

## SECTION 1, CHAPTER 2

### SCREW THREADS

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#### Introduction

1. A screw thread is the ridge produced by forming, on a cylindrical or conical surface, a continuous helical groove of uniform section: if the groove is formed on the external surface of a cylinder or cone the resulting ridge is said to be an external or "male" screw thread, while the ridge formed by cutting the groove in the wall of a cylindrical or conical hole is termed an internal or "female" screw thread. For simplicity, the term 'screw thread' is often abbreviated to 'thread', and a thread formed on a cylindrical surface is known as a "parallel thread" to distinguish it from a "taper" thread, which is formed on a conical surface.

2. If male and female threads are formed by cutting identical helical grooves in the external surface of a cylinder and in the wall of a cylindrical hole—this could be done, for example, by cutting a groove 0.08 in. deep on the surface of a cylinder of 1.0 in. diameter and a similar groove in the wall of a cylindrical hole 0.92 in. in diameter—then the two threads will "mate" when the threaded cylinder (the screw) is offered up

to the threaded hole of the "nut", and is turned in a given direction; this will also apply, of course, if the nut is offered up to the screw and is turned in the same direction. This combination of male screw and female nut is extensively utilized in engineering practice, the two major applications being in detachable fastening devices and as a medium for the transmission of mechanical effort. A screw thread is said to be "right-hand" if, when assembled with a fixed mating thread and turned in a clockwise direction, it moves away from the operator; if it moves towards the operator it is said to be "left-hand".

3. **Screw-Type Fastening Devices.** Just as a lever mechanism converts a low-value force acting over a considerable distance into one of much greater magnitude acting over a correspondingly shorter distance, so a small thrust applied radially to the moving member of a screw pair having one fixed component is reproduced as a thrust of much higher value delivered by the moving member along the axis of the screw. Consider, for example, the circumstances arising when

the moving member, on being turned through  $360^\circ$ , makes an axial advance of 0.1 in., and radial thrust is applied at a point 10 in. from the axis of the screw. To obtain an axial advance of 0.1 in., the radial thrust must be applied through one complete revolution of the moving member, i.e. through a distance of 10 in.  $\times 2 \times 3.142 = 62.84$  in. This is the equivalent of a lever system having arm-length ratio  $62.84 : 1$ ; hence a force of 1 lb. applied radially to the moving member will result in an output (axial) thrust of 62.84 lb. (neglecting internal losses due to friction, etc.). Moreover, the action of such a screw pair is, to all intents and purposes, non-reversing; hence a compression or strain that is imposed by the action of the screw pair is maintained when the radial (input) thrust is discontinued. A screw pair in which one member has no freedom of movement and the other is free to move both radially and axially can thus form the basis of fastening devices which, although easily detachable, give a strong clamping action in which compression is maintained indefinitely.

**4. Transmission or Conversion Screws.** Mechanical energy developed in an engine, electric motor, etc., is delivered from the output shaft in rotary form, but in some applications the energy must be converted into linear thrust acting over a distance. This conversion can be obtained by utilizing a special form of a screw pair, one member of which is secured to the output shaft of the power unit and is therefore able to turn but cannot move axially, while the other member is secured to the load and is free to move axially but cannot turn: as in the

case of the fixed-member pair used for fastening purposes, the thread used gives a very small axial movement for each complete revolution of the rotary member. The action of the rotary thread on the axially free member is similar to that of a fine wedge when it is driven between a fixed base and a movable weight, and just as a wedge of this type supports the weight in position when the driving force is discontinued, so the thread action maintains the sliding member in position after the rotary member has ceased to turn, no matter what linear thrust is imparted to the sliding member by the load.

### Terms Relating to Screw Threads

5. The principal terms used in connection with screw threads (Fig. 1) are as follows:—

(a) **Single-Start Thread.** This is formed when a single continuous helical groove is cut. Standard forms of screw-type fastening devices invariably make use of single-start threads.

(b) **Form.** The "form" of a screw thread is the shape of one complete contour of the thread between corresponding points on adjacent ridges, as revealed in an axial section.

