

[54] **LOCKING FASTENER**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 91,730, Nov. 23, 1970, abandoned.

[52] U.S. Cl. **151/22, 85/46, 10/111**

[51] Int. Cl. **F16b 39/30**

[58] Field of Search **151/22, 21 B; 85/46**

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[57]

ABSTRACT

A locking screw arrangement and fastener member are disclosed which provide for predictability and control of the locking action attained. In addition, there is disclosed a novel type of locking thread configuration wherein the leading or following flank of one or more thread turns on the fastener are bulged outwardly in an axial direction, with the opposite flank depressed, whereby said bulged flank will engage the corresponding flank of the female member to produce flank-to-flank interference. In order to obtain said predictability and control, said locking arrangement employs an internally threaded female member having a thread configuration formed within industry accepted tolerances, which female member is engaged with an externally threaded fastener having a construction which eliminates any variables due to the tolerance encountered in the thread form of the female member that adversely effect the locking action. In this regard, the threaded portion of the fastener includes a preparation section and a locking section, the thread turns and the preparation section being such as to reshape and size the internal thread of the female member upon engagement therewith, thereby eliminating the effect of dimensional variables that may be encountered. Therefore, upon subsequent engagement of said reshaped internal threads with the thread turns of the locking portion, a predetermined locking action will be obtained.

21 Claims, 16 Drawing Figures

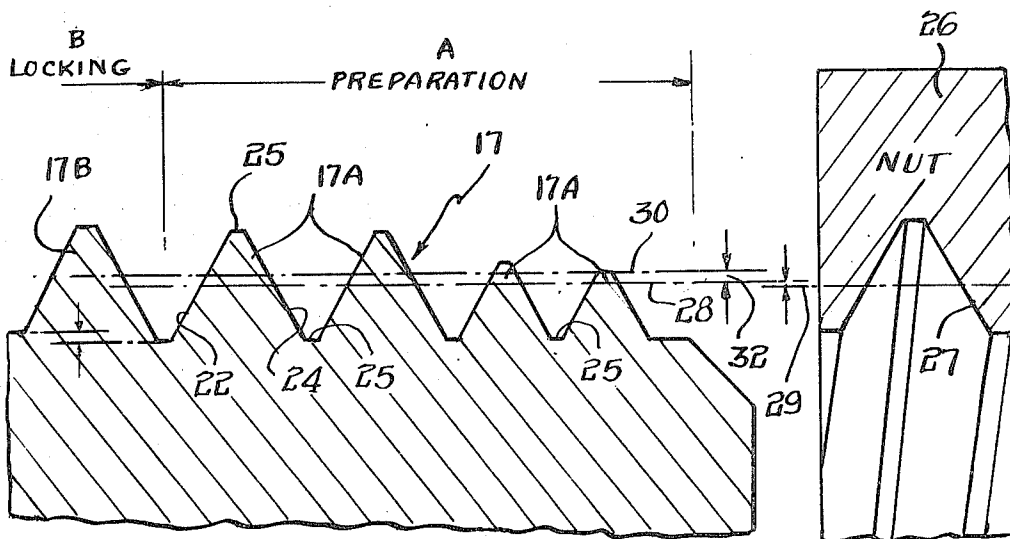


FIG. 1.

