INTERNATIONAL STANDARD 497

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Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

Prior to 1972, the results of the work of the Technical Committees were published as ISO Recommendations; these documents are now in the process of being transformed into International Standards. As part of this process, International Standard ISO 497 replaces ISO Recommendation R 497-1966 drawn up by Technical Committee ISO/TC 19, *Preferred numbers.*

The Member Bodies of the following countries approved the Recommendation :

Australia
Austria
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Denmark
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Finland
France
Germany
Greece
Hungary
India
Israel
Italy
Japan
Morocco
Poland
Sweden
Switzerland
United Kingdom
U.S.A.
U.S.S.R.
Yugoslavia

No Member Body expressed disapproval of the Recommendation.

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Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers

1 SCOPE AND FIELD OF APPLICATION

This International Standard completes ISO 17 by supplementary directives regarding the choice of series and the possible use of more rounded values as mentioned in section 7 of that International Standard :

a) it gives the only more rounded values admissible, in the form of two series rounded to a greater or lesser degree;

b) it states the conditions on which these more rounded values may be used and the consequences of using them;

c) it gives rules by means of which any uncertainty in the choice between the preferred numbers and the various more rounded values can be avoided.

2 REFERENCES

ISO 3, *Preferred numbers – Series of preferred numbers.*

ISO 17, *Guide to the use of preferred numbers and of series of preferred numbers.*

3 ADVANTAGES OF ADHERING STRICTLY TO PREFERRED NUMBERS

The advantages of using preferred numbers, set out in ISO 3 and ISO 17, are recalled and amplified below.

These advantages are obtained not merely in the standardization of various machine elements by themselves, but above all in the construction of complete machines when the functional characteristics, as well as the sizes of each of the various elements, are in a geometrical progression.

3.1 Best progression

Preferred numbers ensure the best progression from the point of view of regularity and the possibility of adapting them to new requirements for the creation of closer series by the insertion of intermediate values.

3.2 Universal applicability

Preferred numbers offer the most logical means of uninterrupted coverage of the complete range of requirements in a given field (powers of motors, output of pumps, etc.).

3.3 Simplification of technical and commercial calculations

Since the products and quotients of preferred numbers are by definition also preferred numbers, calculations, which should be made by using the logarithmic values or serial numbers and not the preferred numbers themselves, are considerably simplified, especially when the series of values (dimensions, list prices, etc.) are multiplied or divided in the same proportions.

3.4 Conversion into other systems of measurement

Conversion into other systems of measurement is greatly facilitated when the series of values in which the measurements are expressed comprise preferred numbers and, at the same time, the conversion factors approximate to preferred numbers.

4 EXCEPTIONAL USE OF MORE ROUNDED VALUES

4.1 In certain applications, imperative reasons prohibit the use of the preferred numbers themselves :

a) because it is impossible or absurd to retain all the significant figures, in particular when a whole number is necessary (for example 32 instead of 31,5 for the number of teeth in a gear);

b) because, in the absence of any indication of tolerances, the number of significant figures gives the impression of a precision which is neither desired nor measurable (for example 1/30 instead of 1/31,5 second for time exposures for cameras or 224 for an output which in practice is verified at about 10 %).

4.2 Further, during the transition period, it is possible that preferred numbers may not be accepted by certain branches of industry or by the general public, for reasons :

a) of an economic nature (for example the wish to continue using existing tools and gauges in the factories);

b) of a psychological nature (for example the wish to use values expressed in a more simple manner, especially when, in a given case, it may be difficult to write or say the number of figures contained in the preferred numbers themselves).[1]

4.3 The use of more rounded values may therefore be justified by imperative reasons (see 4.1), and these values should thus be used rather than dispensing altogether with the use of preferred numbers.

On the other hand, the use of more rounded values should not be permitted for economic or psychological reasons (see 4.2); since these are subjective reasons and may not be the same everywhere, they could give rise to differing company or national standards, making wider national or international unification difficult.[2]

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[1] Also, in certain cases where it is useful to have terms with additive properties, the use, which should remain exceptional, of more rounded values, such as those of the R″ series, provides a solution to the problem, to a limited extent at least, for example

$$3 + 4 = 7 \qquad 3 + 5 = 8 \qquad 3 + 6 = 9 \qquad 3 + 7 = 10$$

$$3{,}5 + 4{,}5 = 8 \qquad 7 + 7 = 14 \qquad \text{etc.}$$

[2] The use of exceptional values which are neither preferred numbers nor more rounded values – whether for the sake of alignment with existing standards which were not formulated in accordance with preferred numbers and have not yet been revised, or to maintain particular production processes for the sake of interchangeability, or to use existing tools and gauges – renders future standardization difficult both in the national and international fields and prevents the building of machines in series with geometrical scaling.