(c) **Crest.** The crest is the prominent point of the thread, whether the thread be external or internal.

(d) **Root.** The root of the thread is the bottom point of the thread groove, whether the thread be external or internal.

(e) **Flanks.** The flanks of a thread are the straight sides which connect the crest and the root. The front flank is that which

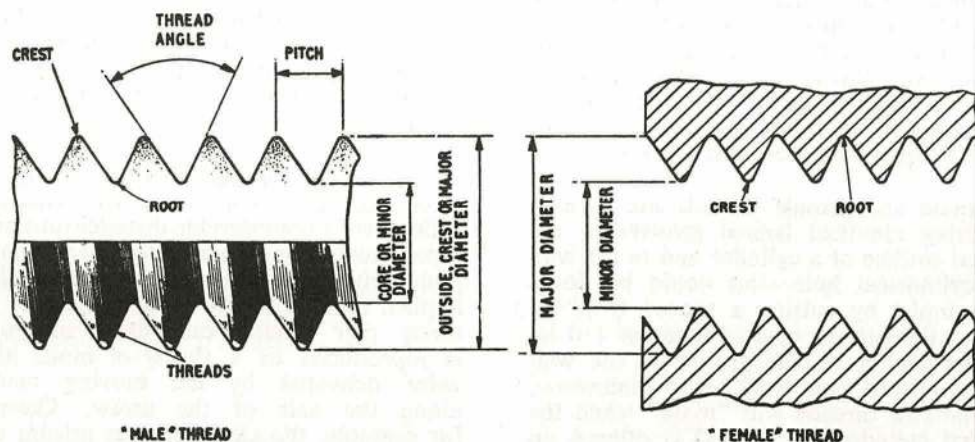


Fig. 1. SCREW THREAD DETAILS

faces the point of entry into the mating part of a screw pair.

(f) **Depth.** The depth of the thread is the radial distance between the crest and the root.

(g) **Thread Angle.** The angle made by the front and rear flanks of the thread is termed the thread angle.

(h) **Major Diameter.** The major diameter of a parallel thread is the diameter of the imaginary co-axial cylinder which coincides with the crests of an external thread or the roots of an internal thread. When applied to male screws, the major diameter is also referred to as the crest, outside or normal diameter.

(j) **Minor Diameter.** This is the diameter of the imaginary co-axial cylinder which coincides with the roots of an external thread or the crests of an internal thread.

(k) **Pitch.** The pitch of a screw thread is the distance, measured parallel to the screw axis, between corresponding points on adjacent thread forms in the same axial plane.

(l) **Lead.** The lead of a screw thread is the distance that the moving member of a

fine-pitch thread of the same major diameter, and the axial movement produced in a coarse-pitch pair for a given rate of turning is, consequently, more rapid than in a fine-pitch pair of similar major diameter. The increased rapidity of action is, however, obtained at the expense of the minor diameter of the male screw—this is appreciably smaller in the coarse-pitch pair, and the male member of this pair is correspondingly weaker than its fine-pitch counterpart, although the coarse-pitch threads are stronger. In general, it can be said that a fine-pitch screw, when embodied in a fastening device, has a stronger root portion, tighter grip, finer adjustment, and is more resistant to slackening under conditions of vibration than is a coarse-pitch screw of similar major diameter.

**7. Multi-Start Threads.** Where the screw thread is utilized as a medium for the conversion of rotary effort into high-value linear thrust, a fairly high ratio of axial movement to rotary movement may be desirable, yet this must be allied to maximum minor diameter for a given major diameter in the interests of mechanical strength. This requirement can, in many cases, be met by the use of a multi-start thread (Fig. 3), which is formed by cutting two or more

