

## IMPLEMENTATION OF INTERNATIONAL REQUIREMENTS WHEN PRESENTING RESEARCH RESULTS

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**Abstract:** This paper describes basic requirements and typical nonconformities with international requirements in order to in particular avoid ambiguity when expressing measurement and test results. The new International standards ISO 80000 series revises/supplements the previous versions of international standards ISO 31 series, ISO1000 and IEC 60027. According to these international requirements, there are still a lot of different approaches in presenting the research results. Not only that we noticed this problem in undergraduate, graduate and postgraduate education processes, but also in presenting research results in international journals. This paper presents only basic requirements in presenting the results in graphical and tabled way and some typical examples of non-conform presentation of research results.

**Keywords:** ISO 80000, equation writing, units writing, graph presentation, table presentation.

### 1. INTRODUCTION

To easily understand each other, people should present their founding in a way that is consensually agreed internationally. There is still room for freedom of expression in a free form of presented results, but basic results presentation rules shall be considered. The proper understanding of these rules should start in medium and higher education processes, since later is even heavier to change the way of expression your own research results. It is interesting that nowadays some important international journals requires that researchers prepare their papers for publications in a way which is not according to the international requirements for presenting results. This paper is beyond dealing with requirements from [1],[2] and does not explain background of SI unit system, but deals only with basic requirements from the international standard ISO 8000 series[3].

Lately was made the last correction of the basic ISO 80000 series standard (ISO 80000-1:2009/Cor 1:2011). This new series revises ISO 31, ISO 1000 and IEC 60027 series standards. All chapters were updated and reorganized. On well developed branches there were almost no changes, only a few completions. Table 1 presents relations between old versions and new versions of standards. Every international standard can be used without adoption in each member

country of the international standards organization and is legal also in other countries.

**Table 1:** Relation between old and new versions of standards, [4].

Standard	Title	Dealed before in
ISO 80000-1	General	ISO 31-0, IEC 60027-1 and IEC 60027-3
ISO 80000-2	Mathematical signs to be used in the natural sciences and technology	ISO 31-11, IEC 60027-1
ISO 80000-3	Space and time	ISO 31-1 and ISO 31-2
ISO 80000-4	Mechanics	ISO 31-3
ISO 80000-5	Thermodynamics	ISO 31-4
IEC 80000-6	Electromagnetism	ISO 31-5, IEC 60027-1
ISO 80000-7	Light	ISO 31-6
ISO 80000-8	Acoustics	ISO 31-7
ISO 80000-9	Physical chemistry and molecular physics	ISO 31-8
ISO 80000-10	Atomic and nuclear physics	ISO 31-9 and ISO 31-10
ISO 80000-11	Characteristic numbers	ISO 31-12
ISO 80000-12	Solid state physics	ISO 31-13
IEC 80000-13	Information science and technology	clause 3.8 and 3.9 from IEC 60027-2 and IEC 60027-3
IEC 80000-14	Telebiometrics related to human physiology	IEC 60027-7

European Council directive 80/181/EEC with amendments shall also be considered when taking into account European market place. The aim of this paper is that researchers who are familiar with ISO 31 series standards find out, that there are new series standards ISO 80000 available and other readers can find basic hints on what is important when presenting the research results to be understand internationally.

The following text presents only basic requirements for presentation of the research results.

## 2. EXPRESSING UNITS, QUANTITIES AND EQUATIONS

Beside [1, 2, 3], there are many useful guides [5, 6] explaining the international requirements for units and quantities and how to present results. In the following paragraphs there are some basic rules.

The value of a quantity is its magnitude expressed as the product of a number and a unit, and the number multiplying the unit is the numerical value of the quantity expressed in that unit. More formally, the value of quantity  $A$  can be written as

$$A = \{A\}[A], \quad (1)$$

where  $\{A\}$  is the numerical value of  $A$  when the value of  $A$  is expressed in the unit  $[A]$ . The numerical value can therefore be written as

$$\{A\} = A / [A], \quad (2)$$

which is particularly recommended for use in graphs and headings of columns in tables. The quantity symbols are always written in italic (sloping) type, irrespective of the type used in the rest of the text. A subscript that represents a physical quantity or a mathematical variable, such as a running number, is printed in italic (sloping) type. Other subscripts, such as those representing words or fixed numbers, are printed in roman (upright) type.

