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An Accurate Computer Correction Program for Quantitative Electron Probe Microanalysis

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Abstract. The aim of this paper is to present a practical and accurate program of correction based on a new mathematical description of $\phi(\rho z)$, which allows a global correction combining atomic number and absorption correction $[ZA]$. Characteristic and continuum fluorescence corrections are also included to complete the program. Elements of atomic number in the range $4 < Z < 92$ and X-ray emission lines $K\alpha$, $K\beta$, $L\alpha$, $L\beta$, $M\alpha$ and $M\beta$ are taken into account by the program which is especially designed for difficult cases (light elements, low overvoltages, low accelerating voltages).

This correction program written in Fortran is designed to work off line under DOS or WINDOWS graphic operating systems on PC compatible microcomputers. The WINDOWS user interface environment makes the software easy to use. The computation and plot of $\phi(\rho z)$ depth distribution function as well as the printing of physical parameters enable the user to easily optimize the experimental conditions.

This procedure has been tested on various databases (Pouchou and Pichoir, Love et al. and Bastin et al.) for medium to heavy elements. For the light elements (*O*, *C* and *B*) Bastin's database has been used. The results presented furthermore reveal the good accuracy of the method and allow a comparison with other correction procedures.

Key words: EPMA, computer program, correction procedure, X-ray depth distribution.

Electron probe microanalysis (EPMA) requires several corrections to quantify a specimen. These corrections allow to convert the measured intensity of the characteristic X-ray into elemental concentration. The measured intensity I_A^e emitted from element *A* in a homogeneous sample is expressed (in the absence of significant fluorescence effects) by:

$$I_A^e = cst \cdot C_A \int_0^\infty \Phi_e(\rho z) \cdot \exp(-\chi_e \rho z) d\rho z, \quad (1)$$

where C_A is the weight fraction of element *A*, ρz is the mass depth in the sample, $\chi = \mu/\rho \cos \theta$, in which μ/ρ is the mass absorption coefficient (MAC) and θ the

X-ray take-off angle, $\Phi_e(\rho z)$ is the X-ray depth distribution. In order to calculate Eq. (1), knowledge of $\Phi_e(\rho z)$, and μ/ρ are required.

Eq. (1) can be calculated in different ways. The first method is the [ZAF] model [1–7]. In this model the atomic number effect [Z] and the absorption correction factor [A] are separately calculated. The atomic number effect [Z] is the intensity generated in the specimen. This factor is composed of the S-factor (stopping power) and the R-factor (backscattering).

$$Z = R/S \propto \int_0^\infty \Phi_e(\rho z) \cdot d\rho z.$$

The absorption correction factor [A] is expressed by:

$$A = \int_0^\infty \Phi_e(\rho z) \cdot \exp(-\chi_e \rho z) d\rho z / \int_0^\infty \Phi_e(\rho z) \cdot d\rho z.$$

In the [ZAF] model, $\Phi_e(\rho z)$ is usually a simple approximation. This has no influence when absorption is low, but leads to significant errors when corrections are large.

The second method is the direct calculation of Eq. (1) by using an accurate $\Phi_e(\rho z)$ distribution [8–16]. This ‘phi-rho-z’ model combines [Z] and [A] corrections and is usually expressed as a ratio “K ratio” (K_A) given by:

$$K_A = \frac{I_A^e}{I_A^s} = C_A[ZA] = C_A \frac{\int_0^\infty \Phi_e(\rho z) \cdot \exp(-\chi_e \rho z) d\rho z}{\int_0^\infty \Phi_s(\rho z) \cdot \exp(-\chi_s \rho z) d\rho z}, \quad (2)$$

where I_A^s is the intensity measured on a standard, and $\Phi_s(\rho z)$ is the depth distribution in that standard.

The correction program presented here is based on a recently ‘phi-rho-z’ model described by a double partial Gaussian expression (Merlet [14]). This program takes into account not only the [ZA] correction but also the fluorescence correction [F] combining characteristic and continuum effects.