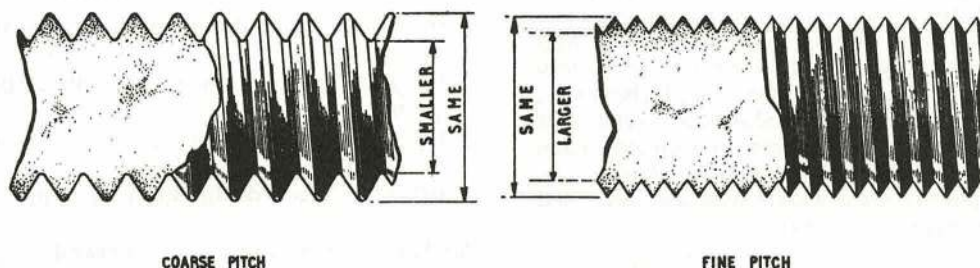


Fig. 2. PITCH OF SCREW THREADS

mating pair advances axially when it is turned through one complete revolution. The lead of a single-start screw thread is equal to its pitch.

**6. Coarse and Fine Pitch.** Two screw threads may have similar major diameters and thread forms, yet have different depths of thread (Fig. 2): in such a case the screw with the deeper thread will have fewer threads per inch of axial length, and its pitch is said to be coarser than that of the screw with the shallower thread. A coarse-pitch single-start thread has a greater lead than a

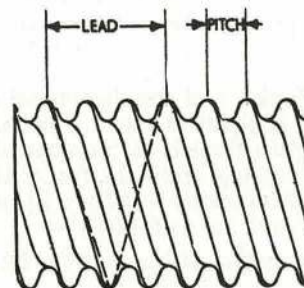


Fig. 3. MULTI-START THREAD (TRIPLE)

continuous grooves of identical characteristics to form the thread, the starts of the individual grooves being arranged symmetrically around the circumference. The definitions of lead and pitch, as given in para. 5, apply equally to both the single-start and the multi-start thread: the lead of a two-start thread is thus equal to twice its pitch; hence the operating speed of a two-start pair is twice that of a single-start pair having the same major and minor diameters.

## STANDARDIZED SCREW SYSTEMS

### Introduction

8. Interchangeability of components is essential if screw-type fastening devices are to be a practical proposition, and the first step towards interchangeability lies in obtaining a degree of standardization of the screw threads that are to be used in these devices. A single form of thread, with pitch related to major diameter, and common to all sizes of screw, could conceivably form a basis for such standardization. Unfortunately, a single thread form allied to a definite pitch for a given diameter can never be wholly satisfactory in all circumstances that arise in engineering practice, and a further objection to the standardization of a single system arises from the existence of two distinct systems of measurement, viz. the inch/foot system used in British and American practice, and the metric system used in Continental Europe and elsewhere. As a result several standardized systems of screw threads have been developed, each with individual characteristics. Those systems that are most widely used are described in subsequent paragraphs.

### British Standard Whitworth (B.S.W.) Thread

9. The B.S.W. thread (Fig. 4) has a symmetrical V-type thread-form with thread angle  $55^\circ$ ; the thread is rounded equally at crests and roots by circular arcs blending with the flanks, and the theoretical depth of the thread is equal to  $P \times 0.64$ . This is a coarse-pitch thread, the number of threads per inch varying from 24 for a thread of  $\frac{3}{16}$  in. major diameter to 4 for a  $2\frac{1}{2}$  in. thread. The basic sizes are as follows:—

- (a)  $\frac{3}{16}$  in. major diam. to  $\frac{3}{8}$  in. by steps of  $\frac{1}{16}$  in.
- (b)  $\frac{3}{8}$  in. major diam. to  $1\frac{1}{4}$  in. by steps of  $\frac{1}{8}$  in.

- (c)  $1\frac{1}{2}$  in. major diam. upwards by steps of  $\frac{1}{2}$  in.

