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and September 1981  
(AMD 3730)*

# Limits and fits for engineering —

## Part 3: Recommendations for tolerances, limits and fits for large diameters

# Co-operating organizations

The Mechanical Engineering Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

|                                                                                       |                                                                       |
|---------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| Admiralty*                                                                            | High Commission of India                                              |
| Air Ministry                                                                          | Institute of Marine Engineers                                         |
| Associated Offices' Technical Committee                                               | Institute of Petroleum                                                |
| Association of Consulting Engineers<br>(Incorporated)                                 | Institution of Civil Engineers                                        |
| Association of Mining Electrical and<br>Mechanical Engineers                          | Institution of Gas Engineers                                          |
| British Chemical Plant Manufacturers'<br>Association                                  | Institution of Heating and Ventilating<br>Engineers                   |
| British Compressed Air Society                                                        | Institution of Mechanical Engineers*                                  |
| British Electrical and Allied Manufacturers'<br>Association*                          | Institution of Mechanical Engineers<br>(Automobile Division)          |
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| Engineering Equipment Users' Association*                                             | National Coal Board                                                   |
| Gas Council                                                                           | National Physical Laboratory (D.S.I.R.)*                              |
|                                                                                       | Radio Industry Council                                                |
|                                                                                       | War Office                                                            |

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the Committee entrusted with the preparation of this standard:

|                                                         |                                                                |
|---------------------------------------------------------|----------------------------------------------------------------|
| British Plastics Federation                             | Parsons and Marine Engineering Turbine                         |
| Electronic Engineering Association                      | Research and Development Association                           |
| National Federation of Engineers' Tool<br>Manufacturers | Telecommunication Engineering and<br>Manufacturing Association |

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## Foreword

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 9,000, fully indexed and with a note of the contents of each, will be found in the BSI Catalogue which may be purchased from BSI Sales Department. The Catalogue may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 1916, *Limits and fits for engineering*.

BS 1916-1, *Limits and tolerances*.

BS 1916-2, *Guide to the selection of fits in BS 1916-1*.

This standard relates to tolerances, limits and fits for large diameters and supplements, BS 1916, BS 1916-1, which is limited to diameters up to 19.69 in.

In many industries components in large sizes are being 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.

The "Review of the problems" in this standard discusses the known difficulties which may be encountered and draws attention to those tolerances and fits where the greater difficulties may be expected to arise; the body of the standard 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.

NOTE An explanation of the system to which this standard forms an extension is contained in BS 1916, BS 1916-1, "*Limits and Fits for Engineering*". Reference should be made to that document for information on the terms and symbols used here.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

### Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 19 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.

## Section 1. Introductory

### 1 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 specially so when it is required 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. Persons whose main experience lies in the manufacture of parts of up to about 4.0 in may 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.

The diagrams shown in Figure 1aa and Figure 1bb have been prepared to show the relationship between the fundamental tolerances IT4, 5, 6, 7 and 8 and to the same scale, the change in the size in a steel workpiece due to a change of temperature of 1, 2, 3, 4, 5, 6, 8 and 10 degrees Celsius over the size range of 0 to 19.69 in and 19.69 in to 125 in. These diagrams 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 diagram also shows that a change in temperature of five degrees Celsius on a 120 in steel workpiece absorbs 140 per cent of the IT6 tolerance.

The diagrams in Figure 1aa and Figure 1bb 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 0.0005 in. For an increase in workpiece size of 120 times to 120 in the tolerance only increases 10 times to 0.0050 in.

The diagrams, Figure 1aa and Figure 1bb and the above explanations have been included in this standard to show the increased difficulty which must inevitably occur when manufacturing large parts to a tolerance which is considered as a simple operation on small components. It is for this reason that in the present tables the tolerances quoted do not go below IT6. In addition, special warning must 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 given 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 Appendix A.

In an investigation into the accuracy of measurement undertaken by the National Physical Laboratory<sup>1)</sup>, the actual magnitude of the errors of measurement revealed by the investigation varied over wide limits, but assuming that particular care is taken, it is considered by those who have prepared this standard that an error of 30 micro inches (0.000 03 in) per inch of diameter is appropriate. (This error is equivalent to a temperature difference of 2.75 degC between a steel workpiece and the gauge.) Improvements due to the development of measuring techniques and more accurate control of temperature may enable the magnitude of this assumed error to be reduced at some future date.

There is also some evidence in the results obtained from the National Physical Laboratory investigation that by using present measuring techniques the accuracy of internal measurement is higher than that of external measurement for large diameters. From the point of view of measurement, therefore, the practice recommended in BS 1916, BS 1916-1 and BS 1916-2 of associating a hole of wider tolerance with a shaft of a certain given tolerance is not appropriate to large diameters.

Bearing in mind the above factors, the following conclusions have accordingly been drawn with regard to the measurement of sizes above 20 in.

