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Limits and fits for engineering —

Part 1: Limits and tolerances

Consequent upon the publication of BS 4500 “ISO Limits and fits”,
the tables of metric values are deleted from this Standard.

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British Horological Institute	Radio Industry Council
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Foreword

This standard makes reference to the following British Standards :—

BS 308, *Recommendations for engineering drawing office practice*.

BS 969, *Tolerances for plain limit gauges*.

BS 2045, *Preferred numbers*.

BS 2517, *Definitions for use in mechanical engineering*.

This British Standard has been prepared under the authority of the Mechanical Engineering Industry Standards Committee to supersede BS 164:1924, "*Limits and fits for engineering*".

BS 164 was first issued in 1906 and a revised edition was published in 1924. In 1937, on the recommendation of the Institution of Production Engineers, a Technical Committee was set up to consider the revision of the 1924 edition, but, with the advent of war, it was considered inadvisable to make any important changes in the system. A revised edition was, however, published in 1941 and in this war-time issue the essential tables were reproduced unaltered from the 1924 edition but the explanatory text was revised and simplified.

After the war further thought was given to a complete revision of the standard and the appropriate committee formulated proposals for a system which, whilst offering a wider choice of fits than the existing standard, was nevertheless based on similar principles. Work on this revision had been completed and the new edition was approaching publication when developments occurred in the field of inter-Services standardization which made it appear desirable to review the whole question.

As a result of discussions which took place between Services representatives of the United Kingdom, the United States and Canada at Ottawa in November, 1950, the committee agreed to re-examine the subject and investigate the possibility of obtaining a universal inch system of limits and fits. After due consideration, it was decided to develop a new series of tables based on the ISA system which had long been in general use on the Continent and the system described in this standard is based on ISA Bulletin 25.

The system covers the size range 0.04 inches to 19.69 inches. Work is in progress on sizes above and below this range and the findings will be made available in due course.

NOTE ISA Bulletin 25 was originally prepared and published under the auspices of the International Federation of National Standardizing Associations, generally known as ISA. The work of this body was suspended during the war, and in 1946 it was re-formed as the International Organization for Standardization, generally known as ISO. Among the tasks of its numerous Technical Committees is the ratification of ISA publications as ISO Standards. It has already been agreed in principle that Bulletin 25 should be so ratified but until the necessary formalities have been completed, it is correctly referred to as ISA Bulletin 25, although work on the extension of the system is now in the hands of an ISO committee.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 28 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

General notes on the system

The system comprises suitable combinations of 16 grades of tolerance or, in other words, grades of accuracy of manufacture; and 21 types of *fit* for both hole and shaft ranging from fits of extreme interference to those of extreme clearance. All but very exceptional engineering requirements are covered, from very coarse work to fine gauge manufacture. A selection of fits for general use is given in Figure 4, and further guidance on tolerances for shafts and holes for a wide range of fits are given in Part 2 of this British Standard; but it is intended that a particular industry or organization should extract and use those limits which suit its own product. A unilateral hole basis system is recommended but a full range of holes suitable for use on a shaft basis system, unilateral or bilateral, is also included in the tables.

1 Scope

The recommendations made in this British Standard apply particularly to fits between cylindrical parts, briefly designated as “holes” and “shafts”, in which case the term “size” refers to the diameter of the mating parts. The data may also be applied in appropriate cases, by suitable selection of the grades of allowance and tolerances, to fits between other than cylindrical mating parts, in which case the “size” refers to a length, width or other dimension instead of to a diameter.

2 Definitions relating to limits and fits

A full series of definitions relating to limits and fits is included in BS 2517, “*Definitions for use in mechanical engineering*”. The basic terms used in this standard are illustrated in Figure 1. For the convenience of users to whom they may be unfamiliar, “fundamental tolerances” and “deviations” are defined below.

Fundamental tolerances. The sixteen grades of tolerance for each size range on which the system is based. (See Clause 5 and Table 1 and Table 4.)

Deviations. The algebraic amounts by which the limits of size are greater (+) or less (–) than the basic size.