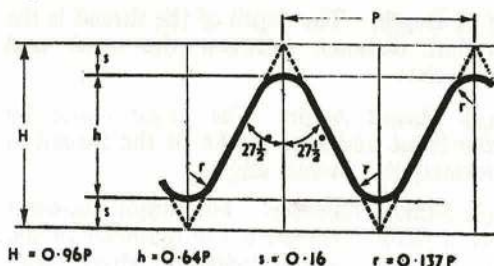


Fig. 4. STANDARD FORM OF WHITWORTH (B.S.W.) THREAD

### British Standard Fine (B.S.F.) Thread

10. The B.S.F. thread uses the same thread-form as the B.S.W. thread, but has a finer pitch: for example, the B.S.W.  $\frac{1}{4}$  in. screw has 20 threads per inch of axial length, while the B.S.F.  $\frac{1}{4}$  in. screw, which has the same major diameter, has 26 threads per inch. The advantages of fine pitch in screw-type fastening devices have already been mentioned in para. 6; because of these advantages, the B.S.F. thread was standardized for use on British aircraft, aero-engines, mechanical transport, mobile equipment and the associated electrical equipment (from  $\frac{1}{8}$  in. upwards). The basic B.S.F. screw sizes are as follows:—

- (a)  $\frac{1}{8}$  in. major diam. to  $\frac{5}{8}$  in. by steps of  $\frac{1}{8}$  in.
- (b)  $\frac{3}{8}$  in. major diam. to 1 in. by steps of  $\frac{1}{8}$  in.
- (c)  $1\frac{1}{8}$  in. major diam. to  $1\frac{3}{4}$  in. by steps of  $\frac{1}{8}$  in.
- (d) 2 in. upwards by steps of  $\frac{1}{2}$  in.

### British Association (B.A.) Thread

11. This fine-pitch thread (Fig. 5) differs from the B.S.W. and B.S.F. threads in having a thread-angle of  $47\frac{1}{2}^\circ$ ; the feature of equal

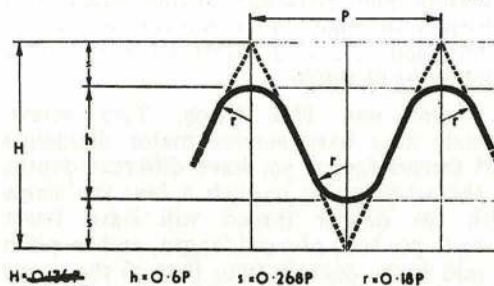


Fig. 5. STANDARD FORM OF BRITISH ASSOCIATION (B.A.) THREAD

rounding of crests and roots is retained. Actual diameter measurements are not quoted in this system: the smallest size, No. 10, has a major diameter of 0.067 in., while the largest, No. 0, has a major diameter of 0.236 in. This is the standard thread for British aircraft work under  $\frac{1}{4}$  in., for instruments, and for most small items of electrical equipment.

### British Standard Pipe

12. This specialized form of standard thread has a fine pitch, and a thread angle of  $55^\circ$  with rounded crests and roots; the thread may be either parallel or tapered. As the name implies, it is essentially for use on pipe connections; the fine pitch ensures that sufficient uncut metal is left on the pipe wall to guarantee a strong connection, and, when the thread is tapered (1 in 16 on diam.), this assists in making a pressure-tight joint. Sizes are based on nominal internal diameter of the pipe; thus a  $\frac{1}{4}$  in. B.S.P. thread has a major diameter of 0.518 in. Basic B.S.P. sizes are as follows:—

- (a)  $\frac{1}{8}$  in. (internal pipe diam.) to 1 in. by steps of  $\frac{1}{8}$  in.
- (b)  $1\frac{1}{4}$  in. to 3 in. by steps of  $\frac{1}{4}$  in.

### British Standard Conduit

13. Screw threads used on metal conduits, couplers and fittings are of standard Whitworth form, as described in para. 9, but the pitch and depth of thread relative to the major diameter are much finer than B.S.F. threads of comparable diameter. Right-hand threads only are used, and sizes, based on the nominal outside diameter of conduit, are as follows:—

- (a)  $\frac{1}{2}$  in. and  $\frac{3}{8}$  in.—18 threads per inch.
- (b)  $\frac{3}{4}$  in., 1 in. and  $1\frac{1}{4}$  in.—16 threads per inch.
- (c)  $1\frac{1}{2}$  in., 2 in. and  $2\frac{1}{2}$  in.—14 threads per inch.