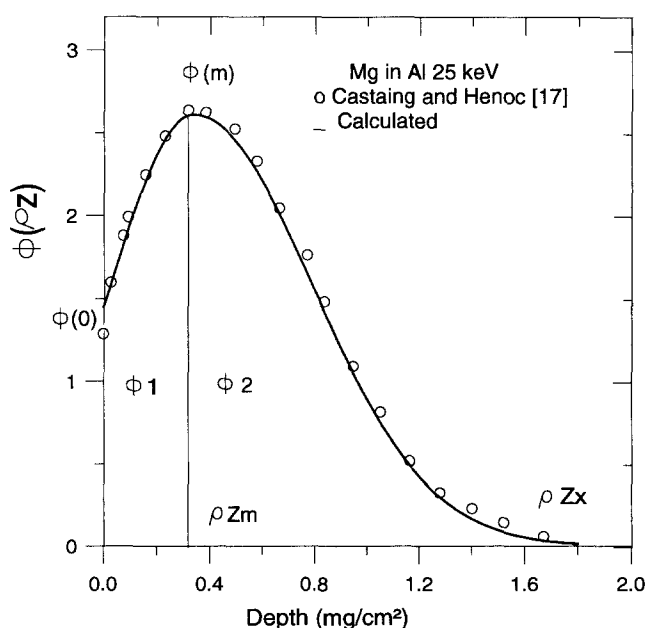


Fig. 1. $\phi(\rho z)$ curve for Mg ($K\alpha$) in an aluminium matrix for 25 keV electron energy. The data points are from Castaing and Henoc [17]. The solid line is the predicted curve using the double Gaussian expression (ϕ_1 and ϕ_2) and the parameters: $\phi(0)$, ρz_m , $\phi(m)$, and ρz_x .

Principles of the Correction Method

The [ZA] Correction

In this model [14, 16], the X-ray distribution is approximated by a double partial Gaussian profile (Φ_1, Φ_2 ; Fig. 1) which requires four parameters at three characteristic penetration depths:

- at the surface, $[0, \Phi(0)]$,
- at the maximum of the $\Phi(\rho z)$ curve, $[\rho z_m, \Phi(m)]$,
- at the X-ray range, $[\rho z_x, \Phi m/100]$.

Thus $\Phi(\rho z)$ may be expressed by:

$$\text{for } \rho z \in [0, \rho z_m], \quad \Phi_1 = \Phi(m) \exp \left\{ - \left(\frac{\rho z - \rho z_m}{\beta} \right)^2 \right\} \\ \text{with } \beta = \rho z_m / [\ln(\Phi(m)/\Phi(0))]^{0.5} \quad (3)$$

$$\text{and for } \rho z \in [\rho z_m, \rho z_x], \quad \Phi_2 = \Phi(m) \exp \left\{ - \left(\frac{\rho z - \rho z_m}{\alpha} \right)^2 \right\} \\ \text{with } \alpha = 0.46598(\rho z_x - \rho z_m)$$

With these expressions, the combined atomic number and absorption correction ([ZA]) [14] becomes:

$$[ZA] = \frac{\Phi(m)_e \left[\beta \exp(c) \left\{ \operatorname{erf} \left(\frac{\rho z_1}{\beta} \right) + \operatorname{erf} \left(\frac{\chi_e \beta}{2} \right) \right\} + \alpha \exp(d) \left\{ 1 - \operatorname{erf} \left(\frac{\chi_e \alpha}{2} \right) \right\} \right]_e}{\Phi(m)_s \left[\beta \exp(c) \left\{ \operatorname{erf} \left(\frac{\rho z_1}{\beta} \right) + \operatorname{erf} \left(\frac{\chi_s \beta}{2} \right) \right\} + \alpha \exp(d) \left\{ 1 - \operatorname{erf} \left(\frac{\chi_s \alpha}{2} \right) \right\} \right]_s} \quad (4)$$

with $c = (\chi\beta/2)^2 - \rho z_m\chi$, $\rho z_1 = \rho z_m - \chi\beta^2/2$, $d = (\chi\alpha/2)^2 - \rho z_m\chi$, and erf is the error function

Since the previous version [16] some modifications have been made to improve the results. For the calculation of Eq. (4) the following parameters are used:

—The position of the maximum ρz_m is given by:

$$\rho z_m = \rho z_{x1} \frac{0.1 + 0.35 \exp(-0.07Z)}{(1. + 10./(U_o^{10}))} \quad \text{g/cm}^2 \quad (5)$$

ρz_{x1} is the X-ray range obtained in the previous version [16], which is given by:

$$\rho z_{x1} = \frac{a(E_o^{(2.2-0.0166E_o)} - E_c^{(2.2-0.0166E_o)})(1 + 2/E_o^2)}{(1.078 - 0.015Z^{0.7})(1.2 - 0.04E_o)}, \quad \text{g/cm}^2 \quad (6)$$

where $a = 1.845 \cdot 10^{-6} (2.6 - 0.216E_o + 0.015E_o^2 - 0.000387E_o^3 + 0.00000501E_o^4)$, E_o is the energy of incident electrons in keV, E_c the energy of level c in keV, Z the atomic number and $U = E_o/E_c$ the overvoltage. ρz_m and ρz_{x1} have been deduced from Monte Carlo simulations.

