287
<b>18 nC</b>	17,93 nC	17,91 nC	6 pC	1,000 967
<b>17 nC</b>	16,93 nC	16,93 nC	6 pC	1,000 344
<b>16 nC</b>	15,94 nC	15,92 nC	6 pC	1,001 123
<b>15 nC</b>	14,94 nC	14,93 nC	6 pC	1,000 763
<b>14 nC</b>	13,95 nC	13,94 nC	6 pC	1,000 368
<b>13 nC</b>	12,95 nC	12,93 nC	6 pC	1,001 452
<b>12 nC</b>	11,95 nC	11,94 nC	6 pC	1,001 282
<b>11 nC</b>	10,96 nC	10,95 nC	6 pC	1,000 747
<b>10 nC</b>	9,960 nC	9,944 nC	0,6 pC	1,001 585
<b>9 nC</b>	8,964 nC	8,950 nC	0,7 pC	1,001 551
<b>8 nC</b>	7,968 nC	7,954 nC	0,6 pC	1,001 777
<b>7 nC</b>	6,972 nC	6,973 nC	0,7 pC	0,999 965
<b>6 nC</b>	5,976 nC	5,978 nC	0,6 pC	0,999 638
<b>5 nC</b>	4,979 nC	4,981 nC	0,6 pC	0,999 673
<b>4 nC</b>	3,984 nC	3,985 nC	0,6 pC	0,999 632
<b>3 nC</b>	2,988 nC	2,988 nC	0,6 pC	0,999 794
<b>2 nC</b>	1,992 nC	1,992 nC	0,6 pC	0,999 877
<b>1 nC</b>	1,002 nC	1,002 nC	0,6 pC	1,000 450

**Table 2.** PTW UNIDOS T10002 electrometer high range results

Again in this case is shown all the calibration coefficient values are around 0'1% and always below 0'2%.

Charge	Applied value	Measured value	Uncertainty	Calibration coefficient
<b>230 pC</b>	229,3 pC	228,3 pC	0,10 pC	1,004 591
<b>220 pC</b>	219,4 pC	218,5 pC	0,06 pC	1,004 500
<b>210 pC</b>	209,4 pC	208,4 pC	0,09 pC	1,004 624
<b>200 pC</b>	199,6 pC	198,6 pC	0,06 pC	1,004 913
<b>190 pC</b>	189,5 pC	188,7 pC	0,10 pC	1,004 347
<b>180 pC</b>	179,6 pC	178,8 pC	0,06 pC	1,004 459
<b>170 pC</b>	169,6 pC	168,8 pC	0,06 pC	1,004 668
<b>160 pC</b>	159,6 pC	158,9 pC	0,06 pC	1,004 656
<b>150 pC</b>	149,7 pC	149,0 pC	0,06 pC	1,004 713
<b>140 pC</b>	139,7 pC	139,0 pC	0,07 pC	1,004 707
<b>130 pC</b>	129,7 pC	129,1 pC	0,06 pC	1,004 732
<b>120 pC</b>	119,7 pC	119,2 pC	0,06 pC	1,004 788
<b>110 pC</b>	109,8 pC	109,2 pC	0,06 pC	1,004 717
<b>100 pC</b>	99,78 pC	99,29 pC	0,01 pC	1,004 921
<b>90 pC</b>	89,80 pC	89,35 pC	0,01 pC	1,005 075
<b>80 pC</b>	79,83 pC	79,43 pC	0,02 pC	1,004 939
<b>70 pC</b>	69,85 pC	69,61 pC	0,01 pC	1,003 377
<b>60 pC</b>	59,87 pC	59,67 pC	0,01 pC	1,003 298
<b>50 pC</b>	49,89 pC	49,72 pC	0,01 pC	1,003 423
<b>40 pC</b>	39,92 pC	39,79 pC	0,01 pC	1,003 254
<b>30 pC</b>	29,94 pC	29,84 pC	0,01 pC	1,003 236
<b>20 pC</b>	19,97 pC	19,68 pC	0,01 pC	1,014 893
<b>10 pC</b>	9,99 pC	9,83 pC	0,01 pC	1,015 470

**Table 3.** PTW UNIDOS T10002 electrometer low range results

In this low range the calibration coefficient values stay around 0’5%, except the two lower points, in which its value is much higher.

#### IV. Conclusions

CEM has initiated the development of a electric charge calibration system. First measurements are very promising, with a 0.1% agreement. At the time of the conference new measurements and uncertainty analysis will be presented. CEM expect to be able to give service to clients in this year.

#### References

- [1] Henderson, L C A, Williams, J, *A guide to measuring resistance and impedance below 1 MHz*, National Physical Laboratory, 1999.