### Metric or Systeme International (S.I.)

14. This type of thread (Fig. 6) is of Continental origin, all dimensions being expressed in millimetres. The thread form is noticeably different from that used in British Standard threads; the thread angle is  $60^\circ$ , while crests and roots are flattened equally to an extent shown in the diagram. The pitch is between that of the B.S.W. and B.S.F. threads; as a result this thread has general

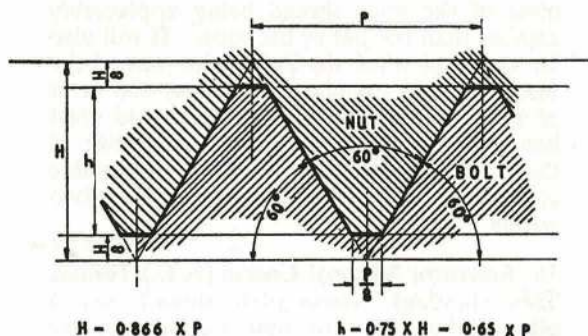


Fig. 6. STANDARD FORM OF METRIC THREAD

applications for general engineering, aircraft and mechanical transport work. Pitches and major diameters between 6 mm. and 80 mm. are standardized internationally; above and below these limits national differences become apparent—for example, the 5 mm. thread used in Germany and Switzerland has a pitch of 0.8 mm., while the 5 mm. thread used in France has a pitch of 0.9 mm. Apart from the S.I. threads, a fine-pitch series of metric threads is also available for special purposes.

### American Threads

15. Two standard American threads, the American National Coarse and the American National Fine, approximate to the B.S.W. and B.S.F. threads respectively, and are used for corresponding purposes. The thread form is quite different from that used in British threads; in many ways it resembles the metric thread, but there are certain important differences. Examination of Fig. 7 will show that the flattening of crest and root of the thread is not equal, the flat on the

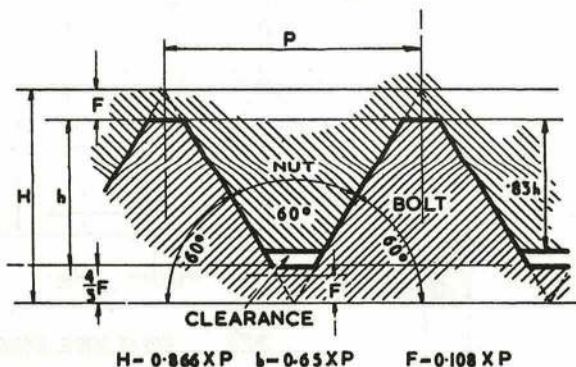


Fig. 7. STANDARD FORM OF AMERICAN NATIONAL SCREW THREAD

crest of the male thread being appreciably smaller than the flat at the root. It will also be seen that while the flat at the root of the female thread matches the flat at the crest of the male thread, the male thread crest has a flat considerably wider than that at the male thread root, and a noticeable clearance is thus created between these two points.

#### 16. American National Coarse (N.C.) Thread.

This standard coarse-pitch thread has a pitch-to-diameter ratio that is approximately equal to that of the B.S.W. thread—the pitch of the 1-in. N.C. thread is 0.125 in., the same as the pitch of the 1-in. B.S.W. thread. Sizes range from No. 1 (major diameter 0.073 in.) by steps of 0.013 in. to No. 12 (0.216 in. major diameter); beyond this point, sizes are indicated by quoting major diameters in fractional inch measure—they range from  $\frac{1}{4}$  in. by steps of  $\frac{1}{16}$  in. to  $\frac{5}{8}$  in., then by steps of  $\frac{1}{8}$  in. to  $1\frac{1}{2}$  in., and upwards by steps of  $\frac{1}{4}$  in.

#### 17. American National Fine (N.F.) Thread.

This thread uses the same thread form as the N.C., but has a much finer pitch; the range of sizes is as for the N.C. thread. The pitch is considerably finer than that of B.S.F. threads of corresponding size—the 1-in. N.F. thread has a pitch of 0.071 in. (just over 14 threads per inch) as compared with a pitch of 0.1 in. (10 threads per inch) of the 1-in. B.S.F. thread.