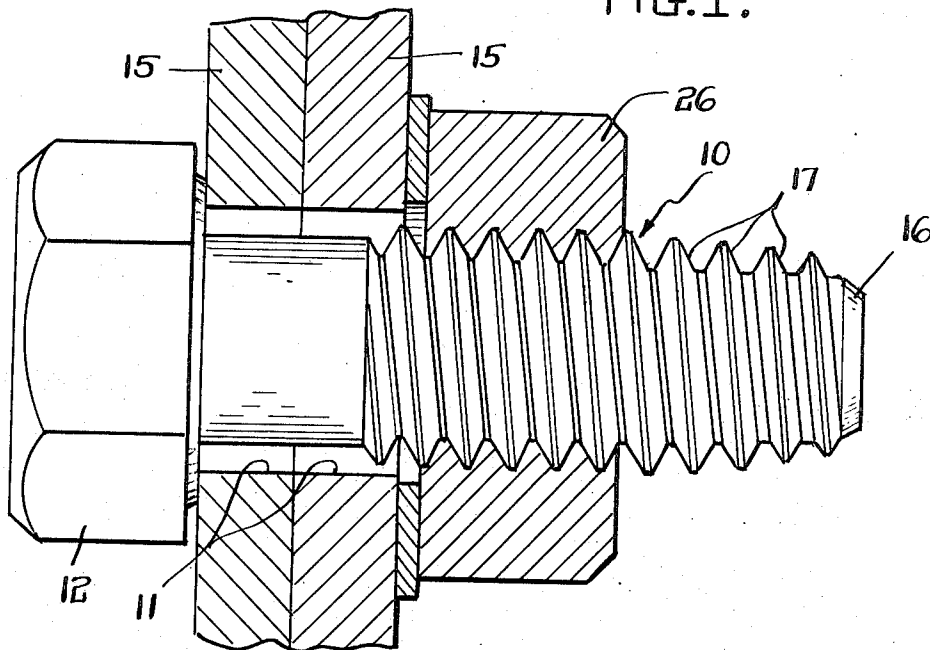


FIG. 2.

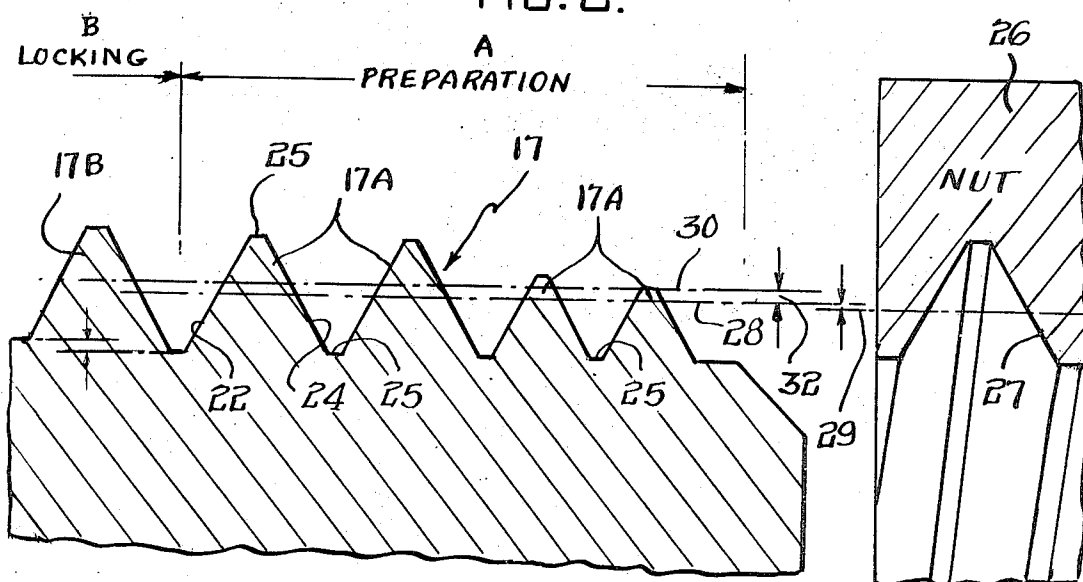


FIG. 3.