- a) The accuracy of *measurement of a size of a part* which can be expected from the average modern engineering shop under normal conditions is not better than  $\pm 30$  micro-inches (0.000 03 in) per inch.
- b) The accuracy of *measurement of a size of a part* which can be expected from a modern engineering shop with *very accurate equipment and considerable experience in such measurements* is not better than  $\pm 15$  micro-inches (0.000 015 in) per inch.

<sup>1)</sup> Harrison, P. W., 1955, *Proc. Inst. Mech. Eng. Lond.*, vol. 169, p. 977, "An investigation into the accuracy of industrial measurement of sizes up to 80 in".

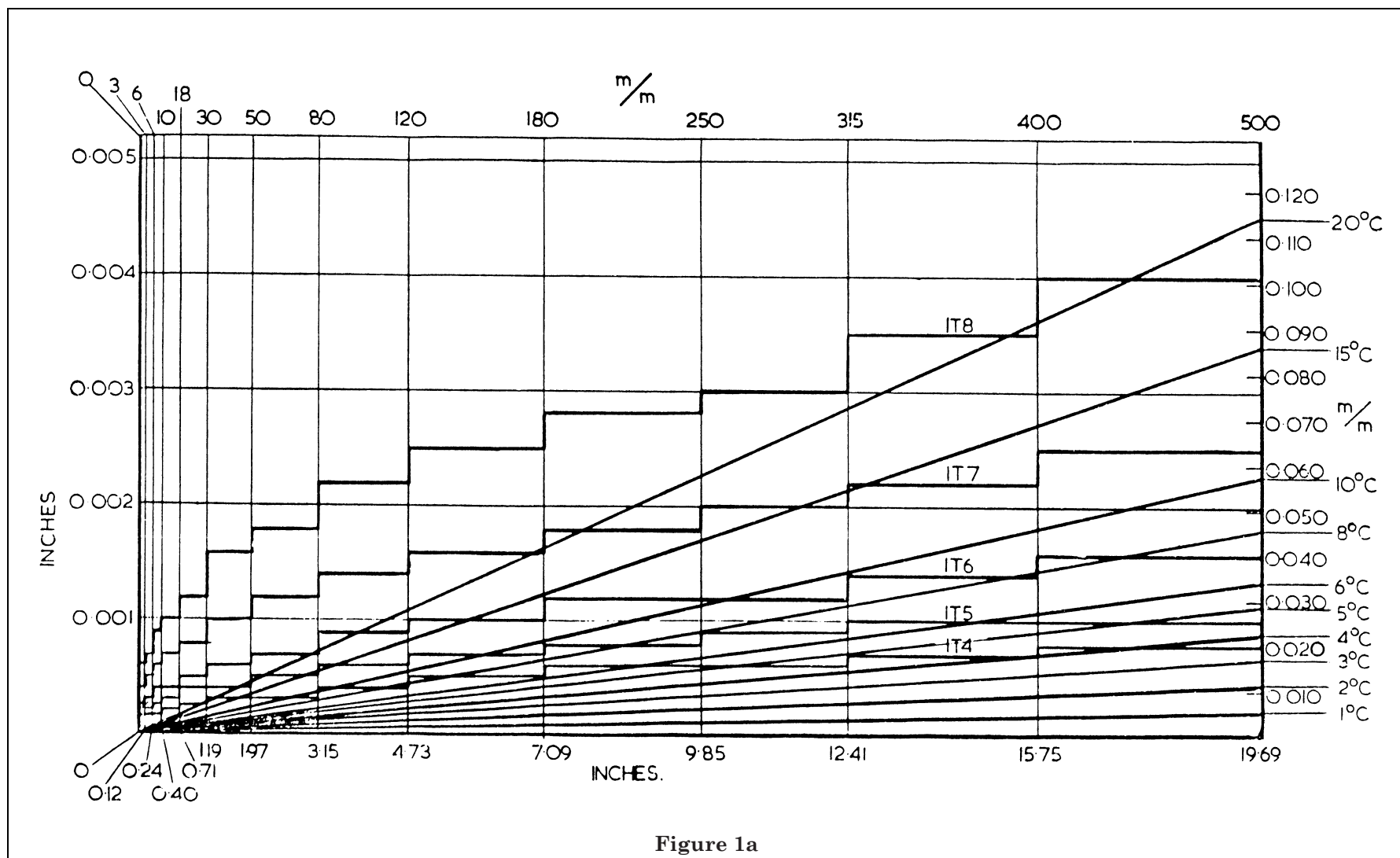


Figure 1a

c) The accuracy of *comparison of the sizes of parts* which can be expected from a modern engineering shop under normal conditions is not better than  $\pm 15$  micro-inches (0.000 015 in) per inch.

## 2 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 will be carried out in the same shop, presumably using the same master measuring equipment or standards. In the other case parts may 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 by the designer is the minimum clearance or the minimum interference.

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

- a) As already mentioned, a single measuring standard will almost certainly be used, so that measurement will entail 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; he may therefore be more generous with the tolerance he does 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.

The diagrams in Figure 2aa and Figure 2bb illustrate the practical significance of errors of measurement in the two cases.

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 micro-inches (0.000 06 in) per inch.

