BS 1916-3:2009

BSI British Standards

Limits and fits for engineering

Part 3: Guide to tolerances, limits and fits for large diameters

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Contents

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

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 30 September 2009. It was prepared by Technical Committee TDW/4, *Technical product realization*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 1916-3:1963, which is withdrawn.

Relationship with other publications

This British Standard is published in three parts:

Part 1 – Guide to limits and tolerances;

Part 2 – Guide to the selection of fits in BS 1916-1;

Part 3 – Guide to tolerances, limits and fits for large diameters.

The ISO 286 (BS EN 20286) series establishes the ISO code-system for tolerances of linear sizes and is published in the following parts:

ISO 286-1 (BS EN 20286-1), *ISO system of limits and fits – Part 1: Bases of tolerances, deviations and fits;*

ISO 286-2 (BS EN 20286-2), *ISO system of limits and fits – Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

The ISO 286 series covers the metric system of limits and fits; the BS 1916 series provides guidance and recommendations on the equivalent inch system (imperial).

Information about this document

In view of the time elapsed since its original publication in 1963, this British Standard was reviewed in detail in 2009. It was decided that the technical provisions of the previous edition were still generally applicable, but the figures have been redrawn for ease of use, the wording of some guidance updated for clarity, and the opportunity was taken to update references to other standards.

Use of this document

As a guide, this part of BS 1916 takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: Introductory

1 Scope

This part of BS 1916 gives guidance on tolerances, limits and fits for large diameters (19.69 in to 125 in).

In many industries, components in large sizes are made to interchangeable as well as to matched fits. There are many practical problems, however, in achieving interchangeable manufacture in large diameters, due mainly to difficulties of measurement.

Clause **4** and Clause **5** in Section **1** discuss the known difficulties which might be encountered and draw attention to those tolerances and fits where the greater difficulties might be expected to arise. Section **2** puts forward tables of tolerances, deviations and limits for shafts and holes.

It is strongly emphasized that these should be regarded as recommendations intended for trial purposes. They are published in the expectation that experience in their use will enable them to be confirmed or modified, and will help to bring to light deficiencies in measuring techniques.

An explanation of the system to which this standard forms an extension is contained in BS 1916-1.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 1916-1:2009*, Limits and fits for engineering – Part 1: Guide to limits and tolerances*

3 Terms and definitions

For the purposes of this part of BS 1916, the terms and definitions given in BS 1916-1 apply.

4 A review of the problems

In the manufacture of parts in the size range of 19.69 in to 125 in as covered by this standard, a number of serious manufacturing and measuring problems arise which are not encountered when working in small sizes. This is especially so when it is necessary to produce large components to small tolerances on a universally interchangeable basis.

In the small size range of 0.040 in to 4.000 in, the number associated with the grade of tolerance (known as the fundamental tolerance) tends to be related in practice to a known degree of difficulty in manufacture. In addition, because changes in the size of the component in this size range due to normal fluctuations in temperature are an insignificant proportion of the tolerance, for parts made to IT6 or larger tolerances, they are usually ignored. Those whose main experience lies in the manufacture of parts of up to about 4.0 in might therefore form the opinion that the temperature of the workpiece can be ignored and

because it is known that tolerance increases with size, the manufacture of parts of 100 inches in diameter to IT6 tolerance will present similar but not substantially greater difficulties than the manufacture of smaller parts to this tolerance.

NOTE The letters of the symbol "IT" stand for "International Tolerance" grade.

Figure 1a and Figure 1b show the relationship between the fundamental tolerances IT4, IT5, IT6, IT7 and IT8 and the change in the size in a steel workpiece due to a change of temperature of 1 °C, 2 °C, 3 °C, 4 °C, 5 °C, 6 °C, 8 °C and 10 °C over the size range of 0 in to 19.69 in and 19.69 in to 125 in. These figures illustrate very clearly that it is possible to manufacture parts of about 2 in diameter to IT6 tolerance and virtually ignore changes of up to five degrees in the temperature of a steel workpiece. The figures also show that a change in temperature of 5 °C on a 120 in steel workpiece absorbs 140% of the IT6 tolerance.

Figure 1a and Figure 1b also show that in the smaller sizes, any of the IT tolerances represent a much larger percentage of the size of the workpiece than in larger sizes. For example, the IT6 tolerance on a 1 in part is 0.000 5 in. For an increase in workpiece size of 120 times to 120 in, the tolerance only increases 10 times to 0.005 in.

Figure 1a and Figure 1b and the preceding explanations demonstrate the increased difficulty which occurs when manufacturing large parts to a tolerance which is considered a simple operation on small components. For this reason, the tolerances in this standard do not go below IT6. In addition, special warning should be given about the very serious and, in some cases, insurmountable difficulties which will be experienced in manufacturing parts to IT6 tolerances in the larger sizes covered in this standard.

When very small fit tolerances are essential on large parts, consideration should be given to the use of a technique known as "Matched fits", which is described in Annex A.

Assuming that particular care is taken, an error of 30 microinches (0.000 03 in) per in of diameter is appropriate. This error is equivalent to a temperature difference of 2.75 °C between a steel workpiece and the gauge.

In terms of measurement, therefore, the practice recommended in BS 1916-1 and BS 1916-2 of associating a hole of wider tolerance with a shaft of a given tolerance is not appropriate to large diameters.

The following conclusions have accordingly been drawn with regard to the measurement of sizes above 19.69 in.

a) The accuracy of measurement of a size of a part which can be expected from a general precision engineering shop under normal conditions is not better than ±30 microinches (0.000 03 in) per inch.

b) The accuracy of measurement of a size of a part which can be expected from a precision engineering shop with very accurate equipment and considerable experience in such measurements is not better than ±15 microinches (0.000 015 in) per inch.

c) The accuracy of comparison of the sizes of parts which can be expected from a precision engineering shop under normal conditions is not better than ±15 microinches (0.000 015 in) per inch.

Figure 1a **Relationship between fundamental tolerance and temperature change for sizes up to 19.69 in**

