

Guide to

The selection of fits —

Part 1: Limits and Fits for Engineering

Co-operating organizations

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Foreword

This standard makes reference to the following British Standards:—

BS 308, *Engineering drawing practice*.

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

The problems facing the design engineer tend to increase in number and complexity, but assistance in the form of clearly tabulated information dealing with certain aspects of design will often simplify the tasks of those engaged on widely differing types of work. There is evidence of a need for a convenient and comprehensive guide to the selection of suitable fits for particular types of application, and it is hoped that this publication will satisfy that need and prove a useful supplement to BS 1916-1:1953, which comprises the complete limit system in inch and metric units.

Preparatory work on such a guide was well advanced when a British delegation participated in a conference at Ottawa in November, 1950, to consider, with representatives from Canada and the United States, the possible unification of engineering drawing practice.

A session was devoted to discussion of the subject of limits and fits, and the conference expressed itself in the following terms:—

“The Conference recommends, from a Service standpoint, that the appropriate authorities in the United States and Canada be asked to co-operate with the BSI on the matter of the circulation of a questionnaire concerning limits and fits to the industries of the two countries in view of the fact that the resulting information will be useful in the ultimate preparation of standards of limits and fits, either individually or collectively”.

The decision of the British Standards Institution Committee on limits and fits to recommend a system based upon a conversion of the ISA system into inch measure has increased the need for guidance because it provides a greater choice of fits, whilst it still remains for the designer to select the most suitable combination of tolerances and allowances to suit his particular problem. Without guidance, selection from the wide choice offered by the system would result in the use of differing tolerances and allowances to meet the same design problem, and, whilst the resulting fits might be satisfactory, a lack of uniformity could arise which would lead to an indefensible multiplicity of gauges. It is thought that the recommendations in this guide book will help the designer to make consistent choices.

It is appreciated that some design problems will not be met by the recommendations given, but it is thought that such cases will be confined to few industries or firms. The committee also realize that designers may be presented with problems for which no exact category appears in the tables. In these instances it is thought that reliable guidance will be provided by the examples given.

The information contained in this guide has been summarized from recommended selections of fits made available in the form of standard sheets by countries which have had many years of experience of using the ISA system, and from the replies to questionnaires which have been circulated to many industrial organizations in Britain, America and Canada. By these means a survey of present day practice has been carried out, thereby ensuring that the recommendations made are based on practical experience rather than on purely theoretical considerations. The British Standards Institution will be pleased to receive from designers any further suggestions, comments or criticisms resulting from the use of this guide.

Special note

The recommendations given in this guide are based on the experience of a number of engineering firms and organizations. It is recognized that some requirements are not yet adequately covered and an early revision of the guide to include more material is envisaged.

In order that it may be as practical and helpful as possible, users are earnestly requested to submit to the Institution their comments, criticisms and constructive suggestions for consideration by the committee responsible. Any information supplied will be treated confidentially and will be of great assistance in rendering this guide of real value to industry.

Observations should be addressed to the Director, British Standards Institution, 2 Park Street, London, W.1.

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 to iv, pages 1 to 42, an inside back cover 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.

1 Scope

The recommendations made in this guide apply, in particular, to fits between cylindrical parts, designated by custom as “holes” and “shafts”, in which case the term “size” refers to the diameter of the mating parts. The recommendations are also applicable to parts other than cylindrical, in which case the term “size” refers to a length, width or other dimension.

Tables of preferred sizes are included to avoid the indiscriminate selection of dimensions, and their use is most strongly recommended.

2 Definitions

The definitions used throughout this standard are those in BS 2517.¹⁾ Figure 1 illustrates the basic definitions used in the text.

3 Terminology

The disposition of the tolerance zone for a HOLE relative to the basic size is denoted by a capital letter and the magnitude, or grade, of the tolerance by a suffix number:—

Thus: H7

The disposition of the tolerance zone for a SHAFT relative to the basic size is denoted by a small letter and the magnitude, or grade, of the tolerance by a suffix number:—

Thus: p6

A fit is described by a combination of symbols:—

Thus: H7 — p6 or H7/p6

(See BS 1916-1:1953, Sections 5 and 6.)

