

## PC TOOL FOR DATA ANALYSIS IN CALIBRATION OF SPECIAL WEIGHTS

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**Abstract** – The paper describes a PC application for processing results in calibration of special weights used by Mass laboratory of National Institute of Metrology.

The application named “GS 2007” is friendly used, complex and safe application. It realizes the necessary functions for calculating the mass and uncertainty of the special weights, according to OIML R 111, including the uncertainty analysis, to optimize the measurement process.

The application allows data recording, interactive dialog, the visualization and the printing of the results.

**Keywords** : special weights, uncertainty analysis, Excel application, data protection.

### 1. INTRODUCTION

The paper describes a PC application for processing results in calibration of special weights used by Mass laboratory of Romanian National Institute of Metrology.

The Excel application realizes the necessary functions for calculating the mass and uncertainty of the special weights, according to OIML R 111, including the uncertainty analysis to optimize the measurement process.

The application also allows data recording, interactive dialog, the visualization and the printing of the results.

To protect and save the electronically stored records and to prevent the unauthorized access to these records, the application meets a specific procedure, implemented in the laboratory, according to [1].

### 2. DESCRIPTION OF THE APPLICATION

The application maintains a data base including the recorded values of all the data used, having a good protection against unwanted or accidentally changes. The main application is accompanied by another independent application UP which is used for upgrading the measurement instruments data (from the main application GS 2007).

#### 2.1 The installation of the program

The installation of the program on the computer is made following the same steps that any installation: selecting the destination path disk, the installation itself (Fig . 1.) and complete installation.

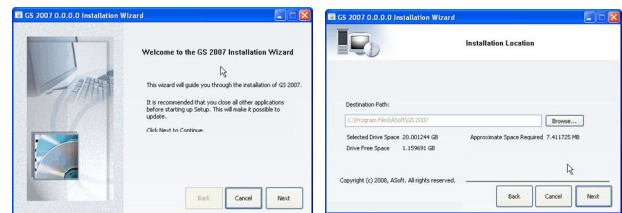


Fig. 1. The installation itself of the application

Also shortcuts are created in the Program Files, Desktop and Taskbar.

After installation, the program does not run all functions, (for example the records are not saved in the database) if is not activated. For activation, it runs the application “actuation” (ACTIVE GS2007), which allows running the complete application.

#### 2.2 Description of the application UP

The application UP is used for upgrading the measurement instruments data (from the main application GS 2007). By a simple click it can be chosen to update the standards weights, weighing instruments or equipments for air density, Fig. 2.



Fig. 2. The window that contains the update of measurement instruments data.

In the Fig. 3 is presented, for example, the setup of new values for the standards weights.


START Upgrade! Standard weights GS 7007		UPE-39925	DATE: 22-apr.-09	Checked .....						
Nominal mass	Modifications	History of modifications	Calibration Certificate, no.	Mass conventional	Unit	Uncertainty	Drift	$\rho_r$	$U_{\rho_r}$	Corrected mass
	 OIML Class I	Class I Manufacturer's series								
1 kg	Et referință 1 kg Sartorius 90132655	02.01-52/2006	0,999 999 997	kg	0,054	0,054	8009,90	7,5	2	
1 kg	Et referință 1 kg Sartorius 90132656	02.01-52/2006	1,000 000 023	kg	0,026	0,026	8008,84	0,34	3	
1 g	Et referință 1 g Kroneiss BEV 5701	2.1.24/2003	0,999 893	g	0,001	0,001	8406,00	30	4	
1 g	Et referință 1 g Kroneiss BEV 5701	2.1.17/2003	0,999 805	g	0,001	0,001	8406,00	30	5	
20 kg	E1 20 kg KERN G047440 A18	02.01-54/2006	20,000 003	kg	4	4	8043,30	4,4	7	
20 kg	E1 20 kg KERN G047441 A19	02.01-006/2009	20,000 021	kg	3	3	8043,30	4,4	8	
10 mg	E1 10 mg KERN G047439 A17	02.01-009/2009	10,000 003 9	mg	0,9	0,9	8013,60	5	9	
10 kg	E1 10 kg KERN G047439 A17	02.01-55/2006	10,000 002 7	kg	1,5	1,5	8015,60	5,4	10	

Fig. 3. Update of standards weights

### 2.3 The security of the data

The security of the data [1], in the Excel workbook is assured at 3 levels: for the user, for the administrator and for the author:

- at the first level the user has the password for access the application “GS 2007” and for modifying or adding data (which do not enter in the calculation of mass, for example the name of the operator or the manufacturer).
- The data, the time and the name of the person who has done the changes are automatically registered; this information may be visualized at any time in the computing file.
- at the second level, a password is defined for the administrator to protect the UP application.