— $\Phi(m)$ represents the amplitude of $\Phi(\rho z)$ as soon as electrons are uniformly scattered and the corresponding analytical expression is:

$$\Phi(m) = \tau \cdot \frac{Q(U_d)}{Q(U_o)} + a \cdot [0.28(1 - 0.5 \exp(-0.1Z))b_1 + 0.165Z^{0.6}b_2], \quad (7)$$

with

$$b_i = \left(\frac{U_d}{U_o} \right)^{d_i} \frac{\ln(U_d)}{\ln(U_o)} \left(\frac{1}{d_i} \right) \left[1 - \frac{(1 - 1/U_o^{d_i})}{d_i \ln(U_d)} \right], \quad U_d = U_o \left[1 - \frac{1.03 \times 10^5 \rho_{zx} Z}{E_o^{1.61} J^{0.3} A} \right]^{0.61}$$

$$d_1 = 1 - m, \quad d_2 = 7 - 4 \exp(-0.1Z) - m, \quad a = 5(1 - 1/(1 + Z)^{0.8})(E_o/30)^{p(Z)},$$

$$p(Z) = -0.25 + 0.0787Z^{0.3},$$

where A is the atomic weight, J the mean ionization potential in KeV (Ruste [18] expression), and $Q(U) = \ln(U)/U^m$ is the ionisation cross-section. The value $m = 0.95$ is used for K lines, and $m = 0.7$ for L and M lines.

For the transmission coefficient (τ), the expression of Zeller and Ruste [19] is adopted. This coefficient is given by: $\tau = \tau_1 + 4.65(\tau_2 - \tau_1)/(3.54 + 0.0356Z - 0.00414Z^2)$ with $\tau_1 = (1 - t)^{N\sigma_1\rho_{zx}}$, $\tau_2 = (1 - t)^{N\sigma_2\rho_{zx}}$, $N\sigma_1\rho_{zx} = 4.65 + 0.0356Z$, $N\sigma_2\rho_{zx} = 1.112 + 0.00414Z^2$, in which $t = \rho_{zm}/\rho_{zx1}$ is given from Eq. (5). For very low overvoltages, when $\rho_{zm} \Rightarrow 0$, the condition $\Phi(m) = \Phi(0)$ is imposed.

—The parameter $\Phi(0)$ represents the amplitude of $\Phi(\rho z)$ at the surface of the sample. $\Phi(0)$ [20–22] has been obtained from a new expression of the energetic distribution of the backscattered electrons $d\eta/dE$, and may be written as:

$$\Phi(0) = 1 + a \cdot \left[0.27b_1 + \left(1.1 + \frac{5}{Z} \right) (b_2 - 1.1b_3) \right], \quad (8)$$

with

$$b_i = \left(\frac{1}{d_i} \right) \left[1 - \frac{(1 - 1/U_o^{d_i})}{(d_i \ln(U_o))} \right].$$

$$d_1 = 0.02Z, \quad d_2 = 0.1Z, \quad d_3 = 0.4Z,$$

$$a = 1.87Z(-0.00391 \ln(Z + 1) + 0.00721 [\ln(Z + 1)]^2 - 0.001067 [\ln(Z + 1)]^3)(E_o/30)^{p(Z)}$$

and $p(Z) = -0.25 + 0.0787Z^{0.3}.$

—The X-ray range is obtained through a procedure based on a new atomic number correction R/S (Merlet [23]). The value of the integral of $\Phi(\rho z)$ is given by R/S so that:

$$\frac{R}{S} \frac{1}{Q(U_o)} = \int_0^\infty \Phi(\rho z) \cdot d\rho z = \frac{\sqrt{\pi}}{2} \Phi(m) \cdot \left[\beta \cdot \operatorname{erf} \left(\frac{\rho_{zm}}{\beta} \right) + \alpha \right]. \quad (9)$$

The new X-ray range ρ_{zx} is deduced from this equation in which $\alpha = 0.46598(\rho_{zx} - \rho_{zm})$:

$$\rho_{zx} = 2.42147 \cdot \frac{R}{SQ(U_o)} \frac{1}{\Phi(m)} - 2.145966 \cdot \beta \cdot \operatorname{erf} \left(\frac{\rho_{zm}}{\beta} \right) + \rho_{zm}. \quad (10)$$

This new X ray range which gives similar results to the previous analytical X-ray range in the general case (Eq. (6)), makes significant improvement in the low overvoltages domain or in the high atomic numbers region.

A specific feature of this model is the weighting used for multi-component specimens. All the parameters are calculated for a characteristic line of pure elements. The corresponding parameters for compounds are:

$$-\overline{\Phi(m)} = \sum_j C_j \frac{Z_j}{A_j} \Phi(m)_j \bigg/ \sum_j C_j \frac{Z_j}{A},$$

$$-\overline{\rho z_x} = \sum_j C_j \frac{Z_j}{A_j} \rho z_{xj} \bigg/ \sum_j C_j \frac{Z_j}{A},$$

$$-\overline{\rho z_{x1}} = \sum_j C_j \frac{Z_j}{A_j} \rho z_{x1j} \bigg/ \sum_j C_j \frac{Z_j}{A},$$

— $\overline{\Phi(0)}$ is calculated by averaging the atomic number ($\bar{Z} = \sum C_i Z_i$),

— $\overline{\rho z_m}$ is obtained by Eq. (5) and by using \bar{Z} and $\overline{\rho z_{x1}}$.