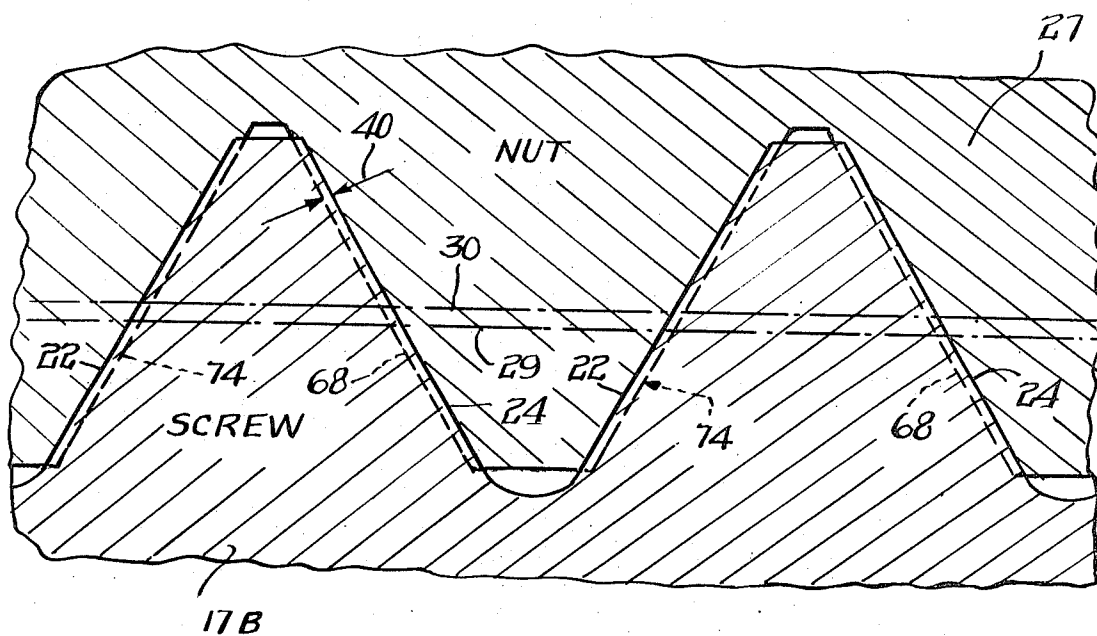
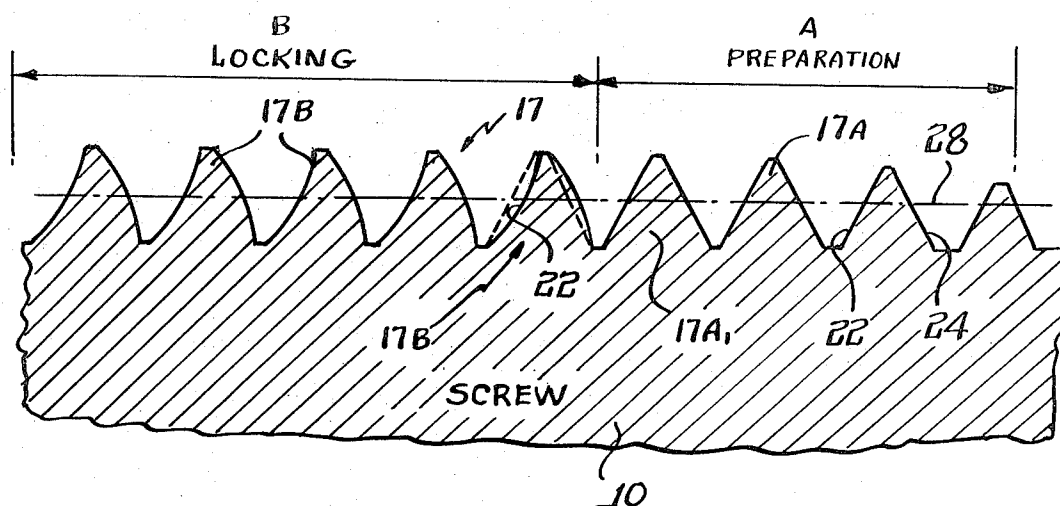
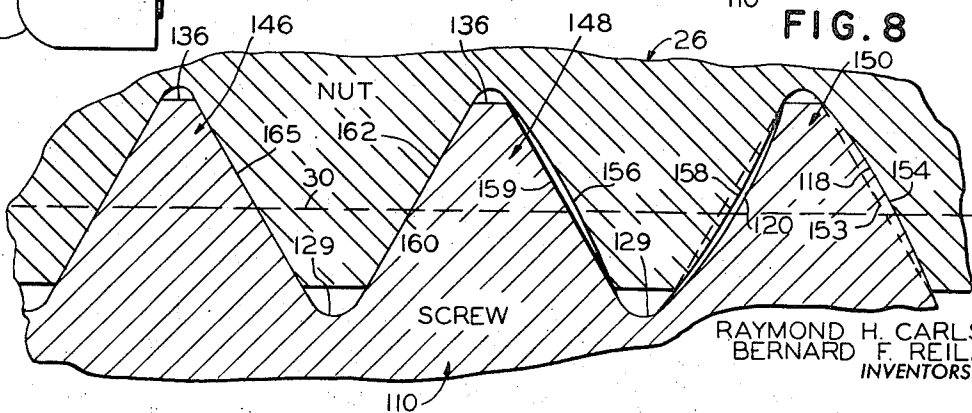