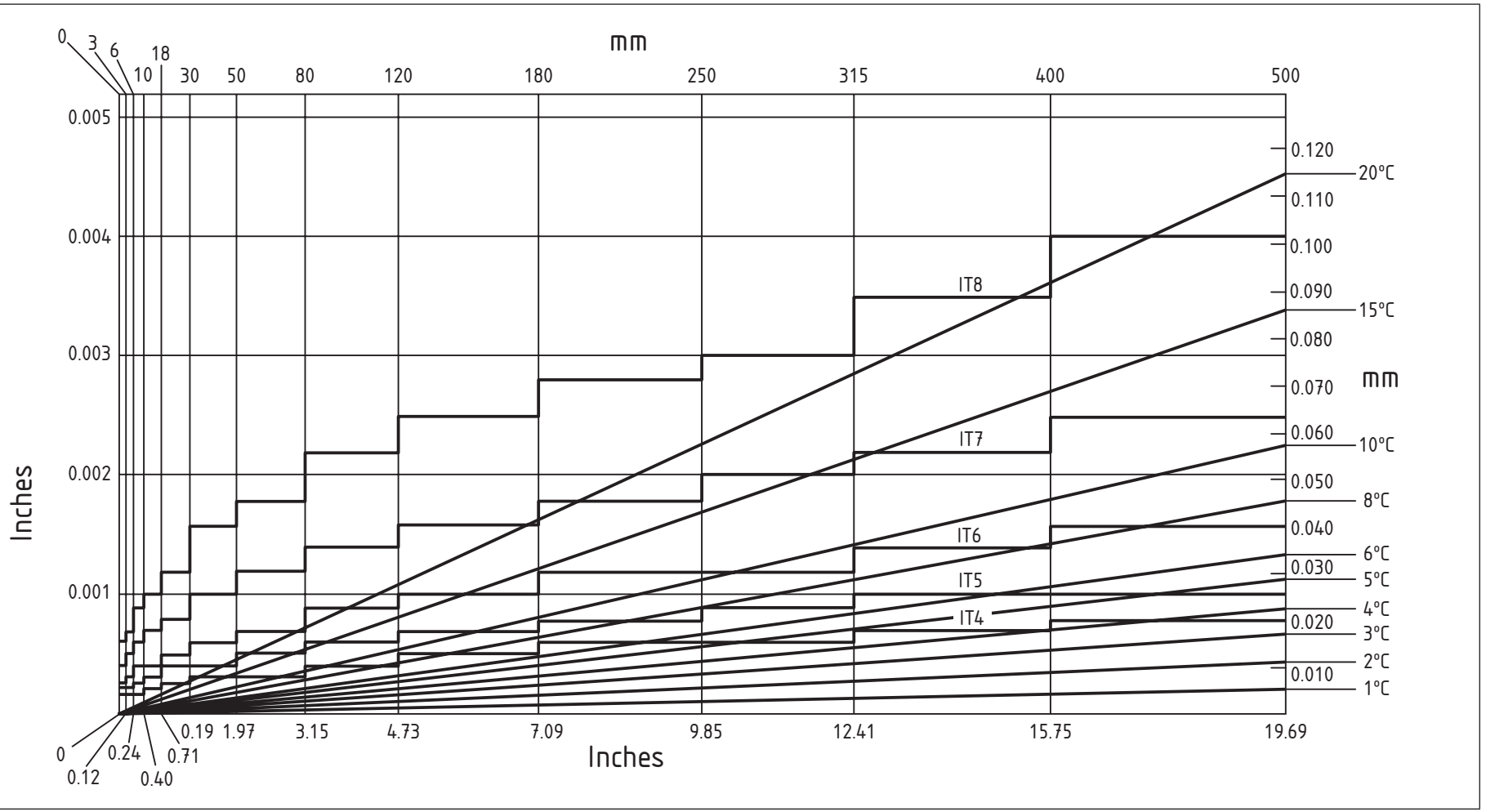
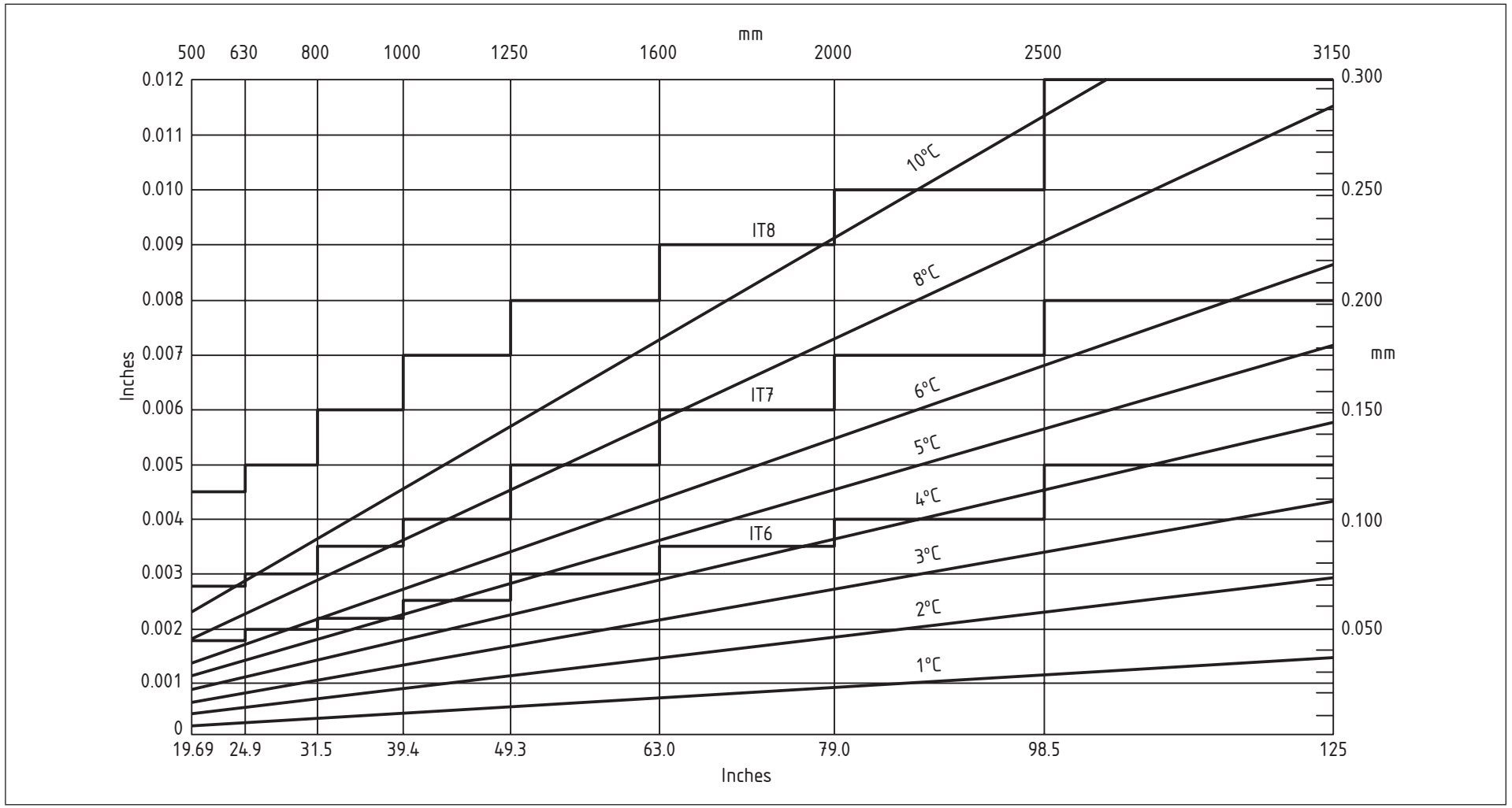


Figure 1b **Relationship between fundamental tolerance and temperature change for sizes from 19.69 to 125 in**



5 The practical effect of errors on tolerances and fits

The two common methods of mating large parts are to manufacture one to suit the other (matched fits), or to specify interchangeable limits of size. The first practice is carried out in the same shop, presumably using the same master measuring equipment or standards. In the other case, parts could conceivably be made in separate shops using different standards.

In either case, the important functional characteristic of the fit to be considered in the first place is the minimum clearance or the minimum interference.

In the case of matched fits (explained in greater detail in Annex A), there are two other important factors to be considered.

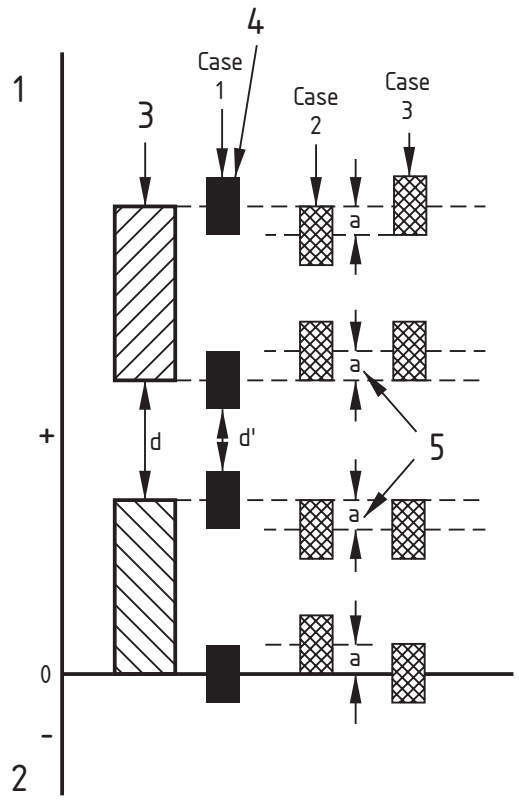
a) As already mentioned, a single measuring standard is almost certainly used, so that measurement entails comparison of size rather than absolute determination.

b) The designer, in specifying a tolerance on the required deviation or allowance, does not have to consider variations of fit resulting from two tolerances, but only from one; they may therefore be more generous with the tolerance they do specify.