NOTE The deviations for the *basic* member of a mating pair are identical with the limits of tolerance for that member. The difference between the deviations for each member is equal to the tolerance for that member.

3 Basis of conversion

In order to obtain fit interchangeability between parts made to the ISA metric system of limits and fits and to the equivalent inch system, both of which are contained in this British Standard, the inch tolerance values have been obtained not from the ISA tolerance formulae, but by direct conversion of the metric tolerance values (see Appendix A). A conversion factor of 1 in. = 25.4 mm. has been used. The method of compiling the tables is identical with that used in the ISA system, namely:

- i) The fundamental tolerances (described in the ISA standard as IT.1 to IT.16) are obtained by converting and rounding-off the metric values.
- ii) The fundamental deviations (“A” to “Z” for holes and “a” to “z” for shafts) are obtained by converting and rounding-off the metric values.
- iii) The final limits are obtained by adding the fundamental tolerances to, or subtracting them from, the fundamental deviations (see Clause 5).

4 Diameter steps

The original metric version uses diameter increments or steps based partly on Preferred Numbers¹⁾ and partly (in the sizes below 180 mm.) on existing Continental practice. In the translation these steps have all been retained and converted to convenient inch equivalents, rounding being to the nearest hundredth of an inch in the upward direction. This ensures that preferred design sizes do not fall between the exact equivalent and the rounded value.

It will be noted that the fine diameter steps are only used with some shafts and holes.

5 Explanation of the system

a) *Fundamental tolerances.* The system provides for 16 grades of tolerances for each size range, designated IT.1 to IT.16 (see Table 1 and Table 4). These are called “fundamental tolerances” and are multiples of the fundamental tolerance unit “i” where:

$$i(\text{microns}) = 0.45 \times \sqrt[3]{D} + 0.001 \times D. \quad (D \text{ in millimetres}).$$

$$\text{or } i(0.001 \text{ in.}) = 0.052 \times \sqrt[3]{D} + 0.001 \times D. \quad (D \text{ in inches}).$$

¹⁾ See BS 2045, “*Preferred Numbers.*”



“D” in each case is the geometric mean of the diameter steps involved. The term $0.001D$ is introduced, to quote from ISA. Bulletin 25, “out of consideration of the uncertainties of measuring with increase in diameter (these being mainly due to differences in temperature and deformation of gauges and working pieces). In practice this is only noticeable in diameters over about 80 mm”.

The tolerances of Grade IT.6 are 10 i. The values IT.7, IT.8, etc., are 16 i, 25 i, etc., in a progression based on the five-series Preferred Numbers; IT.12 is therefore ten times IT.7, IT.13 ten times IT.8, etc. Each tolerance grade is approximately 60 per cent greater than its predecessor.

The values of IT.5 are 0.7 times the values of IT.6; the values of IT.1 are however arranged to suit gauge requirements, and the others, IT.2 to IT.4, in regular but arbitrary progression between IT.1 and IT.5.

b) *Fundamental deviations*. The tolerance determines the dimensional difference between two limits, but to establish the various fits one of the limits must be determined according to some law or formula, the other limit of course being obtained by adding or subtracting the fundamental tolerance. The derivation of the various fundamental deviations is given in Appendix B.

The positions of the tolerance zone boundaries nearest to the zero line, i.e. fundamental deviations, are indicated by 21 letters, using capitals for holes and small letters for shafts, as follows :—

For holes: A B C D E F G H J K M N P R S T U V X Y Z

For shafts: a b c d e f g h j k m n p r s t u v x y z

As shown in Figure 2 and Figure 3, the letters “A” to “H” and “k” to “z” inclusive apply to the tolerance zones above the reference line, the letters “A” and “z” corresponding to the most distant. The letters “a” to “h” and “K” to “Z” inclusive apply to the tolerance zones below the reference line, the letters “a” and “Z” corresponding to the most distant.

The tolerance zones “H” lie on the plus side only of the reference line, the tolerance zones “h” on the minus side only, while the tolerance zones “J” and “j” lie on both sides of the reference line.

Although a free association of the various shafts and holes is possible, it is strongly recommended that the unilateral hole basis system be used (“H” is the standard hole). In the hole basis system the shafts “a” to “h” are provided for clearance fits and “j” to “z” for transition and interference fits.