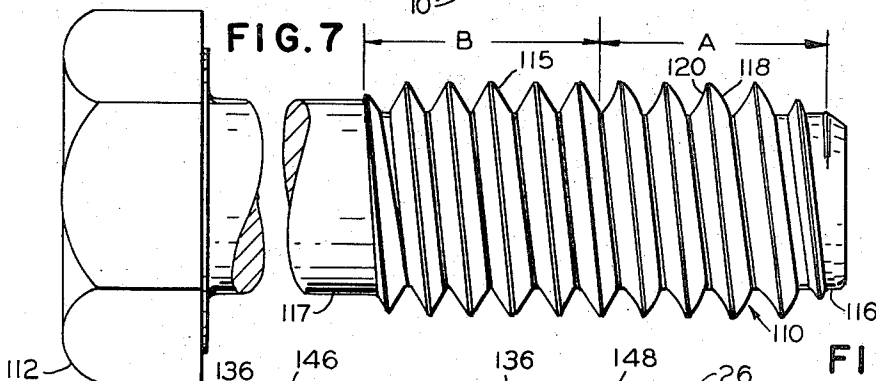
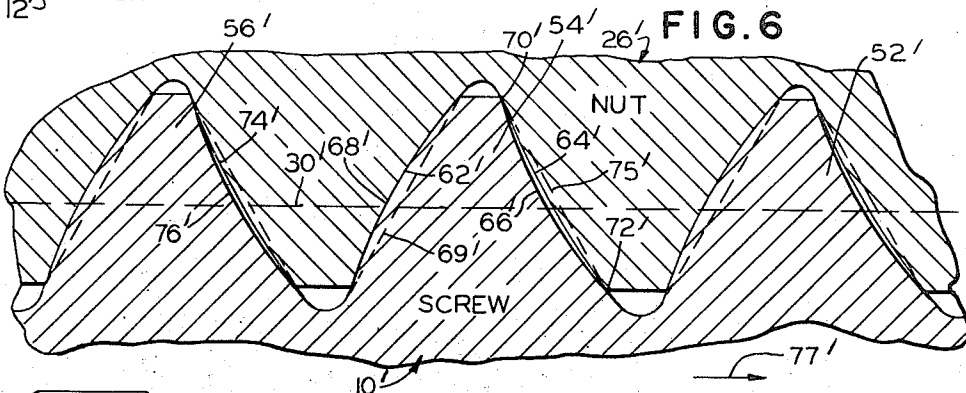