The [F] Correction

The characteristic fluorescence correction is the new updated Reed [24] model. For the continuum fluorescence the Springer model [25, 26] is used. Its influence is often ignored in correction procedures as it lowers the quality of the classical ZAF corrections in standard conditions [25, 27]. The Springer expression is:

$$\frac{I_f}{I_A} = G \frac{r_A - 1}{r_A} A_A \bar{Z} E_c \frac{\mu_c^A}{\mu_c} f_{abs}, \quad (11)$$

where μ_c^A and μ_c , are the MAC of respectively, pure element A and compound, on the high-energy side of the absorption edge of A ; f_{abs} is an absorption factor and G a constant (which includes many constants related to analytical expressions of stopping power, ionization cross section, and continuum intensity). In this program, the constant is equal to 3.6, 2, and 2 respectively for K , L , and M lines. These values have been optimized on various data bases (see below).

Computer Program

The correction program written in Fortran is designed to work off-line under DOS or WINDOWS graphic operating systems on PC compatible micro computers. The WINDOWS user interface environment makes the software easy to use. The computation and plot of $\phi(\rho z)$ depth distribution function as well as the printing of physical parameters enable the user to easily optimize the experimental conditions.

A flow chart of the program is presented in Fig. 2. The program is modular with a main menu which offers many options. It allows to declare a new experimental description or execute an analysis calculation. All experimental descriptions are written in a file DECLAR.XXX, where the extension (XXX) is a label given by the user for a particular problem of analysis. The file DECLAR.XXX has the same structure that the file used in the CAMEBAX MICRO-BEAM.

The first module of the program is the declaration routine in which accelerating voltage, analyzed elements, emerging angle and standards are defined. For compound standards the program is connected to a compound-library-file "STANDARD.TXT", which is visualized in the "standard window". The new declaration is saved in the DECLAR.XXX file.