Whether matched fits or normal interchangeable limits are chosen, however, the deviation is subject to encroachment from either end by the error of measurement.

Figure 2a and Figure 2b illustrate the practical significance of errors of measurement in the two methods.

Figure 2a **Interference fits – interchangeable fits**



CASE 1. No safety zone. The limits can vary by amount of error of measurement. Actual deviation "*d*" can become *d*' where $d - d' = 2 \times 30$ microinches per inch.

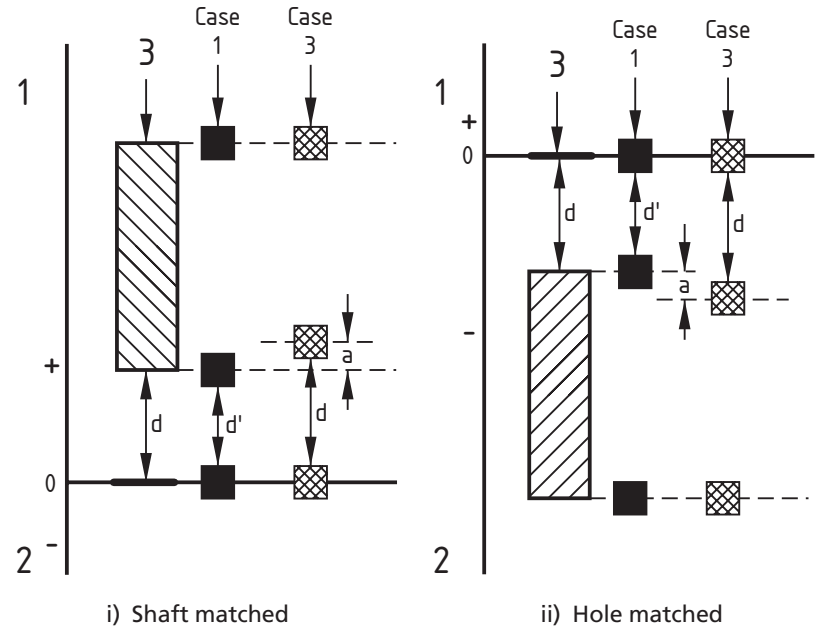
CASE 2. A safety zone is introduced so that real limits do not exceed drawing limits. Safety zone "a" for each limit = 30 microinches per inch. Working tolerance is only nominal tolerances: 2 × 30 microinches per inch.

CASE 3. A safety zone is introduced at the NOT GO end only.

Key

1 Shaft
2 Hole
3 Component tolerance
4 Error of measurement zone applied to upper and lower limits of tolerance
5 Safety zone

Figure 2b **Interference fits – matched fits**



CASE 1. No safety zone.

Limits can vary by amount of error of measurement.

Actual deviation can become d' when $d - d' = 2 \times 15$ microinches per inch.

CASE 3. A safety zone is introduced so that the real limits do not exceed the drawing limits at the NOT GO end. Safety zone "a" applied to matched part. NOT GO end is 2 × 15 microinches per inch.

Key

1 Shaft

2 Hole

3 Component tolerance

In the case of normal interchangeable fits, if no safety zone is introduced, the deviation or allowance between the maximum material limits of the two components may be reduced by 60 microinches (0.000 06 in) per inch.

In many cases it is not unreasonable to allow 20% of the deviation to be absorbed by this error, i.e. the deviation should then be at least 300 microinches (0.000 3 in). If, however, safety zones are introduced to avoid encroaching on the deviation, the working tolerance of each component can be reduced by 60 microinches (0.000 06 in) per in, or half this amount if the often reasonable step is taken of introducing a safety zone only at the GO end.

As a substantial proportion of the tolerance could be involved in either case, tolerance grades of IT7 and finer become impractical. For example, for a diameter of 100 in, the encroachment at the GO end of the tolerance could be 0.006 in with a safety zone and 0.003 in without one, while the tolerance for IT7 is only 0.008 in and that for IT8 is only 0.012 in.

NOTE For an explanation of fundamental tolerance (IT) grades, see BS 1916-1.

In the case of matched fits, where the error of measurement is taken as 15 microinches (0.000 015 in) per inch, Figure 2b shows that the reduction of deviation, and the safety zone required to eliminate it, are smaller.

Figure 3 shows diagrammatically all holes and shafts which are recommended in Section **2**. It should be noted that although data on shaft and hole basis fits are given in Section **2**, it is recommended that, where practicable, hole basis fits be used.

The dotted lines in Figure 3 indicate to scale the extent of the zone of error of measurement based on an error of 30 microinches (0.000 03 in) per inch.

Figure 3 demonstrates that:

a) for a matched fit, most shafts are likely to be practicable, i.e.:

   clearance fits: d, e, f;

   interference fits: p, r, s, t, u;

b) in a normal engineering shop, concerned with interchangeable fits, difficulty might be experienced with shafts e and f unless a safety zone is introduced;

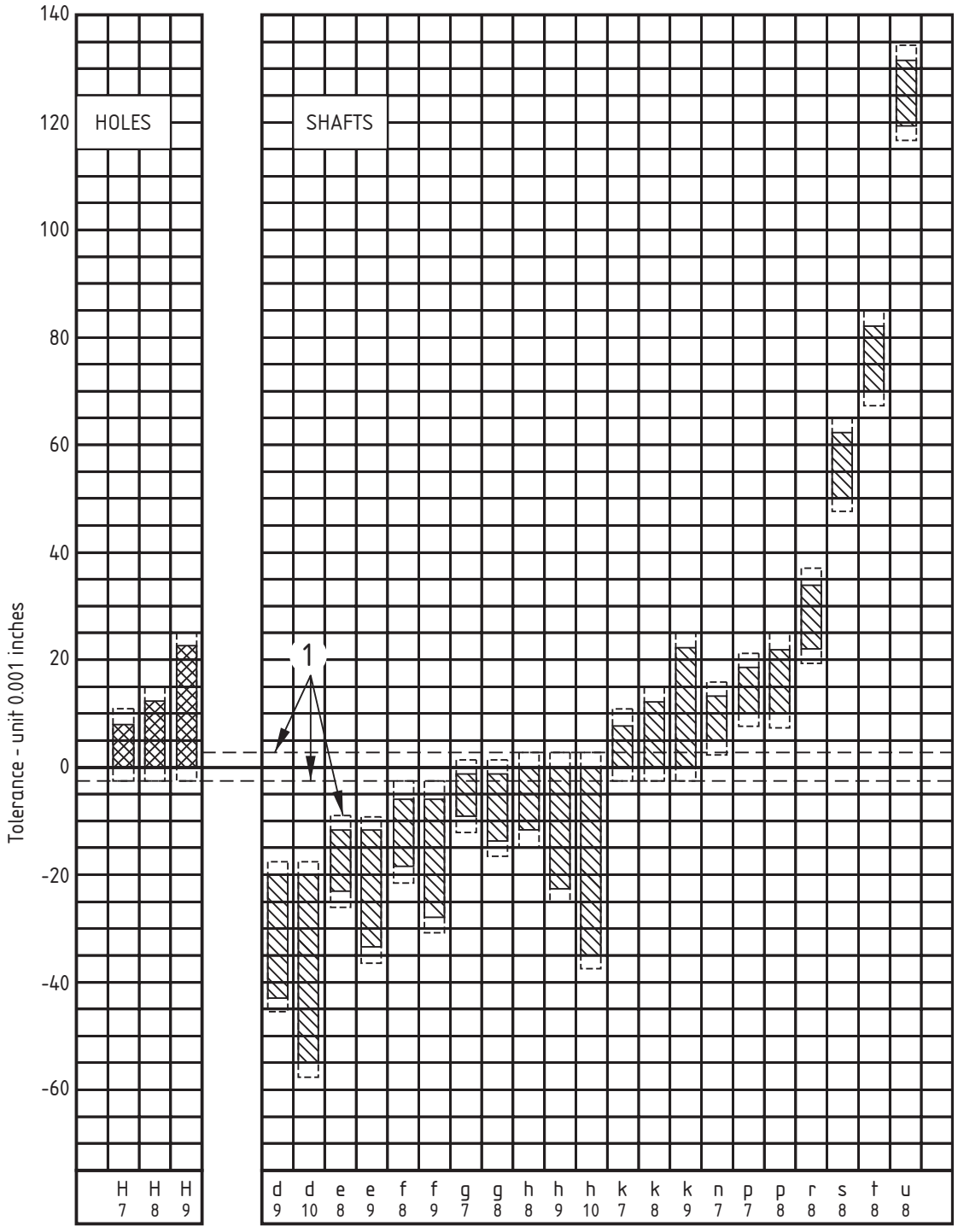
c) in either case, the close running fit g is scarcely practicable, and the fit of slight interference p is difficult without the most careful technique of measurement and the introduction of a safety zone;