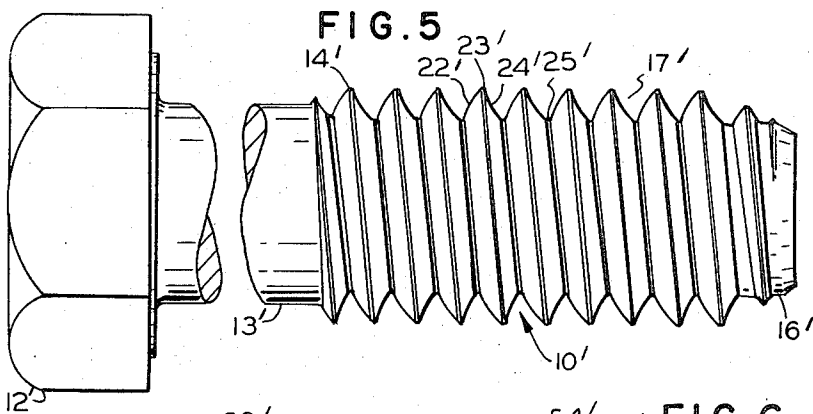
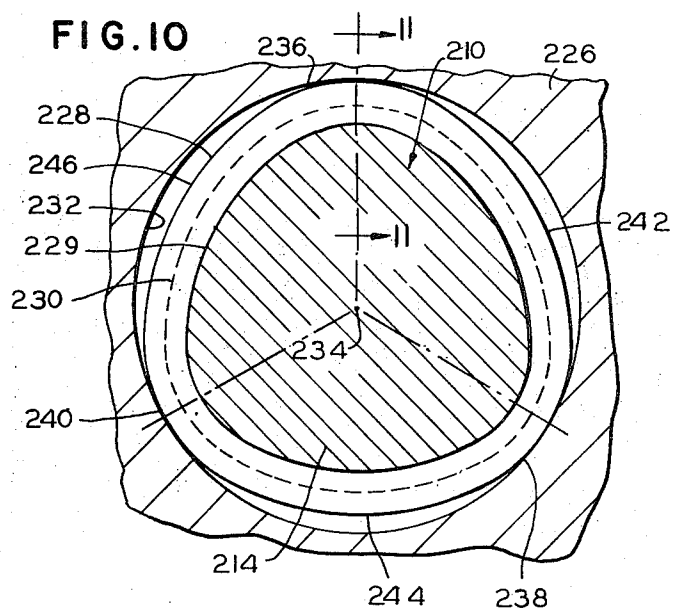
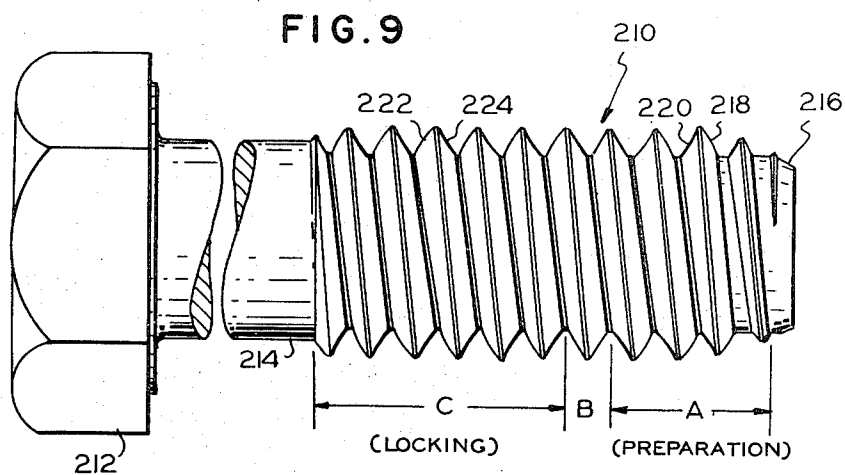