It is recommended that on production drawings the actual limits for both hole and shaft should be stated by one of the methods recommended in BS 308, “*Engineering drawing office practice*”, so that the actual size of the part can be ascertained without reference to the standard. There are, however, certain circumstances, for example in general specifications, or on preliminary design drawings, in which it is convenient to state the particular type of fit by symbols only.

4 Hole tolerances

The following is a summary of the uses of the various grades of the unilateral hole H from H5 to H11.

H5. This grade can normally only be produced by precision boring, fine internal grinding, or honing.

H6. This grade corresponds with the “B” hole of BS 164:1924²⁾, and can be produced by fine grinding or honing, and possibly hand reaming.

H7. This grade lies midway between the “B” and “U” holes of BS 164:1924. It is produced by grinding, broaching or careful reaming.

H8. This grade corresponds with the “U” hole of BS 164:1924, and is produced by boring or machine reaming.

H9. This grade corresponds with the “V” hole of BS 164:1924, it is also used on high quality products for milled or slotted widths.

H10. This grade is not normally used for diameter fits, although it can be used for drilled holes. It is used for milled widths on unimportant parts.

H11. This grade corresponds with the “W” hole of BS 164:1924, and is used for coarse drilled, punched or pressed holes on non-fitting parts.

¹⁾ BS 2517 “*Definitions for use in mechanical engineering*”.

²⁾ BS 164:1924, “*Limits and fits for engineering*”.

5 Classification of fits

The whole range of fits is divided into three main classes:—

Clearance

Transition

Interference

Each main class, using the unilateral (H) hole, is further sub-divided into several types of fit; for example, clearance fits are divided into six types, from very fine to very coarse clearance. Each type of fit is classified by the letter symbol of the shaft which produces that type, for example:—

Clearance fit, shaft “e”, *or*

Clearance fit, shaft “f”.

When familiarity with the various shaft symbols is gained it will be more convenient to refer to a type of fit by the shaft symbol only, e.g. an “e” shaft fit, or an “f” shaft fit. The classification is given on page 8 together with the names commonly applied to the various types of fit, and those fits using the H7 and H8 holes are illustrated in Figure 2. The use of these names is definitely not recommended, since a given type of fit in different materials may require a totally different shaft tolerance.

The interference fits are classified on the basis of the hole H7 mated with the various shafts. It should be remembered that the combination of these shafts with holes of coarser grades may in some cases result in a different type of fit. For example, in the case of the transition fit using shaft “n”, the fine grade, namely H6 — n5, will in fact result in a true interference fit, whereas the combinations H8 — p7 and H7 — r7 will produce transition fits, not interference fits.

Using the unilateral (H) hole, the resulting fits in combination with the various shafts are:

i) *Clearance fits.*

Shafts “a”, “b” and “c” These fits give a large clearance and are not widely used.

Shaft “d” This fit is available in grades 8 to 11 and is generally suitable for loose running fits, e.g. plummer block bearings and loose pulleys.

Shaft “e” This fit is available in grades 7, 8 and 9, and is recommended for general loose clearance fits, and for properly lubricated bearings requiring appreciable clearance. In the finer grades it may be used for large, high speed, heavily loaded bearings such as turbo-generator and large electric motor bearings, according to circumstances.

Shaft “f” This fit is available in grades 6, 7 and 8 and is recommended for use as a normal running fit. It is widely used as a normal grease lubricated or oil lubricated bearing where no substantial temperature differences are encountered. Typical applications are gearbox shaft bearings and the bearings of small electric motors, pumps, etc.

Shaft “g” This fit is expensive to manufacture since the clearance is small, and it is not recommended as a running fit except in precision equipment where shaft loadings are very light. Typical applications are the bearings for accurate linkwork, and for piston and slide valves. In addition it is often used for spigot or location fits.