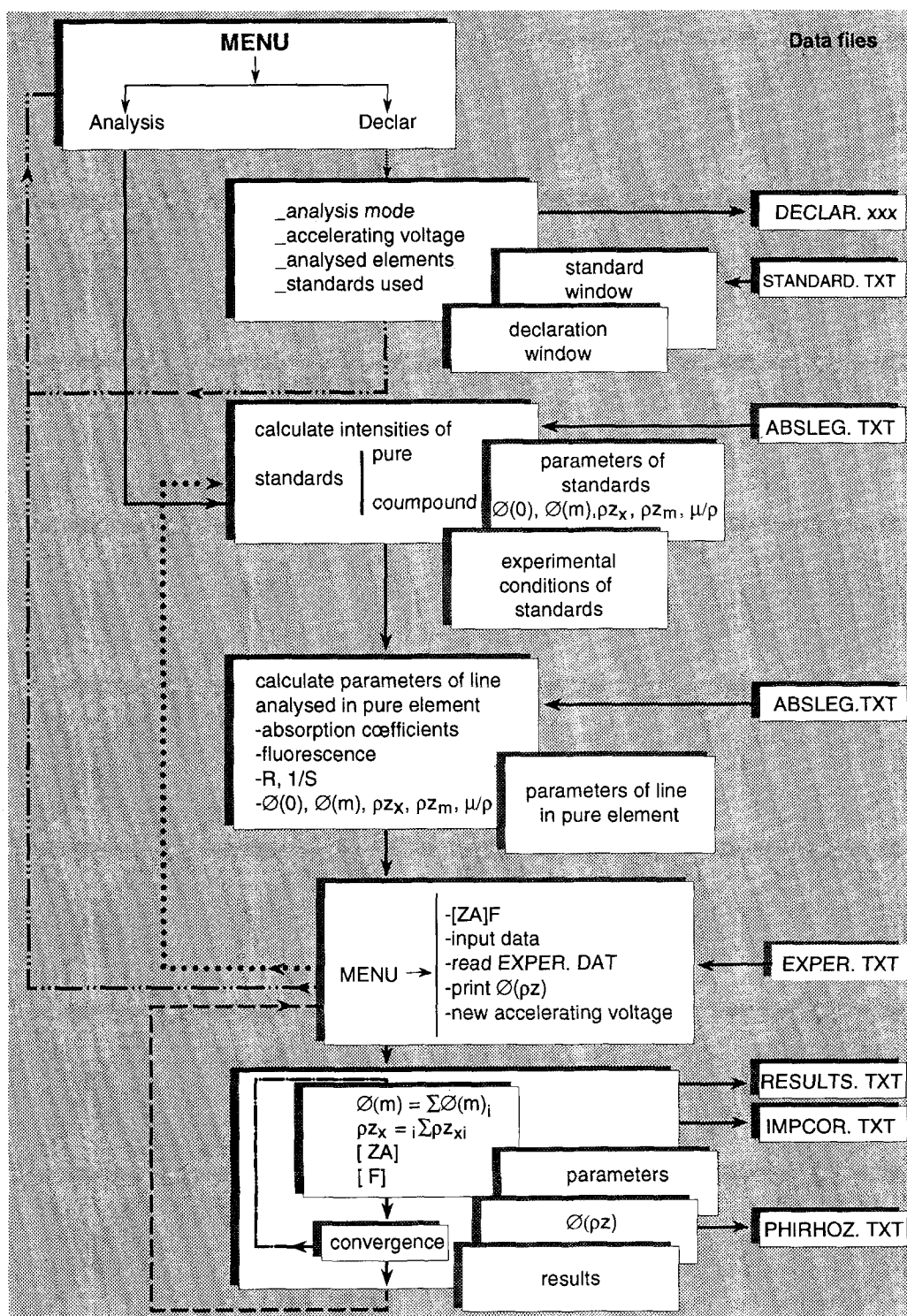


Fig. 2. Flowchart showing the structure of the program

The second module calculates the intensities of standards (pure elements and compounds). Windows display the experimental analytical conditions, and the

parameters ($\Phi(0)$, ρz_m , $\Phi(m)$, ρz_x , μ/ρ , $1/S$, R , $[Z]$, $[A]$, $[ZA]$, characteristic fluorescence and continuum fluorescence) that are used to calculate standard intensities.

The mass absorption coefficients (MAC) for the light elements (< 10) come from the file "ABSLEG.TXT". This file contains Henke MAC's [28], and a quantity of MAC deduced from this model of correction by the use of the light elements database of Bastin et al. (see below) [29, 31]. For elements of atomic number > 9 the MAC are calculated with Heinrich's algorithms [32]. The program allows the modification of these values.

The third module calculates for a given line of an element I , in a matrix J (pure elements), the parameters ($\Phi(0)(I, J)$, $\rho z_m(I, J)$, $\Phi(m)(I, J)$, R , $1/S$, $\rho z_x(I, J)$, $\mu/\rho(I, J)$). The MAC and all the factors for characteristic and continuum fluorescence are computed. As in the previous module, these MAC can be updated by the user, and the light elements MAC's are read in the file "ABSLEG.TXT". An optional window displays these parameters. This preparation module in which all the parameters for a complex problem are calculated, allows to have a fast computation time on the last module. This sequence optimizes the computation procedure when a large set of data coming from measurements of a same description is treated, which is often the case in automated electron microprobe.

An intermediate menu allows to chose many options as:

- input experimental data;
- read a file with experimental data "EXPER.TXT";
- change accelerating voltage;
- print phi-rho-z curves in file "PHIRHOZ.TXT";

etc.

The last module is the correction procedure. The $\phi(\rho z)$ approach is ideal for computer coding. No backscattering and stopping power calculations are required, and $[ZA]$ is calculated by the use of parameters $\Phi(0)(I)$, $\Phi(m)(I)$, $\bar{\rho z_m}(I)$, $\bar{\rho z_x}(I)$, $\bar{\rho z_{x1}}(I)$ for one element (I) in the sample. The $[F]$ factor is calculated from parameters previously calculated in module 3.

Performance of the Model

A large number of measured data are usually taken into account to test a correction program [3–15, 32]. For all these measurements, the calculated K -ratio (K') is compared to the measured K -ratio (K). Good results are expected when $K'/K = 1$. For a given data-base the result is expressed in terms of the average value (\bar{X}) of K'/K and the relative root-mean-square error (RMS) with respect to \bar{X} . These tests have been performed by a second program (a simplified version of the previous one). This program reads a data-base file and gives the K'/K ratio.

In order to assess the performance of this model with the maximum of objectivity while avoiding the creation of a new set of measurements, databases from the literature are used.

- For classical measurements of elements in the range $11 < Z < 93$, databases of Pouchou and Pichoir [12], Sewel et al. [33], and Bastin et al. [10, 30] have been used. These databases allow an easy and objective comparison between this model and those previously published. These sets of measurements show the ability of

the model to account for the atomic number correction. Special attention is paid to measurements at low overvoltages.

- For light elements, data bases of Bastin and Heijligers [29–31] for boron, carbon and oxygen have been tested. These tests show preferentially the ability of the model to account for the absorption correction.