As most ISO publications are based on preferred numbers, previously established national standards also using them will automatically correspond, but it will be more difficult to align those which include the more rounded values or values which are not related to preferred numbers.

The introduction into standards of existing series of values which cannot be modified, such as physical constants, should not be regarded as an application of preferred numbers, even if these values are near to preferred numbers or more rounded values; these series may not possess all the properties of preferred numbers, and their use may create difficulties, particularly in calculations such as those envisaged in 3.4. The same applies to existing series of values which it is difficult to modify at present, such as gear modules.

Column	1		2			3			4		5	6	7	8	9	10
Number of terms or index	5		10			20			40		Serial number	Calculated values ***	Percentage differences between the calculated values and each value in the series			
Approximate ratio	1,6		1,25			1,12			1,06							
Series	**R5**	R″5	**R10**	R′10	R″10	**R20**	R′20	R″20	**R40**	R′40			R 5 to 40	R′ 10 to 40	R″ 20	R″ 5 and 10
	1		1			1,0			1,0		0	1,0000	0			
									1.06	1,05	1	1,0593	+ 0,07	– 0,88		
						1.12	1,1		1,12	1,1	2	1,1220	– 0,18	– 1,96	– 1,96	
									1,18	1,2 **	3	1,1885	– 0,71	+ 0,97		
			1,25		(1,2)	1,25		(1,2)	1,25		4	1,2589	– 0,71		– 4,68	– 4,68
									1,32	1,3	5	1,3335	– 1,01	– $\boxed{2,51}$		
						1,4			1,4		6	1,4125	– 0,88			
									1,5		7	1,4962	+ 0,25			
	1,6	(1,5)*	1,6		(1,5)*	1.6			1,6		8	1,5849	+ 0,95			– $\boxed{5,36}$
									1,7		9	1,6788	+ $\boxed{1,26}$			
						1,8			1,8		10	1,7783	+ 1,22			
									1,9		11	1,8836	+ 0,87			
			2			2,0			2,0		12	1,9953	+ 0,24			
									2,12	2,1	13	2,1135	+ 0,31	– 0,64		
						2,24	2,2		2,24	2,2	14	2,2387	+ 0,06	– 1,73	– 1,73	
									2,36	2,4	15	2,3714	– 0,48	+ 1,21		
	2,5		2,5			2,5			2,5		16	2,5119	– 0,47			
									2,65	2,6	17	2,6607	– 0,40	– 2,28		
						2,8			2,8		18	2.8184	– 0,65			
									3,0		19	2,9854	+ 0,49			
			3,15	3,2	(3)	3,15	3,2	(3,0)	3,15	3,2	20	3,1623	– 0,39	+ 1,19	– $\boxed{5,13}$	– 5,13
									3,35	3,4	21	3,3497	+ 0,01	+ 1,50		
						3,55	3,6	(3,5)	3,55	3,6	22	3,5481	+ 0,05	+ 1,46	– 1,38	
									3,75	3,8	23	3,7584	– 0,22	+ 1,11		
	4		4			4,0			4,0		24	3,9811	+ 0,47			
									4,25	4,2	25	4,2170	+ 0,78	– 0,40		
						4,5			4,5		26	4,4668	+ 0,74			
									4,75	4,8	27	4,7315	+ 0,39	+ 1,45		
			5			5,0			5,0		28	5,0119	– 0,24			
									5,3		29	5,3088	– 0,17			
						5,6		(5,5)	5,6		30	5,6234	– 0,42		– 2,19	
									6,0		31	5,9566	+ 0,73			
	6,3	(6)	6,3		(6)	6,3		(6,0)	6,3		32	6,3096	– 0,15		– 4,90	– 4,90
									6,7		33	6,6834	+ 0,25			
						7,1		(7,0)	7,1		34	7,0795	+ 0,29		– 1,11	
									7,5		35	7,4989	+ 0,01			
			8			8,0			8,0		36	7,9433	+ 0,71			
									8,5		37	8,4140	+ 1,02			
						9,0			9,0		38	8,9125	+ 0,98			
									9,5		39	9,4405	+ 0,63			
	10		10			10,0			10,0		40	10,0000	0			
Maximum irregularity of ratio, % (see § A.1.2)	+ 1,42	– 5,37	+ 1,66	+ 1,66	– 5,61	– 1,83	– 1,97	– 4,48	+ 1,15	+ 2,94						