Shaft “h” The upper shaft limit of this fit is zero, although in practice a slight clearance will usually be found. It exists in grades 5 to 11, and is widely used for non-running parts. It is useful for normal location and spigot fits and in the finer grades may be used as a precision sliding fit.

ii) *Transition fits.*

- Shaft “j” This is a transition fit averaging a slight clearance, and is available in grades 5 to 11. It is recommended for location fits, requiring slightly less clearance than is given with the “h” shaft, and where a slight interference is permissible. Typical applications are coupling spigots and recesses, gear rings clamped to steel hubs, etc.
- Shaft “k” This is a true transition fit averaging virtually no clearance. It is available in grades 5 to 11, and is recommended for location fits where a slight interference can be tolerated with the object, for example, of eliminating vibration.
- Shaft “m” This transition fit averages a slight interference, although appreciable assembly force will be required if the extremes are encountered. It is available in grades 5, 6 and 7.
- Shaft “n” This transition fit averages slightly more interference than the “m” shaft, and gives clearance only on extreme sizes. It is available in grades 5, 6 and 7, and is recommended for generally “tight” assembly fits. The finest grade (n5) is used as a true interference fit with the hole H6.

iii) *Interference fits.*

NOTE The factors governing the choice of an interference fit are such that only generalized recommendations can be made. Some general guidance is given here and some particular examples are quoted in the fit tables (Table 13 to Table 17), but it is recommended that in every case careful consideration be given to the factors affecting the fit, i.e. diameter and length of engagement, materials, surface finish, induced stresses, gripping forces, assembly forces and assembly method, before the final choice is made.

- Shaft “p” This will give a true interference fit with holes of grades 6 or 7, but with holes of grade 8 a transition fit will be obtained. The amount of interference is not excessive but is sufficient to give non-ferrous parts a light press fit which can be dismantled when required. It is the standard press fit for steel, cast iron or brass-to-steel assemblies. The amount of interference is too small for satisfactory fits to be obtained in very elastic materials, such as light alloys.
- Shaft “r” This combination will give a medium drive fit on ferrous parts, and on non-ferrous parts a light drive fit which can be easily dismantled when required. With the hole H8 an interference fit is obtained with diameters over 3.94 in.; with smaller diameters a transition fit results.
- Shaft “s” This is used for the permanent or semi-permanent assembly of steel and cast iron members, the amount of interference being sufficient to provide considerable gripping force. When using elastic materials, e.g. light alloys, it is equivalent to the “p” shaft fit in ferrous materials. Typical applications are collars pressed on to shafts, valve seatings, etc.
- Shaft { “t” These fits involve an increasing degree of interference, and no general recommendations
 “u” can be made.
 “v”
 “x”
 “y”
 “z”

When determining the tolerances for an interference fit, it is necessary to check the minimum as well as the maximum interference, the former with regard to the longitudinal forces and torques to be transmitted, the latter with regard to the permissible stresses in the material and the assembling and dismantling forces. Therefore, for interference fits, the lower deviations of the shafts were determined in such a way as to provide a definite amount of minimum interference with reference to the upper deviations of the hole H7.

If D = geometric mean of the diameter size range in inches, the amounts of minimum interference in units of 0.001 inch are as follows:—

Shaft.

- s Minimum interference = $0.4 \times D$ = (0.0004 inch per inch of dia.)
- t Minimum interference = $0.63 \times D$ = (0.00063 inch per inch of dia.)
- u Minimum interference = $1.0 \times D$ = (0.001 inch per inch of dia.)
- v Minimum interference = $1.25 \times D$ = (0.00125 inch per inch of dia.)
- x Minimum interference = $1.6 \times D$ = (0.0016 inch per inch of dia.)
- y Minimum interference = $2.0 \times D$ = (0.002 inch per inch of dia.)
- z Minimum interference = $2.5 \times D$ = (0.0025 inch per inch of dia.)