The UP application requires two passwords:

- for actualization of the data (for example the setup of new values for the reference standards);
- the transfer of the actualized data to the application “GS 2007”.

Additionally, the second level includes the first level of protection.

- at the third level, the passwords protecting the main application GS2007, the individual application UP and the VBA code (Visual Basic for Applications) are defined by the author, which has the total access in the application.

### 2.4. The structure of the application

The main data file is structured on several areas, which ensure a good run of the application:

#### 2.4.1 GENERAL DATA area, Fig. 4.

Contains data concerning the order, the operator which performs the calibration, the start and the end data for the calibration.

Order:	777	The begin data:	Today	9-dec.-2008	History
Operator:	A. Vălcu	The end data:	Today	9-dec.-2008	Modifications

Fig. 4. General Data area

#### 2.4.2 AIR DENSITY area, Fig. 5.

Contains data concerning the environment conditions (temperature, relative humidity, air pressure) together with the number of calibration certificate for each parameter, the air density calculation and resulted uncertainty.

Environment conditions	Environment conditions instruments	C.E.Nr.:
t = 21,3 °C	u <sub>t</sub> = 0,5 °C	Opus 10 TH1 seria: 6084 (camera OC-08)
h = 46 %	u <sub>h</sub> = 4 %	Barometru (camera SC-08)
p = 102889 Pa	u <sub>p</sub> = 13 Pa	Higrometru YCM02C A30
$\rho_a = 1,212495 \text{ kg/m}^3$	$u(\rho_a) = 0,002195 \text{ kg/m}^3$	Laborator 2008 70 m

Fig. 5. Air density area

#### 2.4.3 STANDARDS area, Fig. 6.

Gives us information on the standards used: accuracy class, the number of calibration certificate, the update data and all the necessary data from the calibration certificate used in mass calculation (mass value and density of the standard, with respective uncertainties). Using a single click all the information concerning the standards are automatically filled.

STANDARDS	UPDATED on:	31 January 2008	$m_{cr} =$	$U_{m_{cr}} =$	$\rho_r =$	$U_{\rho_r} =$	$\delta m =$
C.E.Nr.: 02.01-109 / 2006			2,950 008 7				
E2 2 'g A Halber 51			1,999 999	0,012	7950,0	140,0	0,0120
E1 500 mg Sartorius 90332784			0,500 013 6	0,003	8600,0	170,0	0,0025
E1 200 'mg Sartorius 90332784			0,200 001 5	0,002	8600,0	170,0	0,0020
E1 200 mg KERN G047439			0,200 000 6	0,002	7950,0	140,0	0,0020
E1 50 mg Sartorius 90332784			0,049 994	0,001	8600,0	170,0	0,0013

Fig. 6. Standards area

#### 2.4.4 WEIGHING INSTRUMENT area, Fig. 7.

Contains data concerning the balance used in calibration, the number of calibration certificate, together with all the necessary information used in the calculation.

Weighing instrument	$d =$	$s_p (A) =$	$U_d =$	$U_{s_p} =$	$U_{STAB} =$	$U_{REZ} =$
Comp. 211g AX 206 / 1128030901	div	div	mg	mg	mg	div
C.E.Nr.: 02.01-905/2007	0,001	2,40	0,000 000 008	0	0	0,5

Fig. 7. Weighing instrument area

#### 2.4.5 SPECIAL WEIGHT area, Fig. 8.

Here, we have information on the special weight that will be calibrated (manufacturer, material, density with respective uncertainty).

Special weight	Manufacturer	Material	$\rho_s =$	$U_{\rho_s} =$	$U_{m_s} =$	$U_{c_v} =$
Number			kg/m <sup>3</sup>	kg/m <sup>3</sup>		
25	SAUTER	Stainless steel	7950	140	0	0

Fig. 8. Special weight area

#### 2.4.6 SELECTION OF THE DATA area, Fig. 9.

Contains data concerning the additional standard weights disposed on the special weight. Using a single click all the information concerning the standards is automatically filled.