Medium to Heavy Element Analyses ($Z > 10$)

The results obtained on the 826 measurements of Pouchou and Pichoir database [12] are given in Table 1 and illustrated in Fig. 3. This table reports on the results given by Pouchou and Pichoir for their own model and for other models of correction. Our results are computed with Heinrich's MAC, except for *B* and *C* in which our optimized MAC were used. With this set of MAC's the results are quite similar to the results obtained with the PAP or the XPP programs.

The results obtained on the 554 measurements of Sewel et al. data base [34] are illustrated in Fig. 4. The RMS error of K'/K obtained with our $\phi(\rho z)$ matrix correction program is 2.88%, and the average value (\bar{x}) is 0.996. Our results were computed with the Heinrich's MAC [32]. With their own correction procedure applied to the same data, Scott and Love [6] obtained a RMS error of 3.1%, and a $\bar{x} = 0.994$. Their results were computed with the Heinrich's MAC [32] plus Henke et al. [28] for radiation $< 2\text{keV}$. Though our model gives more consistent results than those obtained by the model of Scott and Love, the RMS error is still important. Bastin [10] criticized this set of measurements due to the large proportion of data measured long time ago.

The last data-base used for elements > 10 , is Bastin's [10]. These sets include 680 measurements in the first version, and 877 measurements in the second version [31] (the previous set of 680 measurements plus 197 metal analyses in borides). The results calculated with the first set of data are compared in Table 2 with the values reported in the literature for others correction procedures. In our model Heinrich's and Henke's MAC are used.

Table 1. Relative RMS values and averages for calculated/measured K -ratio obtained with Pouchou and Pichoir [12] data-base and Heinrich's MAC [32]. for various correction programs

Procedure	826 Analyses		577 Analyses mainly submitted to Z effects		242 Analyses $A < 0.75$	
	Average	R.M.S.%	Average	R.M.S.%	Average	R.M.S.%
this model	0.999	1.68	0.998	1.58	1.001	1.89
Pouchou et al. (1988) ^a						
XPP [12]	0.999	1.79	0.998	1.58	1.002	2.17
Pouchou et al. (1986) ^a						
PAP [11]	0.998	1.91	0.997	1.60	0.999	2.50
Love-Scott II (1992) ^a [6]	0.991	2.59	0.994	1.79	0.984	3.79
Bastin et al. (1986) ^a [10]	1.009	2.92	1.014	2.84	0.998	2.83

^a The results were taken from [12].

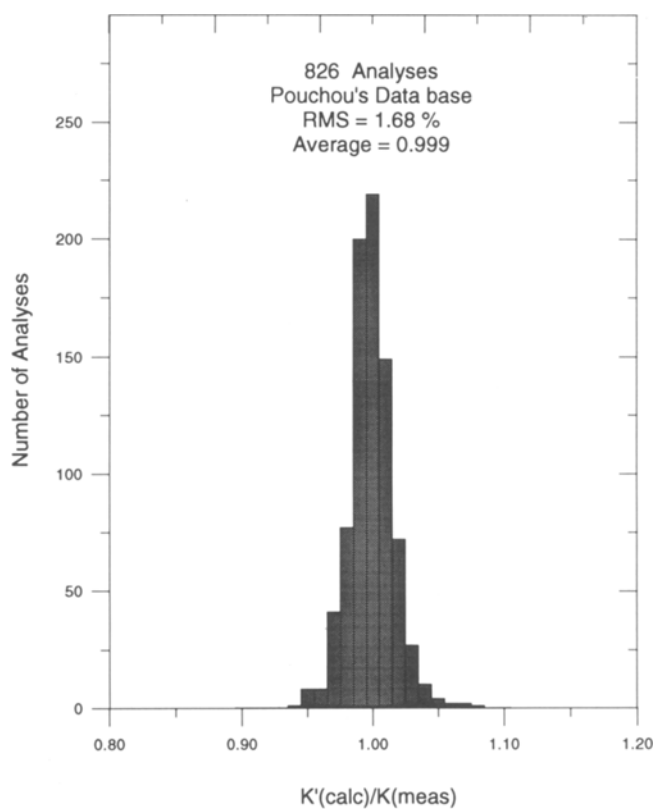


Fig. 3. Error histogram showing the results on the Pouchou's data base [12], for medium to heavy element analyses