6 Choice of fit

The tables of recommended fits in this guide are compiled on the unilateral (H) hole basis system, but if unilateral (h) shaft basis fits are required the same maximum and minimum amounts of clearance or interference are provided by the equivalent shaft basis fits. For transition and interference fits this condition will only be satisfied if the holes are mated with a shaft of the next finer quality. Thus:

Hole basis clearance fit H7 — g6 = Shaft basis clearance fit G7 — h6.

Hole basis transition fit H7 — m6 = Shaft basis transition fit M7 — h6.

A complete list of interchangeable fits is given in Table 25.

The use of the unilateral hole basis is strongly recommended, but even so there is still a need for oversize and undersize holes for special applications, e.g. in the case of two different fits on the same shaft diameter. The system makes provision for this by a series of oversize holes (A to G), and a series of undersize holes (K to Z). Some of these latter will be found useful for outside diameter fits for ball bearings. (Tolerances for these holes will be found in Table 2 of BS 1916-1:1953).

Organizations using the metric system will find that, as a result of the interchangeability of the inch and metric tolerance tables of BS 1916-1:1953, the tolerance symbols given in the tables of recommended fits (Table 3 to Table 17 of this guide book) are equally suitable for inch or metric measure. When using metric measure the tolerance values associated with the symbols will be found in Table 4 to Table 6 of BS 1916-1:1953.

7 Choice of tolerance

In the selection of the grade (i.e. magnitude) of the tolerance as applied to the mating parts of a particular fit, it is strongly emphasized that in order to obtain the most economic manufacture consistent with satisfactory performance the tolerances should be as wide as possible. Figure 10, p. 41, illustrates the degree of accuracy which can reasonably be expected from various machine and manufacturing processes under average conditions.

In the allocation of tolerances to the hole and shaft members of a fit it is generally advisable, owing to the greater difficulty of producing a hole (in diameters of about $\frac{1}{4}$ in. and over), to allocate to it a slightly larger tolerance than to the shaft. In the tables of recommended fits which follow, it is assumed that in general the hole member will be allocated a tolerance one grade coarser than the shaft member, e.g. that holes H7 will be mated with shafts of grade 6.

8 Preferred sizes

The dimensions of manufactured products are determined from design calculations or from considerations of appearance and economy. In each instance the size may vary within certain limits and the designer, having established a theoretical size, will round it off to a convenient value. In rounding off it is strongly recommended that designers refer to the tables of preferred sizes in this guide, i.e.

Table 22: Fractional inch series

Table 23: Decimal inch series

and if possible make their selection of sizes from the “first choice” columns. If a finer division of size is required reference should be made to Table 24, which lists a complete series of preferred inch sizes.

The sizes listed as first choice in the fractional inch series are being used by the British Standards Institution as the basis of standardization and simplification of dimensions, and where it is intended to make use of standard tooling or to fit ancillary items complying with British Standards their availability will be improved by selection from this first choice list.

9 Recommended tolerances for standard fits

In order to facilitate and standardize the allocation of tolerances by design personnel, it is recommended that firms draw up tolerance data sheets in the manner of Figure 3, covering their standard products. The various fits on each assembly should be defined by symbol only, and will therefore be applicable to a range of sizes of that particular product. This procedure will considerably simplify the designer's task, and will relieve him of the responsibility of allocating tolerances. It will also reduce to a minimum the number of fits which are used, with corresponding savings in gauges and tools.

Figure 4 to Figure 9 illustrate typical engineering assemblies and indicate recommended tolerances for the mating parts in each.