Preferred numbers ┃ More rounded values: 1st rounding │ 2nd rounding ¦

5 RULE AND GENERAL TABLE

RULE

recalling and completing section 4
of ISO 17

5.1 In selecting a **group of numerical values** to meet the particular requirements of the application in question.

1) choose the **appropriate ratio** in the order of the indices

5 – 10 – 20 – 40

2) choose the series having the appropriate **precision of values** (see Annex, clause A.1.1) and **regularity of ratio** (see Annex, clause A.1.2), i.e :

a) for preference, the R series of **preferred numbers** themselves;***

b) the R′ series, known as the **first rounding,** if imperative reasons completely prohibit the use of preferred numbers;

c) or the R″ series, known as the **second rounding,** in the last resort.*

5.2 In selecting a **single value,** for example for the establishment of a prototype, bear in mind that this value may subsequently have to be inserted in a series, the ratio of which will have to be assumed, and therefore proceed as in 5.1, choosing a preferred number or, failing this, a more rounded value.

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* These R″ series (values in brackets) and most particularly the value 1,5 should be avoided on account of the dangers explained in section 6.

** In exceptional cases, when a series without regression is necessary in this region for an application requiring a simple scaling of values unrelated to other data, and the preferred numbers themselves are not applicable, adopt the alternative of 1,15 for 1,18 and 1,20 for 1,25 which gives, for the start of the series

1 – 1,05 – 1,10 – 1,15 – 1,20 – 1,30

*** In certain exceptional cases (for example for the manufacture of turbine blades) when very great precision is necessary, use the calculated values (column 6 of the table).

6 DANGERS OF USING MORE ROUNDED VALUES

6.1 The presence in a series of a single more rounded value or of an exceptional value admitted by departing from the rule, and which will not be a preferred number, may make it impossible to transfer subsequently to a series with a smaller ratio.

6.2 The scaling of series of more rounded values is not as good as that of preferred numbers series since, for some intervals, the irregularity may reach 2,94 % in the R′ series and even 5,61 % in the R″ series (see values at the foot of columns in the table[1]).

6.3 The scaling of derived series may be even poorer than that of the corresponding R′ or R″ series, if two adjacent values have been rounded towards each other, for example one downwards and the other upwards; thus, for example for the R′ 40/4 series (. . . 1,05 . . .) the irregularity between 1,32 and 1,7 reaches 1,26 % + 2,51 % = 3,77 % while the maximum irregularity of the original R′ 40 series is only 2,94 %; the fundamental principle of the regularity of preferred numbers series is thus destroyed.

6.4 The degree of precision of more rounded values is not as great as that of preferred numbers. In fact, this lack of precision may reach 2,51 % for the values in the R′ series and 5,36 % for those of the R″ series.

Further, because of this fact, more rounded values cannot be used for technical projects when calculating (see section 5 of ISO 17) with the aid of the serial numbers given in column 5 of the table.[1]

6.5 National and international collaboration in standardization work is rendered much more difficult if, instead of using preferred numbers, different people choose different series of rounded values for the solution of the same problem.[2]

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[1] For example a difference of 5 % on the linear dimension entails a difference

of more than 10 % on the square (cross section and, consequently, strength of a bolt; cross section of a piston and, consequently, power of a motor),

of more than 15 % on the cube (mass of part, bending of a shaft),

of more than 20 % on the 4th power (rigidity of a spring),

of more than 25 % on the 5th power (moment of inertia).

[2] See footnote 2) on page 2.

ANNEX

PRECISION OF THE VALUES AND REGULARITY OF THE RATIO

A.1 DEFINITION

In order to understand the disadvantages and dangers of using the more rounded values and to adopt them only with full knowledge of the facts, it is important first of all to consider what may be called the **degree of precision** in relation to the corresponding theoretical value

- of the calculated values,
- of the preferred numbers,
- of the more rounded values,

and the **degree of regularity** of the ratio of the corresponding series.

A.1.1 The **degree of precision of a term,**[1] in relation to the corresponding theoretical value, is characterized by the relationship, expressed as a percentage,

- of the difference between the value in question and the theoretical value,
- to this theoretical value.

These relative differences are given for the preferred numbers in column 8 of the table in ISO 3 and are repeated in this International Standard in column 7 of the table. This table also gives the corresponding differences for the more rounded values in columns 8 to 10.

A.1.2 The **degree of regularity of the ratio of a series, at a given point,** is characterized by the deviation, expressed as a percentage, between the actual ratio at this point (relation between two adjacent terms) and the theoretical ratio.[2]

These deviations, and therefore the degree of regularity of the ratio between two adjacent terms, can thus be obtained by simple algebraic subtraction of the differences given in columns 7 to 10 of the table, ignoring infinitesimal values.[3]

The maximum irregularity of the ratio at various points in each of the R, R′ and R″ series is given at the foot of columns 1 to 4 of the table.