Additional weights (on the special weight)		UPDATED on: 31 January 2008		$m_{cr} =$	$U_{m_{cr}} =$	$\rho_r =$	$U_{\rho_r} =$	$\delta m =$
C.C.No.:	02.01-011/2007			0,030 007 4				
E1 20 mg Sartorius 90332784				0,020 010 4	0,001	8600,0	170,0	0,0010
E1 10 mg Sartorius 90332784				0,009 997	0,001	8600,0	170,0	0,0010
E1 20 mg Sartorius 90332784								
E1 10 mg Sartorius 90332784								
E1 5 mg Sartorius 90332784								
E1 2 mg Sartorius 90332784								
E1 2 'mg Sartorius 90332784								
E1 1 mg Sartorius 90332784								
E2 20 kg KERN G045983 D18								
Weighing instrument				$d =$	$s_p (A) =$	$U_d =$	$U_{STAB} =$	$U_{REZ} =$
Comp. CC10000U-L 10kg / 12502113				div	div	mg	mg	div
C.C.No.: 02.01-703/2006				0,01	5	0	0	0,5
DIFFERENCES ABBA on the balance								
$\Delta h_1 =$		12673,5 div		$\Delta h_2 =$		12675,0 div		$\Delta h_3 =$
$A_1 =$		12673,5 div		$A_1 =$		12675,0 div		$A_1 =$

Fig. 9. Selection of the data concerning the standards and additional weight area

In the cells, where necessary, can be typed other values than those automatically selected, the text colour being changed from blue in green. The values can be changed automatically using the appropriate buttons, Fig. 10.

Fig. 10. The automatic changes of the values

#### 2.4.7 PRIMARY DATA area, Fig. 11.

Contains the differences ABBA performed on the balance (max. twelve), number of cycles, mean difference, standard deviation of the mass differences.

DIFFERENCES ABBA on the balance					
$\Delta h_1 = 12673.5 \text{ div}$	$\Delta h_2 = 12675.0 \text{ div}$	$\Delta h_3 = 12675.0 \text{ div}$	$\Delta h_4 = 12675.0 \text{ div}$	$\Delta h_5 = 12675.0 \text{ div}$	$\Delta h_6 = 12675.0 \text{ div}$
$\Delta h_7 = 12675.0 \text{ div}$	$\Delta h_8 = 12675.0 \text{ div}$	$\Delta h_9 = 12675.0 \text{ div}$	$\Delta h_{10} = 12675.0 \text{ div}$	$\Delta h_{11} = 12675.0 \text{ div}$	$\Delta h_{12} = 12675.0 \text{ div}$
No. of cycles = 5	$\Delta h = 12674.70 \text{ div}$	$s = 0.670820393 \text{ div}$	$u_A = 0.3 \text{ div}$		

Fig. 11. Primary data area

#### 2.4.8 WARNINGS

When accidentally are introduced some wrong data, visual warnings appear, Fig. 12.

Fig. 12. Visual warnings

#### 2.4.9 RESULTS area, Fig. 13.

Containing a window with the final result of the mass for the special weight calibrated, together with respective uncertainty issued.

RESULTS			
Mass		Uncertainty of measurements	
Conventional	2,962 683	g	$u = 0,015 \text{ mg}$ $U = 0,030 \text{ mg}$

Fig. 13. Results area

#### 2.4.10 UNCERTAINTY BUDGET area, Fig. 14.

Contains detailed information of the mass and conventional mass resulted and measurement uncertainty for each parameter involved in calibration [2,3]. Thus, a complete image of the uncertainty's components provided on the sheet. The smaller or greater components that influence the expanded uncertainty are clear distinguished.