Table 3 to Table 17 illustrate and describe each of the types of fit provided by the system and listed in Clause 5. In each type the selected grade of fit (i.e. the grade of tolerance used) for which the hole and shaft tolerances are listed in full, has been chosen as representing medium to good quality workmanship (see also “Classification of types of fits,” page 8). In any particular organization the choice of grade will depend upon the quality of work being produced and the type and quality of machine tools available, but it is recommended that a choice is made from the grades listed here. The complete range of available types of fit, comprising as it does 15 different types, is unnecessarily extensive for normal engineering requirements, and it will be desirable to compile a short list which will cater for all normal applications and yet achieve the maximum economy of fixed tools and gauges. The following series is suggested as being suitable for use by an organization engaged in good quality light or medium engineering production.

Class of fit	Symbol
Clearance	H8 — d8
	{ H6 — e7
	{ H8 — e8
	{ H6 — f6
	{ H7 — f7
	{ H8 — f8
	{ H6 — g5
	{ H7 — g6
	{ H7 — h6
	{ H8 — h7
Transition	H8 — j7
	{ H7 — k6
	{ H8 — k7
	{ H7 — m6
	{ H8 — m7
Interference	H7 — p6
	H7 — s6
	H7 — u6

The tolerance values for grades other than those whose values are listed in the tables may be obtained by reference to BS 1916-1:1953.

IMPORTANT NOTE It is emphasized that the illustrated examples of applications of each type of fit (see Table 3 — Table 17) are included for general guidance only, and it is appreciated that the fit combinations suggested are not the only solutions to any particular application. It is not implied, for example, that the combination H6 — e7, such as that illustrated in Table 5, is the only satisfactory one for reciprocating engine main bearings, for owing to the variety of conditions of speed, loading, lubrication, etc., which obtain between different engines it is unavoidable that some variation of fit should be encountered. It is considered, however, that the examples illustrated having been extracted from current information provided by the engineering industry, will provide a reliable guide, especially to those having little experience of tolerance application.

Furthermore, it must be pointed out that although the fit combinations recommended are known to be satisfactory in sizes of the order of those quoted in the examples, this does not necessarily hold true throughout the whole range of sizes covered by the tables, i.e. up to 20 inches. Therefore, the diameter of the mating parts has been quoted in each example, and the tolerance values in the size ranges up to 0.24 in. and above 7.09 in. have been printed in italics, indicating that if, within these size ranges it is necessary to specify a fit similar to one of the illustrated examples, all the relevant factors should be carefully considered before using the same fit combinations.

The range of sizes within which these recommendations are known to be satisfactory, i.e., from 0.24 in. to 7.09 in. will meet the majority of requirements, and it is felt that further experience should be gained before general recommendations can be made in the smaller and larger sizes.