### Space between numerical value and unit symbol

In the expression for the value of a quantity, the unit symbol is placed after the numerical value and a space is left between the numerical value and the unit symbol. The only exceptions to this rule are for the unit symbols for degree, minute, and second for plane angle: °, ', and ", respectively, in which case no space is left between the numerical value and the unit symbol.

Example:  $t = 30.2\text{ }^\circ\text{C}$  but not:  $t = 30.2^\circ\text{C}$  or  $t = 30.2^\circ\text{ C}$

When it is used, a space is left between the symbol % and the number by which it is multiplied. Symbol % should be used, not the name "percent."

Example:

$x_B = 0.0025 = 0.25\%$ , but not:

$x_B = 0.0025 = 0.25\%$  or  $x_B = 0.25$  percent

**Unit symbols obtained by multiplication** are indicated by means of either a half high (that is, centred) dot or a space.

Example:  $\text{N} \cdot \text{m}$  or  $\text{N m}$

A half-high dot or space is usually imperative. For example,  $\text{m} \cdot \text{s}^{-1}$  is the symbol for the meter per second while  $\text{ms}^{-1}$  is the symbol for the reciprocal millisecond. If a space is used to indicate units formed by multiplication, the space may be omitted if it does not cause confusion. This

possibility is reflected in the common practice of using the symbol kWh rather than  $\text{kW} \cdot \text{h}$  or  $\text{kW h}$  for the kilowatt hour.

**Symbols for units formed from other units by division** are indicated by means of a solidus (oblique stroke, /), a horizontal line, or negative exponents.

Examples:

$\text{m/s}^2$  or  $\text{m} \cdot \text{s}^{-2}$  but not:  $\text{m/s/s}$

$\text{m} \cdot \text{kg}/(\text{s}^3 \cdot \text{A})$  or  $\text{m} \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$  but not:  $\text{m} \cdot \text{kg/s}^3/\text{A}$

**The multiplication of quantity symbols** (or numbers in parentheses or values of quantities in parentheses) may be indicated in one of the following ways:  $ab$ ,  $a \cdot b$ ,  $a \times b$ .

### Clarity in writing values of quantities

The value of a quantity is expressed as the product of a number and a unit. Thus, to avoid possible confusion, values of quantities must be written so that it is completely clear to which unit symbols the numerical values of the quantities belong. Also to avoid possible confusion, the word "to" be used to indicate a range of values for a quantity instead of a range dash because the dash could be misinterpreted as a minus sign.

Examples:

$51\text{ mm} \times 51\text{ mm} \times 25\text{ mm}$

but not:  $51 \times 51 \times 25\text{ mm}$

$0\text{ }^\circ\text{C}$  to  $100\text{ }^\circ\text{C}$  or  $(0\text{ to }100)\text{ }^\circ\text{C}$

but not:  $0\text{ }^\circ\text{C} - 100\text{ }^\circ\text{C}$

$0\text{ V}$  to  $5\text{ V}$  or  $(0\text{ to }5)\text{ V}$

but not:  $0 - 5\text{ V}$

$63.2\text{ m} \pm 0.1\text{ m}$  or  $(63.2 \pm 0.1)\text{ m}$

but not:  $63.2 \pm 0.1\text{ m}$  or  $63.2\text{ m} \pm 0.1$

### ppm, ppb, and ppt

According to [3, 6], the language-dependent terms part per million, part per billion, and part per trillion, and their respective abbreviations "ppm," "ppb," and "ppt" (and similar terms and abbreviations), are not acceptable for use with the SI to express the values of quantities. Forms such as those given in the following examples should be used instead.

Examples:

a stability of  $0.5\text{ }(\mu\text{A/A})/\text{min}$

but not:  $0.5\text{ ppm/min}$

a shift of  $1.1\text{ nm/m}$

but not:  $1.1\text{ ppb}$

a sensitivity of  $2\text{ ng/kg}$

but not:  $2\text{ ppt}$

**Celsius temperature** ( $t$ ) is defined in terms of thermodynamic temperature ( $T$ ) by the equation

$$t = T - T_0, \quad (3)$$

where  $T_0 = 273.15\text{ K}$  by definition. This implies that the numerical value of a given temperature interval or temperature difference whose value is expressed in the unit degree Celsius ( $^\circ\text{C}$ ) is equal to the numerical value of the same interval or difference when its value is expressed in the unit Kelvin (K).