In many cases it will not be unreasonable to allow 20 per cent of the deviation to be absorbed by this error, i.e. the deviation must then be at least 300 micro-inches (0.000 3 in). If, however, safety zones are introduced to avoid encroaching on the deviation, the working tolerance of each component may be reduced by 60 micro-inches (0.000 06 in) per inch, 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 may be involved in either case, tolerance grades of IT7 and finer become unreasonable. For example, for a diameter of 100 in the encroachment at the go end of the tolerance may 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, BS 1916-1.

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

The chart in 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 this section, it is recommended that, where practicable, hole basis fits be used.

The dotted lines in the chart indicate to scale the extent of the zone of error of measurement based on an error of 30 micro-inches (0.000 03 in) per inch.

Examination of the diagram will show that:

- a) for a matched fit, most shafts are likely to be practicable, viz:

|                   |                |
|-------------------|----------------|
| clearance fits    | d, e, f.       |
| interference fits | p, r, s, t, u. |

- b) in a normal engineering shop, concerned with interchangeable fits, difficulty may be experienced with the 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., will, however, be 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.

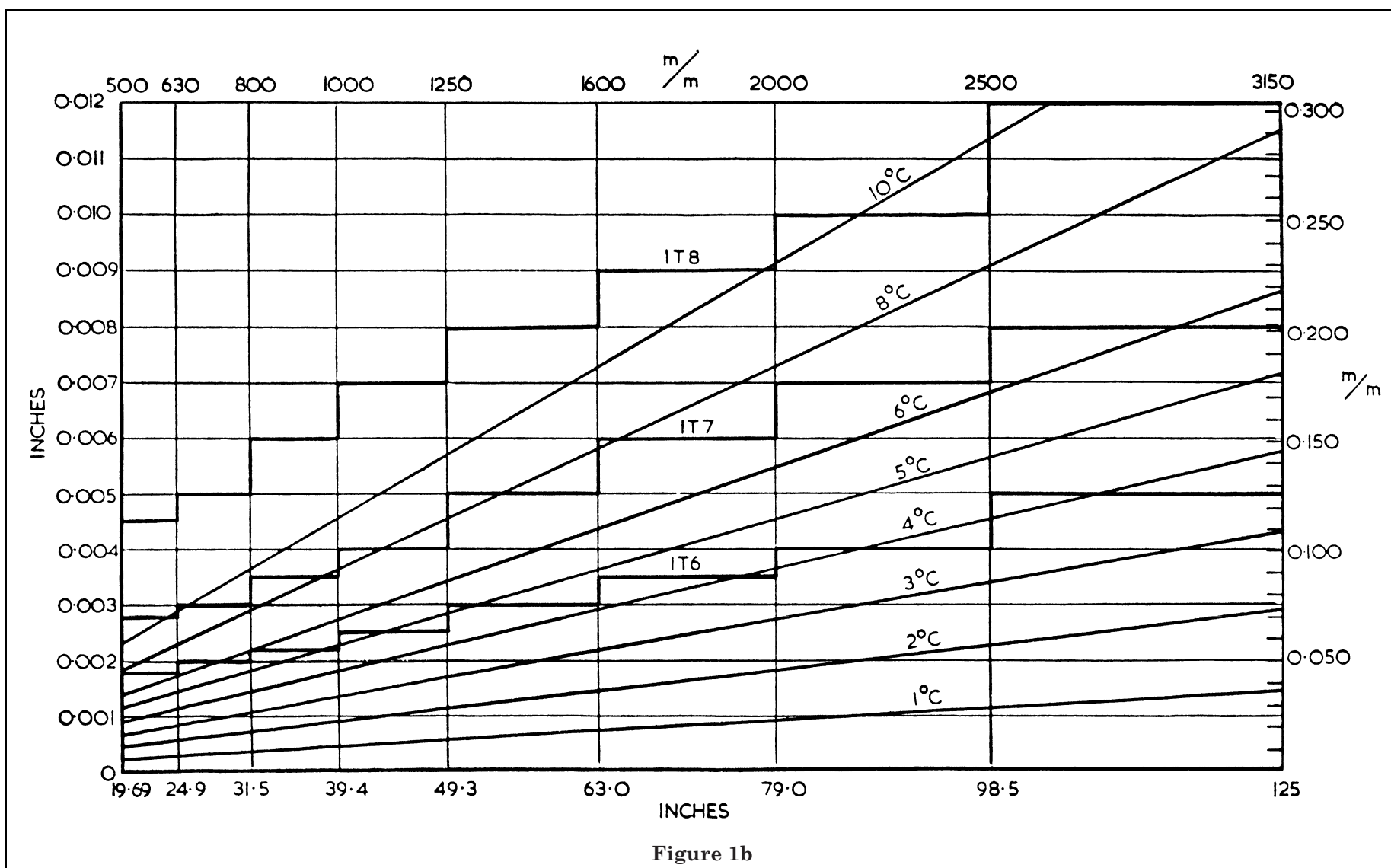


Figure 1b