Quantity $X_i$	Value $x_i$	Expanded uncertainty $U$	Distribution	Standard uncertainty $u(x_i)$	Sensitivity coefficient $C_i$	Uncertainty contribution $u_i = C_i \cdot u(x_i)$ [mg]
$m_{ref}$ [g]	2,960 008 7	$U$ [mg] = 0,0198 $u$ [mg] = 0,0198	N	0,0099	1	0,009900
$m_{sp}$ [g]	0	$U$ [mg] = 0,0000 $u$ [mg] = 0,0000	N	0	1	0,000000
$\rho_a$ [kg/m <sup>3</sup> ]	1,212	$U$ [kg/m <sup>3</sup> ] = 0,0044 $u$ [kg/m <sup>3</sup> ] = 0,0022	N	0,0022	$C_{\rho_a}$ [kg/m <sup>3</sup> ]	2,681 46E-06
$\rho_r$ [kg/m <sup>3</sup> ]	7950,0	$U$ [kg/m <sup>3</sup> ] = 140,0000 $u$ [kg/m <sup>3</sup> ] = 70	N	70	$C_{\rho_r}$ [kg/m <sup>3</sup> ]	2,0E-10
$\rho_s$ [kg/m <sup>3</sup> ]	8115,3	$U$ [kg/m <sup>3</sup> ] = 354,8239 $u$ [kg/m <sup>3</sup> ] = 177,41195	N	177,41195	$C_{\rho_s}$ [kg/m <sup>3</sup> ]	1,9E-10
$C_1$	3,20042E-08	$U$ = 3,68E-08 $u$ = 1,84E-08	N	1,84E-08	$m_s$	3
$m_s$ [g]	3	$n$ cycles = 5				
$\Delta$ [div]	12674,70	$U$ [div] = 0,671 $u$ [div] = 0,3355	N	0,3355	$d$ [mg/div]	0,001
$d$ [mg/div]	0,001	$U$ [mg/div] = 0,000000008 $u$ [mg/div] = 0,000000004	N	0,000000004	$\Delta$ [div]	12674,7
$U_{ref}$ [div]	0,50	$U$ [div] = 0,408 $u$ [div] = 0,204	R	0,204	1	0,000408
$U_{sp}$ [mg]	0,0000	$U$ [mg] = 0,000 $u$ [mg] = 0,000	R	0,000	1	0,000000
$U_{std}$ [mg]	0,0000	$U$ [mg] = 0,000 $u$ [mg] = 0,000	R	0,000	1	0,000000
$U_{ref}$ [mg]	0,0000	$U$ [mg] = 0,000 $u$ [mg] = 0,000	R	0,000	1	0,000000
$U_{std}$ [mg]	0,0000	$U$ [mg] = 0,000 $u$ [mg] = 0,000	R	0,000	1	0,000000
$U_{ref}$ [mg]	0,0000	$U$ [mg] = 0,000 $u$ [mg] = 0,000	R	0,000	1	0,000000
$U_{std}$ [mg]	0,0000	$U$ [mg] = 0,000 $u$ [mg] = 0,000	R	0,000	1	0,000000
Conventional Mass		2,962 683 g				
				Combined standard unc. $u_c$ [mg] =		0,0151
				Expanded uncertainty ( $k=2$ ) $U$ [mg] =		0,0303
Mass		2,962 683 g		Combined standard unc. $u_c$ [mg] =		0,0021
				Expanded uncertainty ( $k=2$ ) $U$ [mg] =		0,0042

Fig. 14. The complete image of the uncertainty's components

#### STEPS IN THE UNCERTAINTY BUDGET

The first column contains the inputs quantities, having the estimations in the second column.

The expanded uncertainty from the next columns is calculated in accordance with [2], having the contributions further described in the same order that are viewed:

- uncertainty associated with the reference standard,

Uncertainty of the reference standard comprises a component from calibration certificate ( $u$ ) and another one from its drift ( $\delta m$ ) (stability of standard) [2].

$$u_{ref} = \sqrt{u^2 + \delta^2} \quad \text{With } u = \frac{U}{k} \quad (1)$$

The same formula is used for additional weights.