### 3. TABLES AND GRAPHS

#### Graphical presentation of results

When the measurement data are inserted in a graph they shall be clearly marked to easily identify measured value of a presented curve. The curve shall be smooth unless there is a reason for broken connection between measured values, e.g. when presenting measurement error.

Axis shall be equipped with a scale, a symbol and a unit of a presented variable. The scale is typically divided to equal distances, unless other division is more effective in presentation of results, and with as less as adequate numbers. To eliminate the possibility of misunderstanding, an axis of a graph or the heading of a column of a table can be labelled "t/°C" instead of "t (°C)" or "Temperature (°C)." Similarly, an axis or column heading can be labelled "E/(V/m)" instead of "E (V/m)" or "Electric field strength (V/m)." or even symbol separated from unit by coma, e.g. temperature in Kelvin "T, K".

Many international journals, accredited calibration laboratories, international standards still avoid international requirements for quantities and units.

Examples of non-conform presentation of data in table or graph, according to [3], taken from various international journals:

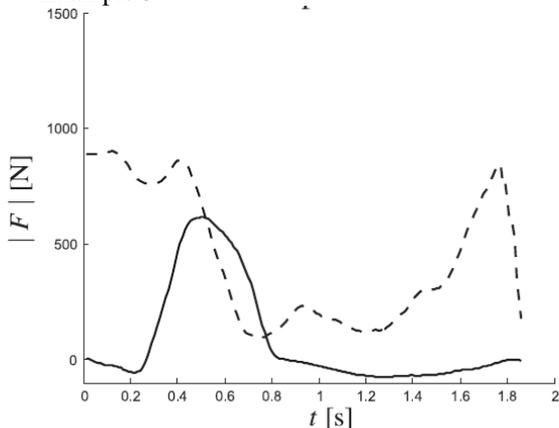
Example 1

Load on sec.	Before improvement [μT]	1. improvement [μT]	2. improvement [μT]
100 A	7,5	2,0	0,65
200 A	15	4,0	1,5
909 A	70	10	8

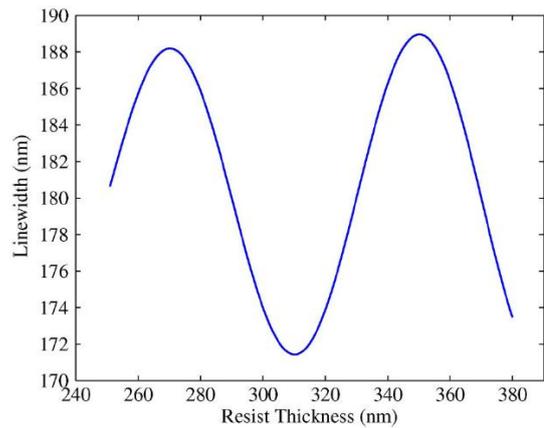
Example 2

Subject	Age (years)	Height (cm)	Weight (kg)
<i>Experts</i>			
E1	38	190	88
E2	31	196	88
E3	22	197	100
E4	32	189	84
E5	29	186	85
<i>Non-experts</i>			
N1	25	186	82
N2	29	171	80
N3	25	183	85
N4	32	186	100
N5	29	188	76