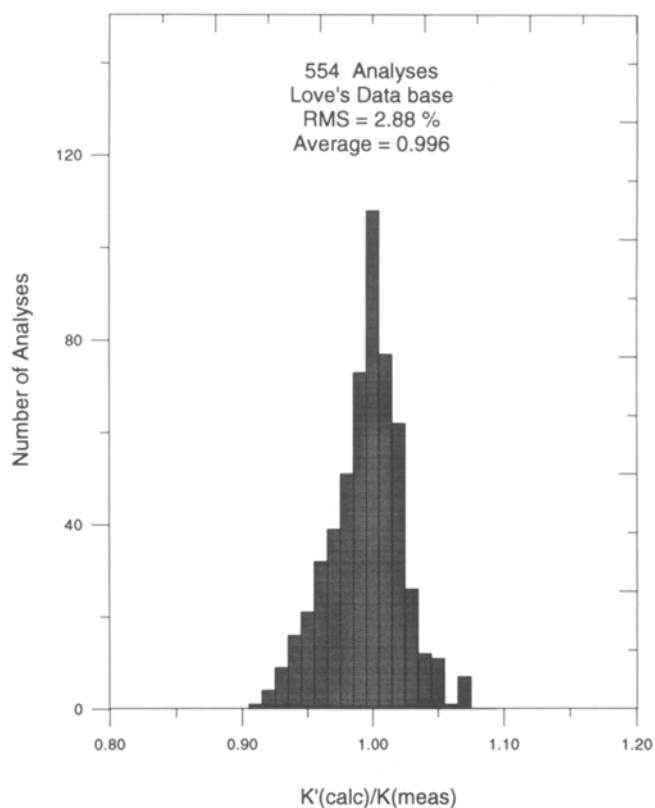
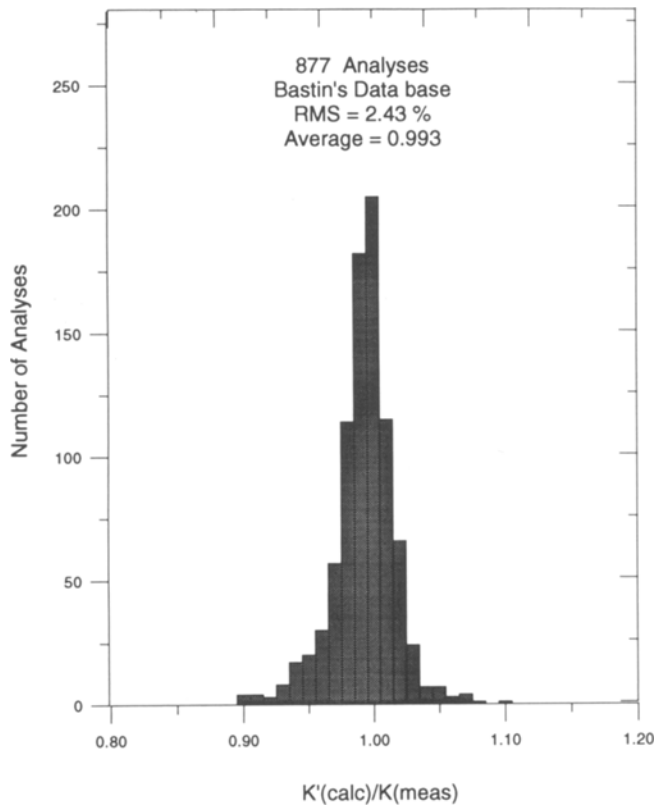


Fig. 4. Same as Fig. 3 but on the Sewell's data base [34]

Table 2. RMS and average values K'/K -ratio obtained with Bastin's 680 measurement set [10]

Procedure	Average	R.M.S.%	MAC
This model	0.991	2.64	Heinrich [32] and Henke [28]
Bastin PROZA ^a (1990) [31]	0.995	2.63	Heinrich [32] and Bastin [30]
Bastin 86 ^b (1986) [10]	1.001	2.99	Bastin [30]
Gaber ^c (1992) [5]	1.002	3.00	Bastin [30]
Love-Scott II (1992) ^c [6]	1.004	4.17	Bastin [30]

^{a, b, c} The results were taken from [5], [10], [15] respectively.

**Fig. 5.** Same as Fig. 3 but on the Bastin's data base [10]

For the second set (877 measurements), the results are shown in Fig. 5. The RMS error of K'/K obtained with our $\phi(\rho z)$ matrix correction program is 2.43%, and the average value (\bar{x}) is 0.993. Our results were computed with Heinrich's [32] and Henke's MAC [30]. A RMS error of 2.44% and a $\bar{x} = 0.994$ was found by the use of the same data base by Bastin et al. [31] with their own correction procedure (which is one of the most performing up to now).

The statistics of the results calculated with various databases consistently shows that this new model gives in all cases good results and that the RMS error is mainly

due to the inaccuracies in the measured K -values. The various figures show that the distribution of the data are symmetrical with a mean value very close to unity.

Light Elements Analyses (B, C, O)

For that purpose, the light elements measurements achieved by Bastin and Heijligers [29–31] have been chosen.

The results obtained with the program on boron are reported in Table 3. The data for Ni-borides were eliminated as suggested by Pouchou and Pichoir [12], so that only 153 measurements were considered. This set of measurements is the most severe test because an ultra-light standard (boron) is used and no compensation in atomic number correction between the sample and the standard is available. Nevertheless on this test the proposed procedure gives good results.