- Uncertainty associated with the air buoyancy corrections,  $u_b$  is estimated using the formula [2]:

$$u_b^2 = C_{\rho_a}^2 \times u_{\rho_a}^2 + C_{\rho_t}^2 \times u_{\rho_t}^2 + C_{\rho_r}^2 \times u_{\rho_r}^2 \quad (2)$$

with the following sensitivity coefficients:

$$C_{\rho_{ai}} = \frac{1}{\rho_t} - \frac{1}{\rho_r}; \quad C_t = (\rho_a - \rho_0) \times \frac{1}{\rho_t^2} \quad \text{and} \quad (3)$$

$$C_r = (\rho_a - \rho_0) \times \frac{1}{\rho_r^2}$$



- *The type A uncertainty*

Due to the fact that usually only two or three ABBA measurement cycles are executed, an experimental standard deviation cannot be calculated. For this reason, are used data obtained from previous repeatability evaluations on the mass difference between two weights of same nominal value, resulting a pooled standard deviation  $s_p$ . If  $n$  is the number of ABBA cycles performed, the type A uncertainty is calculated as:

$$u_A = \frac{s_p}{\sqrt{n}} \quad (4)$$

- *Uncertainty due to the sensibility of the balance*

If the balance is calibrated with a sensitivity weight (or weights) of mass,  $m_s$ , and standard uncertainty,  $u_{(ms)}$ , the uncertainty contribution due to sensitivity is [2]:

$$u_s^2 = \Delta m_c^2 \cdot [u_{ms}^2/m_s^2 + u_{(\Delta I_s)}^2/\Delta I_s^2] \quad (5)$$

- *Uncertainty due to the display resolution of the balance,  $u_{rez}$ , (for electronic balances) is calculated according to the formula [2]:*

$$u_{rez} = \left( \frac{d/2}{\sqrt{3}} \right) \times \sqrt{2} \quad (6)$$

- *Uncertainty due to eccentric loading*

The contribution of the eccentric loading effect of the standard scale (mass comparator) to the budget of uncertainties of the measurement is [2]:

$$u_{EX} = \frac{\frac{d_1}{d_2} \times D}{2 \times \sqrt{3}} \quad (7)$$

Where:

$D$  is the difference between maximum and minimum values from the eccentricity test performed

$d_1$  is the estimated distance between the centers of the weights; and

$d_2$  is the distance from the center of the load receptor to one of the corners.

- *Uncertainty due to instability in indications of the balance (mass comparator)*

If the indication of the balance fluctuates, the standard uncertainty resulting from the instability of the balance  $u_{STAB}$  is estimated by taking into account the semi-largeness of variation  $\delta m_{STAB}$  of indications of the balance (amplitude/2):

$$u_{STAB} = \frac{\delta m_{STAB}}{\sqrt{3}} \quad (8)$$

- *Uncertainty due to magnetic effects  $u_{ma}$*

When the weights have the magnetic properties which correspond to the requirements from [2], one may consider

the magnetic effect and its contribution to the standard uncertainty to be negligible.

- *Uncertainty due to convection effects  $u_{cv}$*

The convection effects determined by the difference between the temperature of the air in the lab and the temperature of the weight to be calibrated and its contribution to the standard uncertainty of the calibration are negligible provided provisions are observed as stipulated in [2].

The next columns in the uncertainty budget are in the following order: distribution, standard uncertainty for each input quantity,  $u(x_i)$ , sensitivity coefficients  $C_i$  and the last one, the partial uncertainties,  $u_i = C_i \cdot u(x_i)$ .

The sheet also gives both the mass and conventional mass with the respective uncertainties.

#### 2.4.11 ACCESSIBILITY TO THE DATABASE

There is a possibility to access the database, to view or print certain information of a previous calibration Fig. 15.

Fig. 15. Accessibility in the database

#### 2.4.12 THE SYSTEM INFORMATION

Can be viewed information such as: application version, title, author, excel version, operating system, Fig. 16.

Fig. 16. System information

### 3. ADVANTAGES OF THE APPLICATION

Some of the advantages of the application “GS 2007” are:

- the well known Excel procedure is easy to use;
- a complete image of the uncertainty's components provided on the sheet. The smaller or greater components that influence the expanded uncertainty are clear distinguished;
- a fast selection of the data concerning the standards, the measurement instruments, manufacturer, etc., by choosing them from the lists COMBO BOX type. Using a single click, all the information for the measurement instrument (for example: calibration certificate, density, volume, etc) are automatically filled;
- visual signals when inadequate input data or some discrepancies of these (for instance between the nominal value of the mass standard and that of the maximum capacity of the balance) are introduced;
- the possibility to stock in the database all the data, including the results of the calibration. These can be visualized and printed at any time;
- visual signals when (by the mistake) a multiple choice of the same weight has done for the respective calibration;
- taking into account that the special weights haven't an exact nominal value, the application gives the possibility to use until ten additional standard weights on one of the weights which are compared;
- the individual application UP upgrades easily and rapidly the main application which is settled on different PC's;
- during the upgrading, it is no risk to depreciate or block the main application by inadequate commands;
- the upgrading data is visualized in the main application and remains unchanged until to the next upgrading.