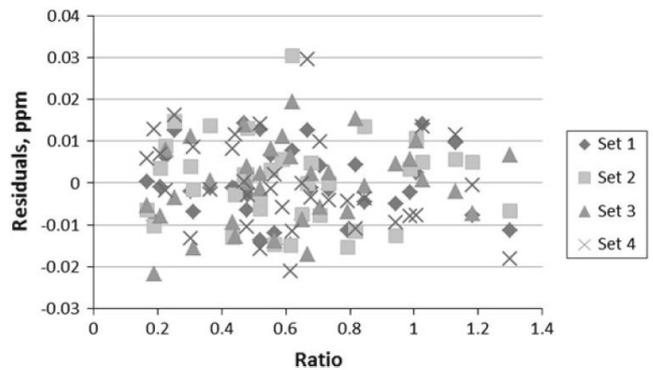
Example 3



Example 4



Example 5

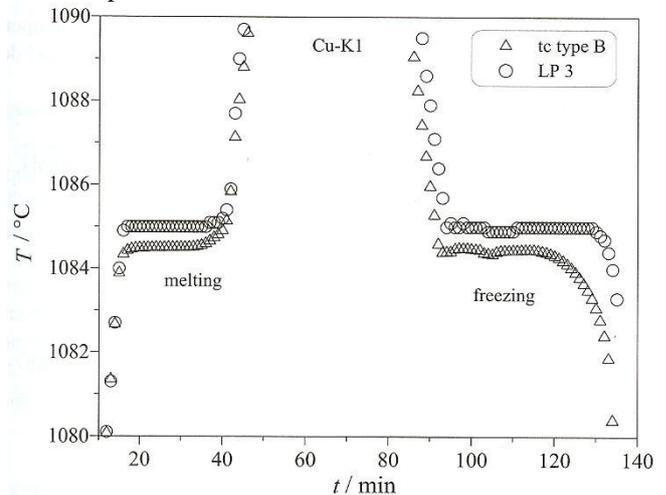


Examples of conform presentation of data in table or graph, according to [3]:

Example 1

Date of direct comparison	$\Delta T$ / mK
August 1996	-0.01
September 1996	-0.02
July 1998	-0.03
June 2002	-0.02
All 4 direct comparison sets	-0.02

Example 2



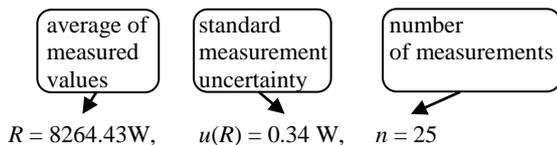
#### 4. MEASUREMENT RESULT PRESENTATION

To understand the presented result uniquely, it is important to be presented in a proper way. Rounding of the results is important as well. Detail information is in [2]. Result can be presented with standard measurement uncertainty or with expanded measurement uncertainty.

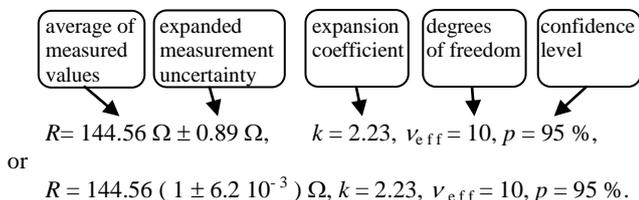
The numerical values of the estimate  $y$  and its standard uncertainty  $u_c(y)$  or expanded uncertainty  $U$  should not be given with an excessive number of digits. It usually suffices to quote  $u_c(y)$  and  $U$  [as well as the standard uncertainties  $u(x_i)$  of the input estimates  $x_i$ ] to at most two significant digits, although in some cases it may be necessary to retain additional digits to avoid round-off errors in subsequent calculations. Sometimes measurement uncertainty shall be quoted to one significant digit if rounding to two significant digits would not be in line with the resolution of the instrument. For example, if instrument measures 17.24 mA and calculated measurement uncertainty is 0.0781 mA, then the measurement uncertainty expressed in the result should be 0.08 mA. In reporting final results, it may sometimes be appropriate to round uncertainties up rather than to the nearest digit. For example,  $u_c(y) = 10,47 \text{ m}\Omega$  might be rounded up to 11 m $\Omega$ . However, common sense should prevail and a value such as  $u(x_i) = 28,05 \text{ kHz}$  should be rounded down to 28 kHz. Output and input estimates should be rounded to be consistent with their uncertainties; for example, if  $y = 10,057 \text{ 62 } \Omega$  with  $u_c(y) = 27 \text{ m}\Omega$ ,  $y$  should be rounded to 10,058  $\Omega$ .

Measurement result can be expressed with the standard measurement uncertainty or with the expanded measurement uncertainty. Examples below show both.

Measurement result with standard measurement uncertainty:



Measurement result with expanded measurement uncertainty:



#### 4. CONCLUSIONS

This paper discusses changes in the international requirements dealing with quantities and units. Basic requirements for measurement results are presented with examples. An overview of many international journals shows, that results presented in the papers are in spite of standardized international requirements still very different.

If international standards are in place, it is important to take them into consideration as much as possible also when presenting measurement/test results.

#### 5. REFERENCES

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