A.2 PERMISSIBLE DEVIATIONS

A.2.1 If consideration is given only to the condition that a rounded value shall remain closer to the corresponding theoretical value than to the adjacent theoretical values, this condition is expressed by a maximum permissible deviation which (if the ratio $\sqrt[n]{10}$ is not too great) is approximately equal in relative value to

$$\pm\frac{\sqrt[n]{10}-1}{2}$$

A.2.2 At the limit, however, the relation between two successive numbers may thus become near to 1 (or twice the ratio), which is not permissible for the regularity of the series.

A.3 ACTUAL DEVIATIONS OF THE CALCULATED VALUES

In ISO 3, the calculated values are given in column 7 of the table to five significant figures, which corresponds to a maximum deviation not exceeding 0,000 05 in absolute value, and to a relative difference of 0,004 8 % in relation to the theoretical value.

A.4 ACTUAL DEVIATIONS OF THE PREFERRED NUMBERS

A.4.1 In ISO 3, the **preferred numbers** are given to three significant figures, and the relative difference between them and the calculated values is shown in column 8.

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[1] For example for the preferred number 8,5, ignoring the difference between the calculated value and the theoretical value, the degree of precision is

$$100 \times \frac{8,5-8,414\,0}{8,414\,0} = +\,1,02\ \%$$

[2] For example in the series R 40, taking the terms 1,60 and 1,70, this deviation is

$$\sqrt[40]{10} - \frac{1,70}{1,60}$$

[3] For example the terms 1,60 and 1,70 give approximately

$$\frac{1,70}{1,60} = 1,059\,3\left(1+\frac{1,26-0,95}{100}\right) = 1,059\,3\,(1+0,003\,1)$$

The exact relation is 1,062 5, the exact deviation is 0,003 25 or 0,3 % to the nearest 2/10 000 (in this case).

A.4.2 This relative difference does not exceed 1,26 %, whereas the absolute error is sometimes large; but it may be noted that the conventional roundings have been chosen in such a way that the regularity of the series, i.e. the relationship between two terms, remains very close to the theoretical ratio (maximum irregularity 1,15 % in R 40).

A.5 ACTUAL DEVIATIONS OF MORE ROUNDED VALUES

A.5.1 **The only more rounded values** which may be used, and then only in exceptional cases, have been formulated to give only **two significant figures,** or even only **one single significant figure,** and to maintain the permissible degree of precision and of regularity in the series R′ and R″, for the constitution of which they are provided.1)

A.5.2 Nevertheless, they differ from the theoretical values very much more than do the preferred numbers themselves (see columns 7 to 10 of the table — maximum differences in frames). The regularity of the ratio of the R′ and R″ series is similarly poorer than that of the preferred numbers series; for example in R″ 5, the maximum irregularity (see foot of columns 1 to 4 of the table) reaches 5,37 %, compared with 1,42 % in R 5, while in R′ 40 it reaches 2,94 %, compared with 1,15 % in R 40.

A.5.3 It should be noted that for certain terms a rounding which is allowable in R″ 5 or R″ 10 is not allowable in closer series. Thus, the value 1,5, differing by 5,36 % from its theoretical value, entails a deviation of 5,60 % in the ratio between it and the succeeding term 2,0, a permissible deviation in R″ 10, which has a ratio in the neighbourhood of 1,25 and maximum permissible deviation of 12,9 %, according to clause A.2.1. But this value cannot be retained in R″ 20, which has a ratio in the neighbourhood of 1,12, as it would result in a deviation of 6,58 % in relation to the succeeding term 1,8, and the maximum permissible deviation is 6,1 %.

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1) The value 1,2 provided in R′ 40 in place of 1,18, deviates from the theoretical value by + 0,97 %, and it is thus almost as acceptable as 1,18 which deviates by − 0,71 %; but, if the scaling is considered, the value 1,2 does not fit in well between 1,1 and 1,25; in fact, the deviation from the theoretical ratio 1,059 3, obtained from the algebraic difference of the differences in columns 7 and 8, as indicated in clause A.1.2, is modified

$$\text{between } 1{,}2 \text{ and } 1{,}1 \text{ by } \frac{+0{,}97 + 1{,}96}{100} = +2{,}93\ \%$$

$$\text{between } 1{,}25 \text{ and } 1{,}2 \text{ by } \frac{-0{,}71 - 0{,}97}{100} = -1{,}68\ \%$$

The two consecutive ratios are thus 1,088 6 and 1,042 5, instead of 1,059 3.