Holes for use on a unilateral shaft basis system may also be selected with “h” as the standard shaft. In the shaft basis system holes “A” to “H” are provided for clearance fits and “J” to “Z” for transition and interference fits.

6 Terminology

A hole is described by the appropriate capital letter followed by a suffix number denoting the tolerance grade,

e.g. H7.

A shaft is described by a small letter followed by a suffix number denoting the tolerance grade,

e.g. p6.

A fit is described by the hole symbol followed by that of a shaft,

e.g. H7—p6

or H7/p6

It is recommended that on production drawings the actual limits for both hole and shaft should be explicitly stated by one or other of the methods laid down in BS 308, “Recommendations for engineering drawing office practice”, so that the parts to be measured by measuring instruments indicating actual size can be manufactured without any necessity for reference to the British Standard. There are, however, certain circumstances — for example, in general specifications, or on preliminary design drawings — in which it is convenient to be able to designate a particular type of fit by symbols only. In some works it is customary to use the symbolic notation also on production drawings and for the identification of gauges, but where this is done it is recommended that the symbols should be quoted in addition to the actual limits if any production requirements necessitate their use.

7 Selection of limits

It is intended that a particular industry or organization should extract from the tables those limits which best suit its own products. Certain recommendations are made in Clause 8. Part 2 of this British Standard will contain definite recommendations on the limits and fits to be used for a wide range of applications.

8 Initial selection for normal use

a) For ordinary engineering purposes, only a small number of the many possible fits is required. The full range of shaft fits recommended for use with the holes H6, H7, H8 and H11 is given in Figure 4. The following table indicates those fits which will be found to meet many of the needs of the average engineering organization.

Hole	Associated shafts
H8	d10, e9, f8, h7, j7, k7, m7
H7	e8, f7, g6, h6, k6, p6, s6
H6	f6, g5, k5

b) Satisfactory clearance fits are obtained with the following combinations of holes and shafts :—

Hole	Associated shafts
H6	g5, f6, e7
H7	g6, f7, e8, d8/d9, c8/c9, b8/b9, a9
H8	f8, e9, d10

c) Satisfactory interference fits are obtained with the following combinations of holes and shafts :—

Hole	Associated shafts
H6	n5 to x5
H7	p6 to z6
H8	s7 to z7

9 Gauge limits

The ISA System specifies gauging practice and gauge tolerances. This matter, however, is under review and it is recommended that for the time being use should be made of gauge limits as specified in BS 969, “*Tolerances for plain limit gauges*”.

10 Equivalent fits

For the convenience of those changing over to the new system, the following table gives the equivalence of BS 1916 fits and those of BS 164 and the Newall systems.

The actual dimensions in the various systems are not, of course, interchangeable and it should be emphasized that the comparisons are not exact, particularly on larger sizes, and designers should check that particular cases are satisfactory.

a) i) *Holes*.

BS 1916	BS 164:1924	Newall
H6	B	—
H7	—	A
H8	U	B
H9	V	—
H10	—	—
H11	W	—

ii) *Shafts.*

BS 1916	BS 164:1924	Newall
f6	M	—
f7	Q	Y
e8	R	X
d9	S	—
b11	TT	—

b) *Clearance fits.*

BS 1916	BS 164:1924	Newall
H7/b9 H7/c9 H7/d9	U.T U.S	— —
H7/e8 H7/f7 H7/g6	U.R U.Q B.P	A.X A.Y —
H8/g7 ^a H7/h6 H8/h7	— U.L	A.Z A.P
H6/h6	B.L	—
^a This is a non-preferred association. H7/f7 or H8/f7 is suggested.		

c) *Transition fits.*

BS 1916	BS 164:1924	Newall
H8/j7 H7/j6 H7/k6 H7/m6	U.K B.K U.C U.D	— — — —

d) *Interference fits.*

BS 1916	BS 164:1924	Newall
H7/p6 H6/n5 H7/s6 H8/s7 H7/x6	U.E B.E U.F —	— — { A.D B.D approx. A.F