Table 3. Relative RMS values and averages for K'/K K -ratio obtained with various correction programs for boron Bastin's data base [30]

Procedure	Borides 153 analyses	
	Average	R.M.S. %
This model	0.998	2.87
Pouchou et al. (1986) ^a [11]	1.007	3.95
Pouchou et al. (1988) ^a [12]	1.011	4.76
Bastin et al. (1986) ^a [30]	1.008	5.17
Scott et al. (1992) ^b [6]	1.017	5.3
Ruste et al. (1977) ^a [2]	1.039	9.59

^{a, b} The results were taken respectively from [6] and [12].

Table 4. Relative RMS values and averages for K'/K K -ratio obtained with various correction programs for carbon measured by Bastin and Heijligers [29]

Procedure	Carbides 117 analyses	
	Average	R.M.S. %
this model	1.005	3.60
Bastin et al. (1986) ^a [30]	0.998	3.96
Scott et al. (1992) ^b [6]	0.997	3.8
Rehbach et al. (1988) ^c [13]	0.964	5.76
Ruste et al. (1977) ^a [2]	0.946	11.94
ZAF ^a	0.989	17.86

^{a, b, c} The results were taken from [6], [13], [30] respectively.

The results with carbon are reported in Table 4. Our program gives results not so good as the boron data base, may be due to the fact that this set of measurements is the oldest of the three light elements database (1984). In this test the Fe_2O_3 standard is used.

The use of the most recent oxygen data base (1990), shows that our procedure performs remarkably well up to accelerating voltages as high as 40 keV, and with high MAC's (Table 5, Fig. 6). The best results are obtained with this set of measurements, in which, the discrepancy between the predicted and the experimental K -ratio

Table 5. Relative RMS values and averages for calculated/measured K -ratio obtained with various correction programs for oxygen, measured by Bastin and Heijligers [31])

Procedure	Oxides 344 analyses	
	Average	R.M.S. %
This model	1.000	1.52
Bastin et al. (1990) ^a [31]	0.999	2.48
Scott et al. (1992) ^b [6]	0.994	3.4

^{a, b} The results were taken from [6], [31] respectively.

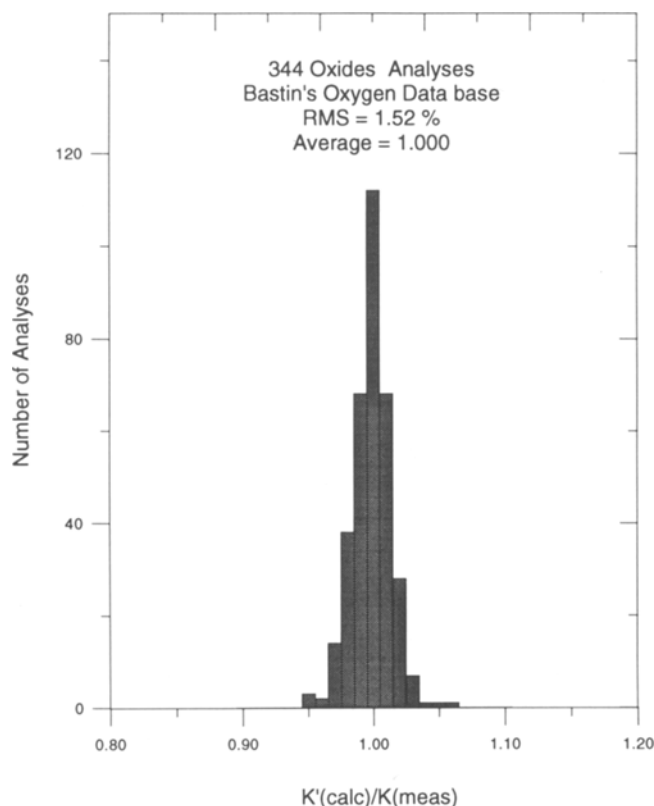


Fig. 6. Error histogram representing the results on the oxygen Bastin's measurements set [31]

never exceeds 5% (relative). It is worth noting that equivalent RMS values are obtained at low and very high MAC, which is a proof of the accuracy of the $\Phi(\rho z)$ distribution.

The MAC values selected for the light elements are close to those used by Bastin and Heijligers [29, 31]. These MAC are deduced from intensity measurements versus accelerating voltage by least square fitting [35, 36].

Conclusion

The results obtained by this model of correction shows that it is currently one of the most successful. One of the advantage of this program is the WINDOWS user interface environment which makes the software easy to use particularly for difficult cases (light elements, low overvoltages, low accelerating voltages).

These program (main and test program) are available shareware free of distribution. To receive the package, send one floppy disk to the author.

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