d) the transition fits h, js, k, etc., are, however, more or less practicable, although the differences between them become slight, and the character of the fits is greatly affected by measurement errors.

Table 1 summarizes the possibilities.

Figure 3 **Disposition of basic holes and recommended shafts**

Diagram to scale for 100 inches diameter



NOTE The diagram illustrates the effect of errors of measurement on the actual limits if no safety zone is introduced.

Key

1 Dotted lines indicate zones of uncertainty due to error of measurement of 30 microinches per inch (0.003 inches at 100 inches diameter)

Table 1 **Summary of manufacturing possibilities**

Shaft symbols	Safety zone	Interchangeable fit in normal shop	Interchangeable fit with special measurement technique	Matched fit
d	No	Difficult	Practicable	Practicable
	Yes	Practicable	—	—
e, f	No	Probably impracticable	Difficult	Difficult
	Yes	Practicable	—	Practicable
g (as a clearance fit)	No	Impracticable	Impracticable	Impracticable
	Yes	Practicable except in grade 7	Practicable except in grade 7	Practicable except in grade 7
h (transition fit) js, k, m, n	No	Practicable	Practicable	Practicable
p7, p8, p9 (as transition fits)	No	Practicable	Practicable	Practicable
p7 (as an interference fit)	No	Impracticable	Difficult	Difficult
	Yes	Impracticable	Practicable	Practicable
r	No	Difficult	Difficult	Practicable
	Yes	Practicable	Practicable	—
s, t, u	No	Practicable	Practicable	Practicable

NOTE 1 For shafts d, e, f and g, the safety zone is applied at the GO end. For shafts p7 and r, the safety zone is applied at the NOT GO end.

NOTE 2 The assessment of the practicability or otherwise of fits listed in the above table is based on the following factors.

a) The assumption of an error of measurement of ±30 microinches (0.000 03 in) per in, equivalent to ±0.003 in at 100 in.

b) For clearance fits, the permissible encroachment on the deviation is approximately 20%, therefore interchangeable fits without a safety zone become "difficult" if the deviation is less than 0.03 in.

c) When special techniques are used, an error of measurement of ±15 microinches (0.000 015 in) per in or ±0.001 5 in at 100 in can be assumed; when these techniques are used, interchangeable fits without a safety zone become "difficult" if the deviation is less than 0.015 in.

d) The safety zone for a normal shop is 0.003 in. The safety zone when using special techniques is 0.001 5 in.

e) Safety zones are applied at one end of the work tolerance zone only.

f) The permissible encroachment on the work tolerance zone is approximately 20% so that for normal workshops, IT8 is the finest practicable quality, but IT7 can be used if special measuring techniques are applied.

g) For matched fits, the error of comparison of size is ±15 microinches (0.000 015 in) per in or ±0.001 5 in at 100 in so that matched fits without a safety zone become "difficult" if the deviation is less than 0.015 in.

Section 2: Limits and tolerances for large diameters (19.69 in to 125 in)

6 Tolerance formula

The recommended tolerance formula is:

Fundamental tolerance unit i (0.001 in) = 0.004 D + 0.083 (D in inches).

A series of grades from IT5 to IT16 is recommended (see Note 2), the relative magnitude being as follows.

- IT5 – 7i
- IT6 – 10i
- IT7 – 16i
- IT8 – 25i
- IT9 – 40i
- IT10 – 64i
- IT11 – 100i
- IT12 – 160i
- IT13 – 250i
- IT14 – 400i
- IT15 – 640i
- IT16 – 1 000i

NOTE 1 The values of the fundamental tolerances for eight ranges of diameters between 19.69 in and 125 in are given in Table 5 in units of 0.001 in.

NOTE 2 Grades IT5 and IT6 should only be used with extreme caution, in view of the difficulty of providing a safety zone within the relatively small tolerances.

NOTE 3 Graphical representations of tolerance zones for holes and shafts are included in Annex B.

7 Diameter steps

The inch diameter steps are converted from metric diameters based on the R10 and R20 series of Preferred Numbers (see BS 2045).

After conversion to inches, they have been rounded upwards to two decimal places.

8 Fundamental inch tolerances

The inch tolerance values given in Table 2 have been rounded off to avoid the use of excessively precise tolerances.

Table 2 **Fundamental tolerances of grades 6 to 16**
Tolerances in 0.001 in

Nominal diameters (in)		**Tolerance grades**										
Over	**To**	**IT6** [A)]	**IT7**	**IT8**	**IT9**	**IT10**	**IT11**	**IT12**	**IT13**	**IT14**	**IT15**	**IT16**
19.69	24.81	1.8	2.8	4.5	7	12	18	28	45	70	120	180
24.81	31.50	2	3	5	8	12	20	30	50	80	120	200
31.50	39.38	2.2	3.5	6	9	14	22	35	60	90	140	220
39.38	49.22	2.5	4	7	10	16	25	40	70	100	160	250
49.22	63.00	3	5	8	12	20	30	50	80	120	200	300
63.00	78.75	3.5	6	9	14	25	35	60	90	140	250	350
78.75	98.43	4	7	10	18	28	40	70	100	180	280	400
98.43	124.02	5	8	12	22	35	50	80	120	220	350	500

[A)] Use not recommended (see Clause **4**).

The table of preferred tolerances given in BS 1916-1:2009, Table A.1, has been extended and the complete series is as follows, in Table 3.

Table 3 **Preferred series of tolerances**
Unit = 0.001 in

0.10	0.3	1.0	3.0	10	30	100	300	1 000
	—	1.2	3.5	12	35	120	350	—
	0.4	1.4	4.0	14	40	140	400	—
0.15								
	—	1.6	4.5	16	45	160	450	—
	0.5	1.8	5.0	18	50	180	500	—
0.20	0.6	2.0	6.0	20	60	200	600	—
	0.7	2.2	7.0	22	70	220	700	—
0.25	0.8	2.5	8.0	25	80	250	800	—
	0.9	2.5	9.0	28	90	280	900	—

9 Fundamental deviations

The formulae used for determining the deviations of the various shafts and holes are given in Table 4, which also lists the tolerance grades recommended for each shaft or hole. The tabulated values for all deviations are given in Table 5.