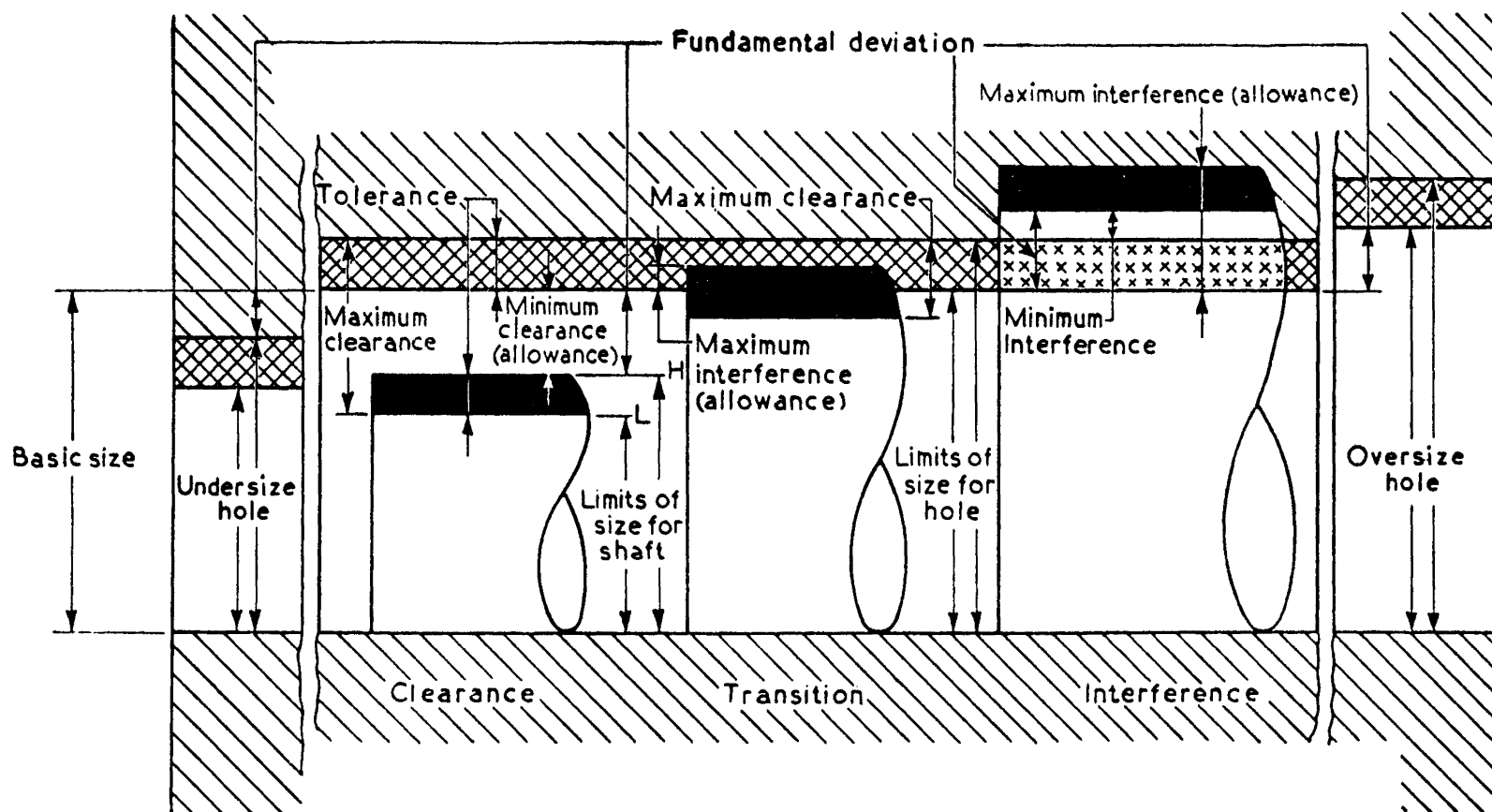


Figure 1 — Diagram showing disposition of limits and tolerances (unilateral hole basis)

Classification of types of fits

Classification		With holes				Remarks
		H6	H7	H8	H11	
Clearance	Shaft a	—	—	—	—	No general recommendation can be made.
	Shaft b	—	—	—	—	
	Shaft c		c8	c9	c11	Extra loose running.
	Shaft d		d8	d8/d10	d11	Loose running.
	Shaft e	e7	e8	e8/e9		Easy running.
	Shaft f	f6	f7	f8		Running.
	Shaft g	g5	g6	(g7 ^a)		Close running.
	Shaft h	h5	h6	h7/h8	h11	Slide.
Transition	Shaft j	j5	j6	j7		Push
	Shaft k	k5	k6	k7		Easy keying.
	Shaft m	m5	m6	m7		Tight keying.
	Shaft n		n6	n7		Drive.
				p7		
				r7		
Interference		n5				
	Shaft p	p5	p6			Light press.
	Shaft r	r5	r6			
	Shaft s	s5	s6	s7		Press.
	Shaft t	t5	t6	t7		
	Shaft u	u5	u6	u7		Heavy press or shrink.
	Shaft v	—	—	—	—	No general recommendations can be made.
	Shaft x					
	Shaft y					
	Shaft z					

^a This is a non-standard shaft. If required, the limits for it can be derived by reference to BS 1916-1:1953.