### Unified Screw Threads

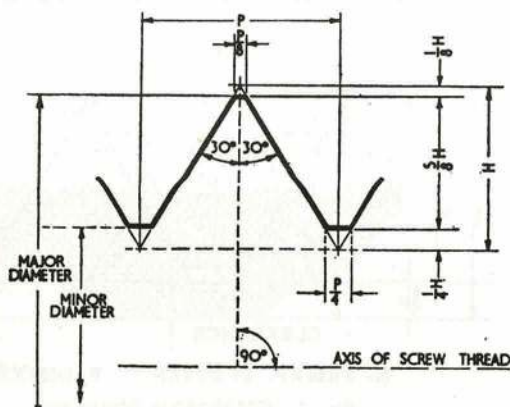
18. The need for a common standard for screw threads has long been recognized, and negotiations between the Standards

Institutions and Associations of the United Kingdom, Canada, and the United States resulted in the adoption of unified standard screw threads with metric equivalents. These threads are of two basic series, in which major diameter is related to pitch; both use the same thread form, and they are designated as the Unified Coarse Thread (U.N.C.) and the Unified Fine Thread (U.N.F.). The U.N.C. series of threads corresponds to the B.S.W. and A.N.C. series so far as applications are concerned and covers sizes ranging from  $\frac{1}{4}$  in. (major diameter) up to 4 in.; the U.N.F. series of threads corresponds to the B.S.F. and A.N.F. series, and is available in fractional sizes ranging from  $\frac{1}{4}$  in. to  $1\frac{1}{2}$  in.

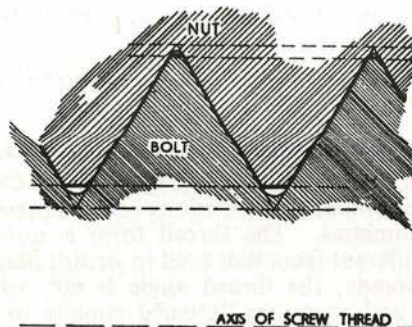
*Notes.* 1. For diameters or pitch of thread outside the range of the two basic types, a Unified Special Thread (U.N.S.) is available.

2. It is intended to introduce Unified threads below  $\frac{1}{4}$  in. diameter, which will supersede the B.A. range of screw threads.

19. **Thread Form.** The basic form of the Unified thread (Fig. 8) is derived from an equilateral triangle disposed with one side parallel to the axis of the screw thread. This triangle is truncated by an amount equal to one-eighth of its height ( $\frac{H}{8}$ ) at the major diameter of the thread, and by an amount equal to one-quarter of its height ( $\frac{H}{4}$ ) at the minor diameter; the truncation at the major diameter of the triangle has a width



BASIC FORM



PRACTICAL FORM

Fig. 8. UNIFIED STANDARD SCREW THREAD FORM

equal to one-eighth of the pitch ( $\frac{P}{8}$ ), while that at the minor diameter has a width equal to one-quarter of the pitch ( $\frac{P}{4}$ ).

**20. Internal and External Threads.** In practice, the form of the internal thread used in nuts and that of the external thread used on bolts, etc., differs slightly from the basic form. As regards the internal thread, the roots are rounded and cleared beyond the width ( $\frac{P}{8}$ ) to avoid sharp corners; the form is otherwise the same as the basic form. Similarly, the practical form of the external thread is much the same as the basic form except that the roots are rounded below the width ( $\frac{P}{4}$ ). Although the crests should be

flat, modern manufacturing methods result in the production of external threads with crests which are, to some extent, rounded rather than flat.

**21. Classification.** The quality (class of fit) of internal and external Unified threads is divided into three classes:—

- (a) **Class 1.** This class applies to screw threads of commercial quality.
- (b) **Class 2.** This class applies to the better grade screw threads, and is used for aircraft parts.
- (c) **Class 3.** This class applies to screw threads which require a fine snug fit; it is a close tolerance thread.