Table 4 **Formula for deviations**

Symbol	**Formulae for deviations in 0.001 in** (for *D* in inches)	**Suggested grade** (see Note 1)
d, D	$2.62D^{0.44}$	9, 10
e, E	$1.63D^{0.41}$	8, 9, (10)
f, F	$0.82D^{0.41}$	8, 9, (10)
g, G	$0.3D^{0.34}$	7, 8
h, H	0	7, 8, 9, 10, (11)
js, JS	$\pm$IT/2	8, 9, 10, (11)
k, K	0	7, 8, 9, (10)
m, M	$0.024D + 0.5$	7, 8
n, N	$0.04D + 0.83$	7, (8)
p, P	$0.072D + 150$	7, 8, (9)
r, R	G.M. of p and s	8, (9)
s, S	$0.4D$ + IT7	8, (9)
t, T	$0.63D$ + IT7	8, (9)
u, U	D + IT7	8, (9)

NOTE 1 The coarser grades given in brackets are suggested only for matched fits.

NOTE 2 For shafts s, t and u, the minimum interference (0.4D, 0.63D, etc.) is determined on the assumption that grade 7 is used for both the hole and the shaft. Grades 8 and 9 are recommended, but this means that the minimum interferences obtained are less than those given by the formulae.

Table 5 **Fundamental deviations for shafts d to u and holes D to U**
Fundamental deviations in 0.001 in

Nominal diameters (in)		**d D**	**e E**	**f F**	**(g) (G)**	**h H**	**js JS**	**k K**	**m M**	**n N**	**p P**	**r R**	**s S**	**t T**	**u U**
Over	**To**														
19.69	22.05	10	6	3	0.9	0		0	1	1.8	3	6	12	16	25
22.05	24.81											6	12	18	25
24.81	27.96	12	6	3	0.9	0		0	1.2	2	3.5	7	14	20	30
27.96	31.50											7	14	22	35
31.50	35.44	12	7	3.5	1.0	0		0	1.4	2.2	4	8	16	25	35
35.44	39.38											9	18	28	40
39.38	44.10	14	8	4	1.0	0		0	1.6	2.5	4.5	10	20	30	45
44.10	49.22											10	22	35	50
49.22	55.12	16	9	4.5	1.2	0	See Note	0	1.8	3	6	12	25	40	60
55.12	63.00											12	28	40	60
63.00	70.87	16	9	4.5	1.2	0		0	2.2	3.5	7	14	30	45	70
70.87	78.75											16	35	50	80
78.75	88.19	18	10	5	1.4	0		0	2.5	4.5	8	18	40	60	90
88.50	98.43											18	45	60	100
98.43	110.24	20	12	6	1.4	0		0	3	5	9	22	50	70	110
110.24	124.02											22	60	80	120

NOTE In the case of js shafts and JS holes, the fundamental tolerance is divided equally plus and minus about the nominal size, rounded if necessary to the preferred value immediately above.

10 Suggested associations of holes and shafts

The following associations of holes and shafts, in Table 6, are recommended for trial. The limits are given in Table 7 and Table 8.

Table 6 **Suggested association of holes and shafts for interchangeable manufacture**

Hole	**Shafts**		
H7	d9, e8, f8	g7 [A], h8, k7	p7 [B]
H8	d9, e8, f8, g8	h9, k8, n7, p8	r8, s8, t8, u8
H9	d10, e9, f9, g8	h10, k9	
Type of fit	Clearance	Transition	Interference

[A] The shaft g is regarded as a transition fit because of the effect of the errors of measurement on the minimum clearance.

[B] Special measuring techniques should be used.

Table 7 **Limits for holes (inch units)**
Tolerance unit = 0.001 inch

Nominal diameters (in)		**D**			**E**				**F**				**(G)**		
		9	**10**	**9, 10**	**8**	**9**	**(10)**	**8–10**	**8**	**9**	**10**	**8–10**	**7**	**8**	**7–8**
Over	**To**	**High** +	**High** +	**Low** +	**High** +	**High** +	**High** +	**Low** +	**High** +	**High** +	**High** +	**Low** +	**High** +	**High** +	**Low** +
19.69	22.05	17	22	10	10.5	13	18	6	7.5	10	15	3	3.7	5.4	0.9
22.05	24.81														
24.81	27.96	20	24	12	11	14	18	6	8	11	15	3	3.9	5.9	0.9
27.96	31.50														
31.50	35.44	21	26	12	13	16	21	7	9.5	12.5	17.5	3.5	4.5	7	1
35.44	39.38														
39.38	44.10	24	30	14	15	18	24	8	11	14	20	4	5	8	1
44.10	49.22														
49.22	55.12	28	36	16	17	21	29	9	12.5	16.5	24.5	4.5	6.2	9.2	1.2
55.12	63.00														
63.00	70.87	30	41	16	18	23	34	9	13.5	18.5	29.5	4.5	7.2	10.2	1.2
70.87	78.75														
78.75	88.19	36	46	18	20	28	38	10	15	23	33	5	8.4	11.4	1.4
88.19	98.43														
98.43	110.24	42	55	20	24	34	47	12	18	28	41	6	9.4	13.4	1.4
110.24	124.02														

NOTE The limits given in this table do not take account of the safety zone.

Table 7 **Limits for holes (inch units)** *(continued)*
Tolerance unit = 0.001 inch

Nominal diameters (in)		**H**						**JS**							
		7	**8**	**9**	**10**	**(11)**	**7–11**	**8**	**8**	**9**	**9**	**10**	**10**	**(11)**	**(11)**
Over	**To**	**High** +	**High** +	**High** +	**High** +	**High** +	**Low**	**High** +	**Low** –	**High** +	**Low** –	**High** +	**Low** –	**High** +	**Low** –
19.69	22.05	2.8	4.5	7	12	18	0	2.2	2.2	3.5	3.5	6	6	9	9
22.05	24.81														
24.81	27.96	3	5	8	12	20	0	2.5	2.5	4	4	6	6	10	10
27.96	31.50														
31.50	35.44	3.5	6	9	14	22	0	3	3	4.5	4.5	7	7	12	12
35.44	39.38														
39.38	44.10	4	7	10	16	25	0	3.5	3.5	5	5	8	8	14	14
44.10	49.22														
49.22	55.12	5	8	12	20	30	0	4	4	6	6	10	10	16	16
55.12	63.00														
63.00	70.87	6	9	14	25	35	0	4.5	4.5	7	7	12	12	18	18
70.87	78.75														
78.75	88.19	7	10	18	28	40	0	5	5	9	9	14	14	20	20
88.19	98.43														
98.43	110.24	8	12	22	35	50	0	6	6	12	12	18	18	25	25
110.24	124.02														

NOTE The limits given in this table do not take account of the safety zone.

Table 7 **Limits for holes (inch units)** *(continued)*
Tolerance unit = 0.001 inch

Nominal diameters (in)		**K**					**M**			**N**			**P**			
		7–10	**7**	**8**	**9**	**(10)**	**7, 8**	**7**	**8**	**7, 8**	**7**	**8**	**7–9**	**7**	**8**	**9**
Over	**To**	**High**	**Low** –	**Low** –	**Low** –	**Low** –	**High** –	**Low** –	**Low** –	**High** –	**Low** –	**Low** –	**High** –	**Low** –	**Low** –	**Low** –
19.69	22.05	0	2.8	4.5	7	12	1	3.8	5.5	1.8	4.6	6.3	3	5.8	7.5	10
22.05	24.81															
24.81	27.96	0	3	5	8	12	1.2	4.2	6.2	2	5	7	3.5	6.5	8.5	11.5
27.96	31.50															
31.50	35.44	0	3.5	6	9	14	1.4	4.9	7.4	2.2	5.7	8.2	4	7.5	10	13
35.44	39.38															
39.38	44.10	0	4	7	10	16	1.6	5.6	8.6	2.5	6.5	9.5	4.5	8.5	11.5	14.5
44.10	49.22															
49.22	55.12	0	5	8	12	20	1.8	6.8	9.8	3	8	11	6	11	14	18
55.12	63.00															
63.00	70.87	0	6	9	14	25	2.2	8.2	11.2	3.5	9.5	12.5	7	13	16	21
70.87	78.75															
78.75	88.19	0	7	10	18	28	2.5	9.5	12.5	4	11	14	8	15	18	26
88.19	98.43															
98.43	110.24	0	8	12	22	35	3	11	15	5	13	17	9	17	21	31
110.24	124.02															

NOTE The limits given in this table do not take account of the safety zone.