A general view of the sheet, containing all the areas described before is presented in the Fig. 17.

GS 2007		SEARCH IN DATABASE		SAVE	
Order:	777	This begin data:	2-jun.-2009	History	
Operator:	A. Vălcu	The end data:	Today	Modificati	
<b>Special weight</b>					
Number	25	Manufacturer:	SAUTER	Material:	Stainless steel
		$\rho_s =$	kg/m <sup>3</sup>	$U_{\rho_s} =$	kg/m <sup>3</sup>
		$U_{\rho_s} =$	140	$U_{\rho_s} =$	0
<b>STANDARDS</b>		<b>UPDATED on: 11 august 2005</b>			
C.C. No.:	02.01-102/2006	$m_{CV} =$	g	$U_{m_{CV}} =$	mg
E2 5 kg KERN G045982 D16	5 000,001 000	$U_{m_{CV}} =$	2,500	$U_{m_{CV}} =$	140,0
E2 2 kg KERN G045982 D15	2 000,001 500	$U_{m_{CV}} =$	1,000	$U_{m_{CV}} =$	1,0000
E2 1 kg KERN G045982 D13	1 000,000 000	$U_{m_{CV}} =$	0,500	$U_{m_{CV}} =$	140,0
E2 100 g A Haffner 51	99,999 880	$U_{m_{CV}} =$	0,050	$U_{m_{CV}} =$	0,0500
E2 500 g A Haffner 51	500,000 020	$U_{m_{CV}} =$	0,250	$U_{m_{CV}} =$	140,0
<b>Additional weights (on the special)</b>		<b>UPDATED on: 11 august 2005</b>			
C.C. No.:	02.01-011/2007	$m_{CV} =$	g	$U_{m_{CV}} =$	mg
E1 20 mg Sartorius 90332784	0,020 010 4	$U_{m_{CV}} =$	0,001	$U_{m_{CV}} =$	8600,0
E1 10 mg Sartorius 90332784	0,009 997	$U_{m_{CV}} =$	0,001	$U_{m_{CV}} =$	170,0
<b>Weighing instrument</b>		<b>UPDATED on: 11 august 2005</b>			
Comp. CC100000LL 10kg / 12502113		$d =$	g	$U_d =$	mg
C.C. No.:	02.01-703/2006	$d =$	0,01	$U_d =$	5,00
<b>DIFFERENCES ABBA on the balance</b>		<b>UPDATED on: 11 august 2005</b>			
$\Delta_1 =$	12673,5 div	$\Delta_2 =$	12675,0 div	$\Delta_3 =$	12675,0 div
$\Delta_4 =$	12675,0 div	$\Delta_5 =$	12675,0 div	$\Delta_6 =$	12675,0 div
$\Delta_7 =$	12675,0 div	$\Delta_8 =$	12675,0 div	$\Delta_9 =$	12675,0 div
No of cycles:	5	$\Delta_{10} =$	12674,70 div	$s =$	0,070920303 div
<b>RESULTS</b>		<b>UPDATED on: 11 august 2005</b>			
<b>Mass</b>		<b>Uncertainty of measurements</b>			
Conventional	8 600,698 689	g	$u =$	3,298 mg	$U =$
		DATE /			

Fig. 17. General view of the sheet

Although the application has in its content more files, one of them is always visible for the user all of a sudden. The user can use a file, in terms of necessity.

### 4. CONCLUSIONS

In this paper it was described an Excel application for processing results in calibration of special weights used by Mass laboratory of Romanian National Institute of Metrology.

Only by using some clicks, this PC application enables Excel users to store, process, analyze and print the final results in the calibration of special weights.

This automatic mass and uncertainty calculator use the methods outlined in the [2] and [3].

### REFERENCES

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