*Note.* In addition, the letters A and B are used to classify the thread, e.g., 2A indicates an external thread (bolt), and 2B indicates an internal thread (nut). A class 2A bolt would be assembled with a class 2B nut and so on.

**22. Designation.** Screw threads of Unified form are referred to on drawings by:—

- (a) Diameter of shank ( $\frac{1}{4}$ ).
- (b) Number of threads per inch (20).
- (c) Series (U.N.C.).
- (d) Class (3A), and, if necessary,
- (e) L.H. to indicate left-hand threads, e.g.,  $\frac{1}{4}$ —20 U.N.C.—3A L.H.

**23. Identification.** The symbol used for visual identification of Unified threads is the circle; usually three circles with their borders touching. This symbol is marked on the part or adjacent to the component, so that it will be visible after assembly.

*Notes.* 1. Where components have Unified screw threads, replacement parts must also have these threads.

2. Machined and forged hexagon headed bolts and nuts are marked with three circles on one of the flats. Cold-headed bolts and screws may have a shallow depression (depth .015 in.) in the centre of the head, approximately equal to the shank diameter.

### Transmission Threads

**24.** The basic principle of converting a radial force into a linear thrust through the medium of mating screw threads is discussed in para. 4. There is not the same need for interchangeability between transmission screw components—these are, in many cases, “tailor-made” to suit a particular requirement, as opposed to the mass production methods adopted for screw fastenings—and relatively little standardization is to be found in the field of transmission screw threads. The outstanding exception is the Acme screw thread, an American transmission thread, the basic form of which is shown in Fig. 9. This thread makes use of a thread angle of  $29^\circ$ , and the basic triangle of the thread form is truncated to give flat crests and roots of equal width, and a depth of thread equal to one-half of the pitch. A variant of the Acme thread, known as the

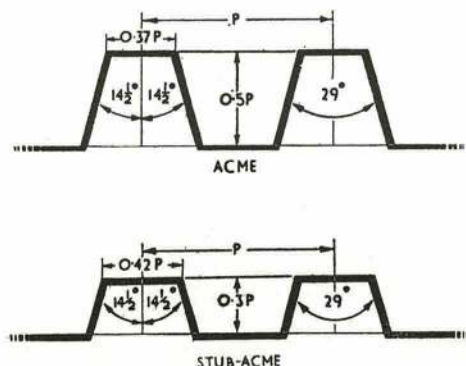


Fig. 9. BASIC FORM OF AMERICAN ACME AND STUB-ACME THREADS

stub-Acme (Fig. 9), has a similar basic triangle, but in this case the degree of truncation is such as to give a depth of thread equal to  $0.3 \times \text{pitch}$ . These threads are suitable for transmitting mechanical effort in either direction.

25. Another form of thread that is widely adopted is the square thread (Fig. 10), a non-standardized thread which is used, often in multi-start form, in many types of electrical linear actuators. Both flanks of this thread form are parallel and are set at  $90^\circ$  to the screw axis, the crests and roots being flat and parallel to the axis. Frictional losses are, naturally, very considerable in screw systems of the square and acme types, and recent developments of the transmission screw aim at reducing these losses by the introduction of what is virtually a "ball-bearing" screw: in this, the normal male and female threads are replaced by two helical grooves of semi-circular section which together form a helical "tunnel" of circular

section; the tunnel so formed is filled with steel balls, and a re-circulating device ensures that the balls are fed continuously into the tunnel as the axial member of the screw pair moves along the rotary member.

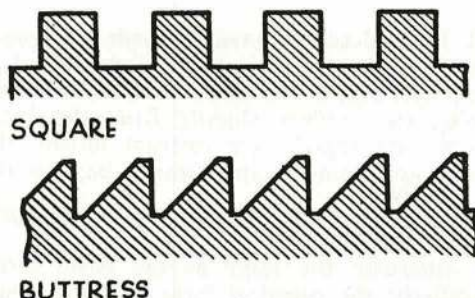


Fig. 10. TYPES OF THREADS

26. **Buttress Thread.** This thread (Fig. 10) is used for transmitting great pressure in one direction, as in vices.

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