Table 7 **Limits for holes (inch units)** *(continued)*
Tolerance unit = 0.001 inch

Nominal diameters		R			S			T			U		
(in)		8, (9)	8	(9)	8, (9)	8	(9)	8, (9)	8	(9)	8, (9)	8	(9)
Over	To	High –	Low –	Low –	High –	Low –	Low –	High –	Low –	Low –	High –	Low –	Low –
19.69	22.05	6	10.5	13	12	16.5	19	16	20.5	23	25	29.5	32
22.05	24.81				12	16.5	19	18	22.5	25	25	29.5	32
24.81	27.96	7	12	15	14	19	22	20	25	28	30	35	38
27.96	31.50				14	19	22	22	27	30	35	40	43
31.50	35.44	8	14	17	16	22	25	25	31	34	35	41	44
35.44	39.38	9	15	18	18	24	27	28	34	37	40	46	49
39.38	44.10	10	17	20	20	27	30	30	37	40	45	52	55
44.10	49.22				22	29	32	35	42	45	50	57	60
49.22	55.12	12	20	24	25	33	37	40	48	52	60	68	72
55.12	63.00				28	36	40	40	48	52	60	68	72
63.00	70.87	14	23	28	30	39	44	45	54	59	70	79	84
70.87	78.75	16	25	30	35	44	49	50	59	64	80	89	94
78.75	88.19	18	28	36	40	50	58	60	70	78	90	100	108
88.19	98.43	18	28	36	45	55	63	60	70	78	100	110	118
98.43	110.24	22	34	44	50	62	72	70	82	92	110	122	132
110.24	124.02	22	34	44	60	72	82	80	92	102	120	132	142

NOTE The limits given in this table do not take account of the safety zone.

Table 8 **Limits for shafts (inch units)**
Tolerance unit = 0.001 inch

Nominal diameters (in)		**d**			**e**				**f**				**(g)**		
		9–10	**9**	**10**	**8–10**	**8**	**9**	**(10)**	**8–(10)**	**8**	**9**	**(10)**	**7–8**	**7**	**8**
Over	**To**	**High** –	**Low** –	**Low** –	**High** –	**Low** –	**Low** –	**Low** –	**High** –	**Low** –	**Low** –	**Low** –	**High** –	**Low** –	**Low** –
19.69	22.05	10	17	22	6	10.5	13	18	3	7.5	10	15	0.9	3.7	5.4
22.05	24.81														
24.81	27.96	12	20	24	6	11	14	18	3	8	11	15	0.9	3.9	5.9
27.96	31.50														
31.50	35.44	12	21	26	7	13	16	21	3.5	9.5	12.5	17.5	1	4.5	7
35.44	39.38														
39.38	44.10	14	24	30	8	15	18	24	4	11	14	20	1	5	8
44.10	49.22														
49.22	55.12	16	28	36	9	17	21	29	4.5	12.5	16.5	24.5	1.2	6.2	9.2
55.12	63.00														
63.00	70.87	16	30	41	9	18	23	34	4.5	13.5	18.5	29.5	1.2	7.2	10.2
70.87	78.75														
78.75	88.19	18	36	46	10	20	28	38	5	15	23	33	1.4	8.4	11.4
88.19	98.43														
98.43	110.24	20	42	55	12	24	34	47	6	18	28	41	1.4	9.4	13.4
110.24	124.02														

NOTE The limits given in this table do not take account of the safety zone.

Table 8 **Limits for shafts (inch units)** *(continued)*
Tolerance unit = 0.001 inch

Nominal diameters (in)		**h**						**js**							
		7–11	**7**	**8**	**9**	**10**	**(11)**	**8**	**8**	**9**	**9**	**10**	**10**	**(11)**	**(11)**
Over	**To**	**High**	**Low** –	**Low** –	**Low** –	**Low** –	**Low** –	**High** +	**Low** –	**High** +	**Low** –	**High** +	**Low** –	**High** +	**Low** –
19.69	22.05	0	2.8	4.5	7	12	18	2.2	2.2	3.5	3.5	6	6	9	9
22.05	24.81														
24.81	27.96	0	3	5	8	12	20	2.5	2.5	4	4	6	6	10	10
27.96	31.50														
31.50	35.44	0	3.5	6	9	14	22	3	3	4.5	4.5	7	7	12	12
35.44	39.38														
39.38	44.10	0	4	7	10	16	25	3.5	3.5	5	5	8	8	14	14
44.10	49.22														
49.22	55.12	0	5	8	12	20	30	4	4	6	6	10	10	16	16
55.12	63.00														
63.00	70.87	0	6	9	14	25	35	4.5	4.5	7	7	12	12	18	18
70.87	78.75														
78.75	88.19	0	7	10	18	28	40	5	5	9	9	14	14	20	20
88.19	98.43														
98.43	110.24	0	8	12	22	35	50	6	6	12	12	18	18	25	25
110.24	124.02														

NOTE The limits given in this table do not take account of the safety zone.

Table 8 **Limits for shafts (inch units)** *(continued)*
Tolerance unit = 0.001 inch

Nominal diameters (in)		k					m			n			p			
		7	8	9	(10)	7–10	7	8	7, 8	7	(8)	7, 8	7	8	9	7–9
Over	To	High +	High +	High +	High +	Low	High +	High +	Low +	High +	High +	Low +	High +	High +	High +	Low +
19.69	22.05	2.8	4.5	7	12	0	3.8	5.5	1	4.6	6.3	1.8	5.8	7.5	10	3
22.05	24.81															
24.81	27.96	3	5	9	12	0	4.2	6.2	1.2	5	7	2	6.5	8.5	11.5	3.5
27.96	31.50															
31.50	35.44	3.5	6	9	14	0	4.9	7.4	1.4	5.7	8.2	2.2	7.5	10	13	4
35.44	39.38															
39.38	44.10	4	7	10	16	0	5.6	8.6	1.6	6.5	9.5	2.5	8.5	11.5	14.5	4.5
44.10	49.22															
49.22	55.12	5	8	12	20	0	6.8	9.8	1.8	8	11	3	11	14	18	6
55.12	63.00															
63.00	70.87	6	9	14	25	0	8.2	11.2	2.2	9.5	12.5	3.5	13	16	21	7
70.87	78.75															
78.75	88.19	7	10	18	28	0	9.5	12.5	2.5	11.5	14.5	4.5	15	18	26	8
88.19	98.43															
98.43	110.24	8	12	22	35	0	11	15	3	13	17	5	17	21	31	9
110.24	124.02															

NOTE The limits given in this table do not take account of the safety zone.