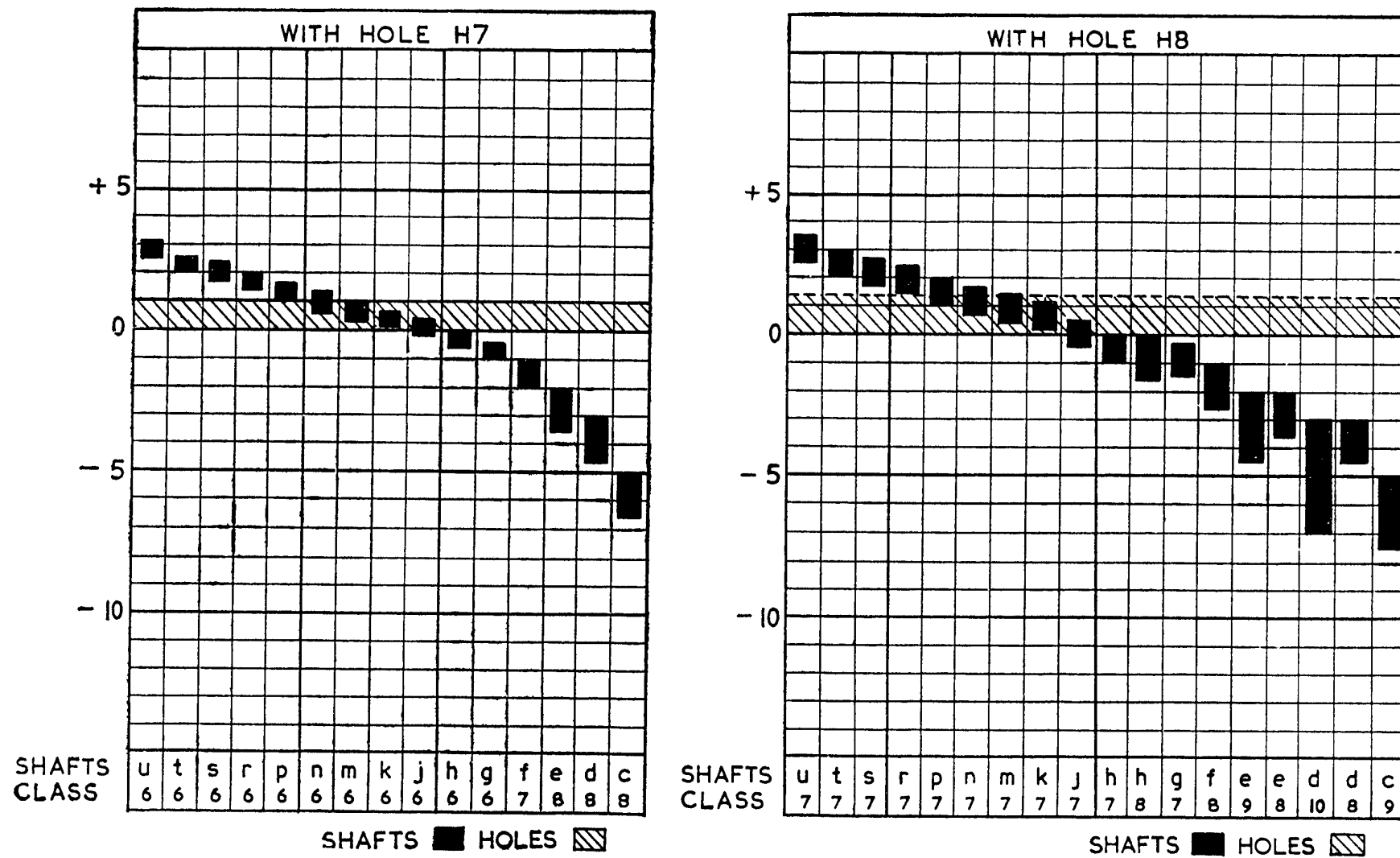


Figure 2 — The disposition of standard shaft fits with H7 and H8 holes for diameter range 1.19 in. to 1.97 in. Unit = 0.001 in.