the coarser errors were eliminated. Another method was that of the mathematical instrument makers, who used a screw and tangent wheel by which a cutter was moved along synchronously with the revolution of the screw blank, a method only suitable for short screws. The first attempt at securing uniformity in screw threads was made by Sir Joseph Whitworth, who communicated a paper on the subject to the Institution of Civil Engineers in 1841. In the course of about twenty years the Whitworth system generally displaced the previous heterogeneous designs of threads, by the existence of which engineers’ repairs had been rendered most inconvenient and costly, almost every establishment having its own “ standard ” set of screwing tackle. In fact it was suspected that firms thought their interest lay in this separation of practice in order to capture repairs, each of its own work.

When Whitworth began his work he made an extensive collection of screw bolts from the principal English workshops, and an average observed for diameters of ¼ in., ½ in., 1 in., and 1½ in. chiefly was taken and tabulated in exact numbers and equal fractional parts of threads per inch, the scale being afterwards extended to 6-in. diameter. In cases above an inch the same pitch is maintained for two sizes, the object being to avoid small fractions, and to simph\*fy the construction of screwing apparatus. The system is therefore a practical compromise based on previous practice. The proportion between pitch and diameter varies throughout the series, and at the extremes the amount of power required to turn a nut is either in excess or insufficient.

When the Whitworth threads were accepted in England, Germany and the United States, it appeared as though they were established for ever in an impregnable position, as a unifica­tion evolved from chaos. Moreover, Great Britain at that time occupied a position of pre-eminence in manufacturing engineering, which was favourable to the establishment of an English system. But two things were wanting to permanence—the facts that the Whitworth threads were not based on the metric system, and that the United States was destined to come into rivalry with Great Britain. Metric systems became standardized on the continent of Europe and the Sellers thread in America overshadowed the Whitworth, though it is impossible to doubt that the Sellers like the Whitworth must in time be swallowed up by some one metric system.

It is easier to devise new standards than to induce manufacturers to accept them. Change means the purchase of a very costly new equipment of screwing tackle, both hand and machine, besides the retention of the old for effecting repairs. There is no question of accommodating or bringing in the threads of one system to others nearly like them. They either fit or do not fit, they arc right or wrong, so that a clean sweep has to be made of the entire screwing tackle in favour of the new. The two great attacks that have been made on the Whitworth thread came, one from the Franklin Institute in 1864, when the Sellers thread was adopted and recommended to American engineers, and the other in 1873, when Delisle of Carlsruhe initiated a metric system. As a result, after several years of effort, the Society of German Engineers took the matter up, and the appointment of a committee gave birth to the International Screw Thread Congress, which has met from time to time for the discussion of the matter. We have thus two broad lines of departure from the Whitworth standard.

The history of the battle of the screw threads in England, America, Germany, Switzerland and France would occupy a volume. The subject is highly technical, involving practical points concerned with manufacture as well as with questions of strength and durability. We can merely state the fact that the threads now recognized as standard are included in about eight great systems, out of about sixty that have been advocated and systematized. Their elements are shown by the diagram, fig. 1; but tables of dimensions are omitted, since they would demand too much space.

*Methods of Cutting Screws.—*There are four methods employed for the cutting of screw threads: one by means of a single-edged tool

held in the saddle of the screw-cutting lathe, and traversed horizon­tally only, the cylinder which is to receive the thread revolving the while; another by means of short master screws, hobs or leaders, controlling chasers or comb tools; the third by means of screw taps

Formulae: *p* = pitch, or distance between centres of contiguous threads; *d* = depth of thread; *h =* total height of thread construction; *r* = radius ; *f* = flat.

A. Whitworth thread. *h* = 0·9605 *p;* d = 0·6403 *p;* leaving ⅛th *h* to be rounded at top and bottom.

B. Sellers, or Franklin Institute, or U.S. standard thread. *h* = 0·866 *p; d* = 0∙6495 *p;* *f* = ⅛th *p.*

C. Sharp Vee thread. *d* = 0∙8660 *p.*

D. British Association standard thread. *d* = 0∙6 *p;* *r =* 2/11th *p.*

E. C.E.I. or Cycle Engineers’ Institute standard thread. *h* = 0∙866 *p;* *d* = 0·5327 *p*; *r* = 1/6th *p.*

F. Löwenherz or Delisle thread (metric, used largely on the continent of Europe). *h = p;* *d* = 0·75 *h*; *f* = ⅛th *h*.

G. International standard thread (metric). *d* = 0∙6495 *p; f* = ⅛th *h*; *r* = 1/16th *h.*

H. Thury thread (metric). *d =* ⅗th *p;* *r'* = ⅙th *p;* *r' =* ⅙th *p.*

J. Square thread. *d* = ½ *p.*

K. Acme thread. *d* = ½ *p* + 0·010; *f* = 0·3707 *p*.

and dies, either the work or the tool being absolutely still. The fourth is by means of a milling cutter presented to the work in a special screw-milling machine, both the work and the cutter revolving.

The problem of screw-cutting in the lathe in the simplest form resolves itself into the relative number of revolutions of the lathe spindle and of the lead screw (fig. 2). If the two rotate at the same speed, the thread cut on the spindle axis will be equal in pitch to that of the lead screw. If the spindle revolves more slowly than the lead screw, a thread coarser than that in the latter will result; if it revolves more rapidly, one of finer pitch will be produced. The spindle is the first factor, being the *driver,* and the lead screw is *driven* therefrom through the change wheels— the variables—which determine the number of revolutions of the latter whether the same, or slower, or faster than the spindle. Screw- cutting in all its details is an extensive subject, including the cutting of what are termed odd or unequal pitches, that is, those which involve fractions, the catching of threads for successive traverses of the tool, the cutting of multiple threads and of right- and left-hand threads, which involve much practical detail. The principle of screw- cutting may be stated briefly thus: the pitch of the guide screw is to that of the screw to be cut as the number of teeth on the mandrel or (headstock) wheel is to the number of teeth on the lead screw wheel. It is therefore simply a question of ratio. Hence for cutting threads finer than that of the lead screw, the guide screw must rotate more slowly than the lathe mandrel ; and for cutting threads coarser than those of the guide screw, the lead screw must rotate faster than the lathe mandrel (fig. 2, C and D). When the ratios are ascertained, these facts indicate when the larger or the smaller wheels must be placed as drivers, or be driven. “ Simple trains ” are those which contain only one pair of change wheels; “ compound trains ” have two, three, four or more pairs (fig. 2), and are necessary when the ratio between the guide screw and the screw to be cut exceeds about six to one.

A device which has become very popular under the name of Hendey-Norton gears comprises a nest of twelve change wheels, mounted and keyed on the end of the lead screw. A stud wheel is made to engage through an intermediate wheel with any one of the twelve change gears, on the simple movement of a lever, giving twelve