Table 8 **Limits for shafts (inch units)** *(continued)*
Tolerance unit = 0.001 inch

Nominal diameters		**r**			**s**			**t**			**u**		
(in)		**8**	**(9)**	**8, (9)**	**8**	**(9)**	**8, (9)**	**8**	**(9)**	**8, (9)**	**8**	**(9)**	**8, (9)**
Over	**To**	**High** +	**High** +	**Low** +	**High** +	**High** +	**Low** +	**High** +	**High** +	**Low** +	**High** +	**High** +	**Low** +
19.69	22.05	10.5	13	6	16.5	19	12	20.5	23	16	29.5	32	25
22.05	24.81							22.5	25	18	29.5	32	25
24.81	27.96	12	15	7	19	22	14	25	28	20	35	38	30
27.96	31.50							27	30	22	40	43	35
31.50	35.44	14	17	8	22	25	16	31	34	25	41	44	35
35.44	39.38	15	18	9	24	27	18	34	37	28	46	49	40
39.38	44.10	17	20	10	27	30	20	37	40	30	52	55	45
44.10	49.22				29	32	22	42	45	35	57	60	50
49.22	55.12	20	24	12	33	37	25	48	52	40	68	72	60
55.12	63.00				36	40	28	48	52	40	68	72	60
63.00	70.87	23	28	14	39	44	30	54	59	45	79	84	70
70.87	78.75	25	30	16	44	49	35	59	64	50	89	94	80
78.75	88.19	28	36	18	50	58	40	70	78	60	100	108	90
88.19	98.43	28	36	18	55	63	45	70	78	60	110	118	100
98.43	110.24	34	44	22	62	72	50	82	92	70	122	132	110
110.24	124.02	34	44	22	72	82	60	92	102	80	132	142	120

NOTE The limits given in this table do not take account of the safety zone.

Annex A (informative) Matched fits

A.1 When using the technique of matched fits, the procedure described in this annex is recommended.

A.2 For a particular nominal dimension, select, if necessary without reference to the tables, the fit tolerance on the basis of an evaluation of the functional requirements of the fit. As an example, assume that the nominal size is 100 in and that an interference fit of 0.010 in to 0.025 in is required.

A.3 Select whichever of the two mating components is considered to be the more difficult to manufacture to a small tolerance but which can be measured to the higher standard of accuracy. In most cases this will be the internal diameter because of the difficulty of manufacture and the relative ease with which a large internal bore can be measured by a simple measuring device in comparison with the difficulty of measurement of a large exterior diameter.

A.4 Allocate an easily attainable tolerance to the component selected in **A.3** which should be manufactured first, assuming that this is an internal bore, manufactured to a unilateral tolerance and with a tolerance of H10 allocated.

A.5 Select from the tables the tolerance which most nearly corresponds to the fit tolerance selected in **A.2**. In the example selected, the ideal fit tolerance for the 100 in dimension was given as an interference of 0.010 in to 0.025 in. The nearest tolerance available is p8 which gives an interference of 0.010 in to 0.022 in.

A.6 Record the complete specification for the matched fit tolerance which will read as follows:

100 in H10 MF p8

A.7 Machine the bore of the component to 100 in H10 (100.000 in)

(100.035 in)

A.8 Measure to the highest possible standard of accuracy the bore of the component which has been machined, assuming that the measured size of the component is 100.001 5 in.

A.9 Declare the tolerance for the shaft, calculated as follows:

$$\begin{array}{r} 100.001\ 5 \text{ in} \\ 0.010\ 0 \text{ in} \\ \hline 100.011\ 5 \text{ in} \end{array} + \qquad \begin{array}{r} 100.001\ 5 \text{ in} \\ 0.022\ 0 \text{ in} \\ \hline 100.023\ 5 \text{ in} \end{array} +$$

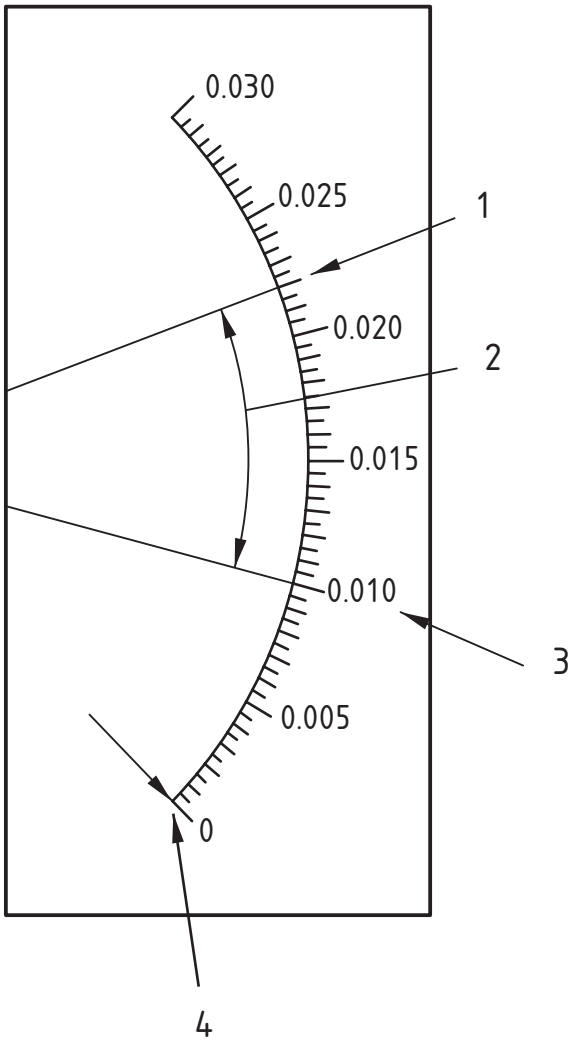
A.10 Manufacture the shaft to the tolerance: 100.011 5 in

100.023 5 in

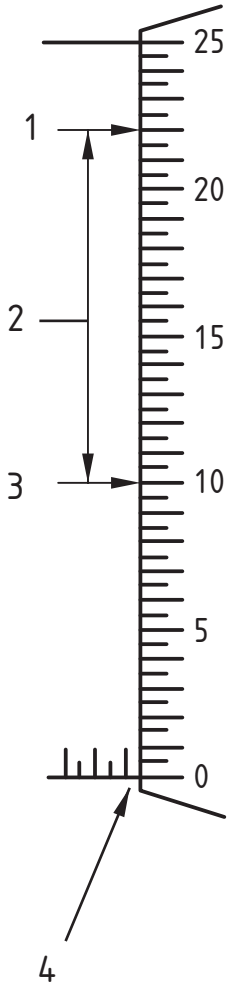
NOTE Detailed recommendations on the methods of measurement to be used when manufacturing parts to large diameters are outside the scope of this standard. However, it is good practice to use the measuring device employed for inspecting the bore of the part (which, in the case under review, can be in the form of a light rigid internal micrometer) as the setting standard for the measuring device which will be used for inspecting the external diameter. For the inspection of external diameters, it is recommended that a large calliper frame of light but rigid construction be used. The most suitable measuring anvils are those with flat parallel faces and one anvil should be fixed and the other movable. The movable anvil should be arranged to operate an indicating device on which it is possible to show the measured size of the bore and the limits of size to which the shaft should be made. The scale of a suitable device for

the case used as the example is shown in Figure A.1. The figure also shows an expanded view of a micrometer drum which can also be used as the indicating device in a suitable large calliper frame.

Figure A.1 **Examples of scales for measuring devices**



Comparator scale



Expanded micrometer scale

Key

1 Limit pointer set to maximum size of shaft (value of maximum interference 0.022 in)

2 Tolerance for shaft 0.012 in

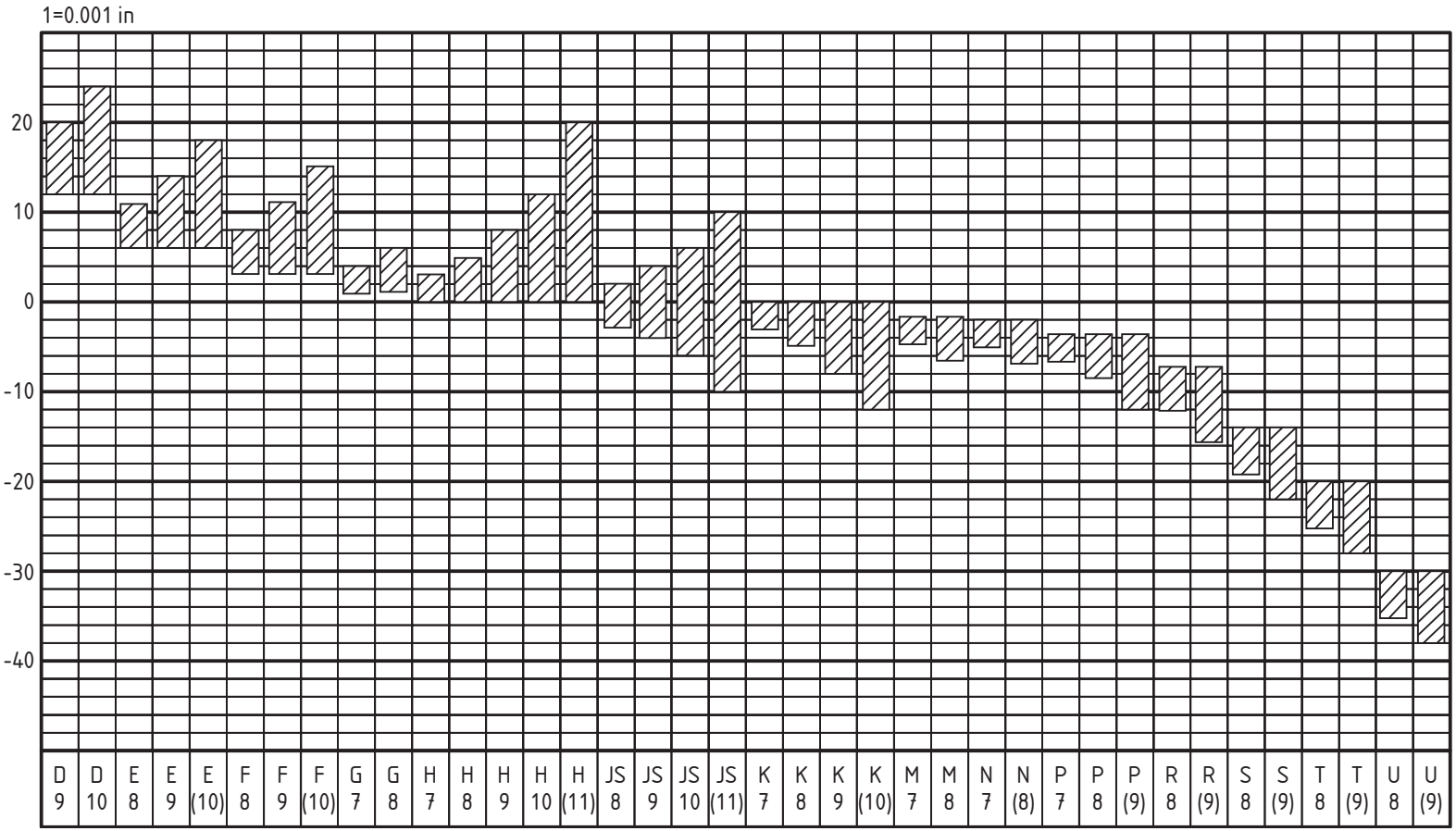
3 Limit pointer set to minimum size of shaft (value of minimum interference 0.010 in)

4 Pointer of the indicating instrument set to zero line on scale when calliper is measuring to distance between measuring anvils of internal micrometer which correspond to internal diameter of the bore

Annex B (informative) Graphical representation of tolerance zones for holes and shafts

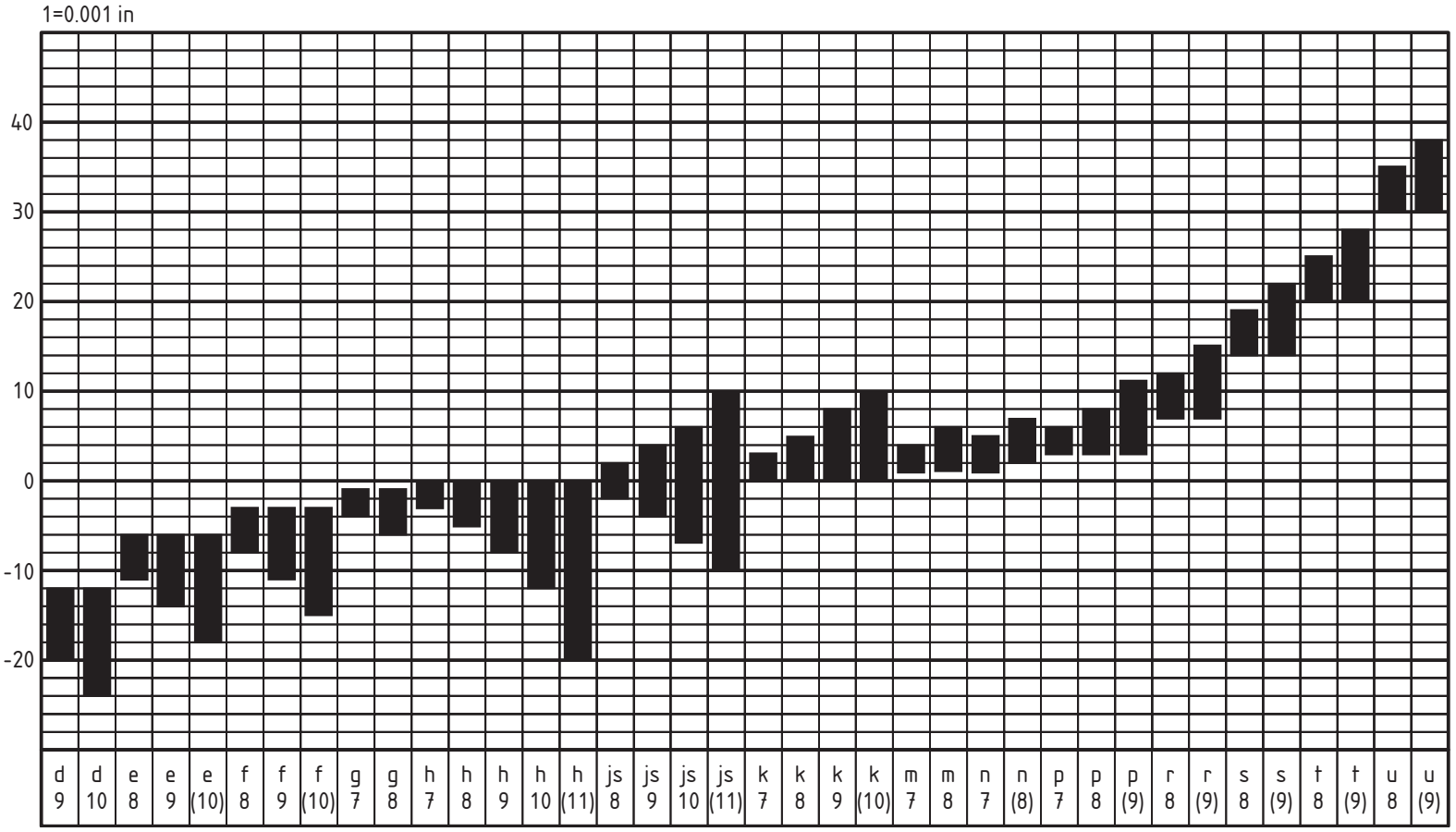
Figure B.1 shows the tolerance zones for holes arranged according to symbol. Figure B.2 shows the tolerance zones for shafts arranged according to symbol.

Figure B.1 **Tolerance zones for holes arranged according to symbol**



NOTE Diagram to scale for diameters 24.81 in to 27.96 in.

Figure B.2 **Tolerance zones for shafts arranged according to symbol**



NOTE Diagram to scale for diameters 24.81 in to 27.96 in.

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[1)] Referred to in the Foreword only.

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