FIG. 4.





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FIG. 11

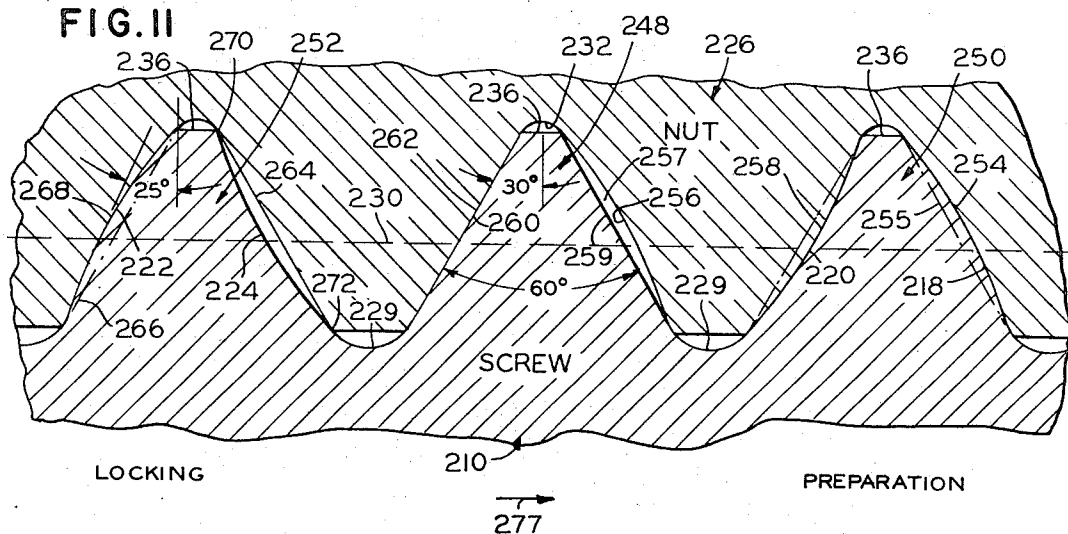


FIG. 12

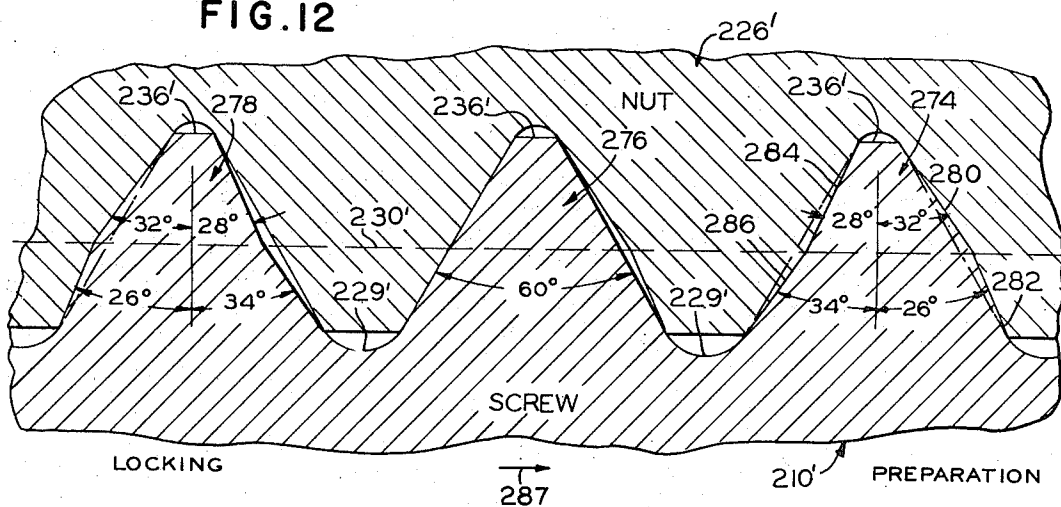


FIG. 13

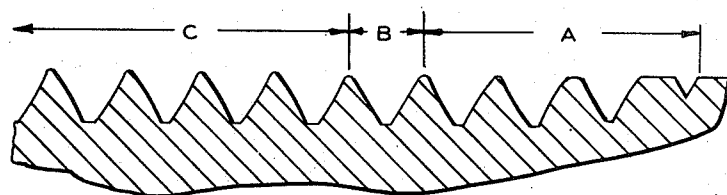
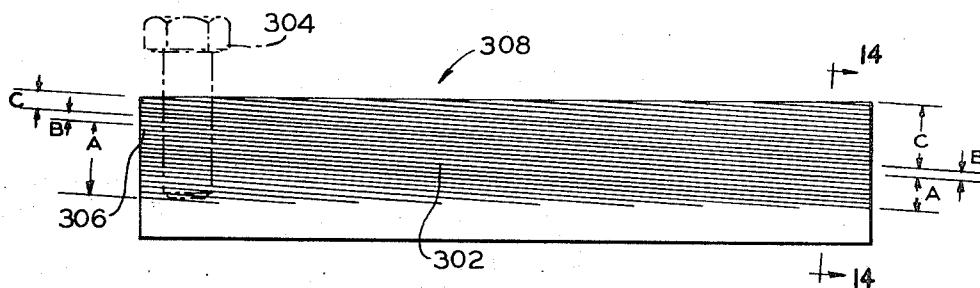


FIG. 14

FIG. 15.

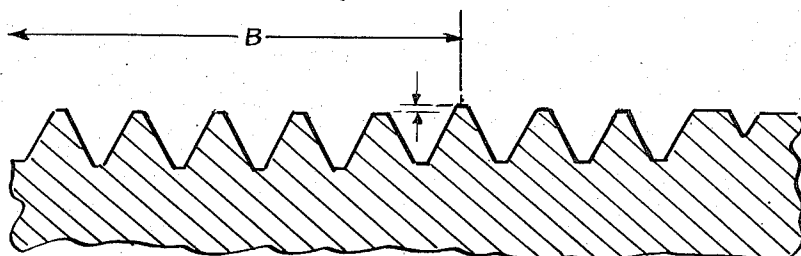
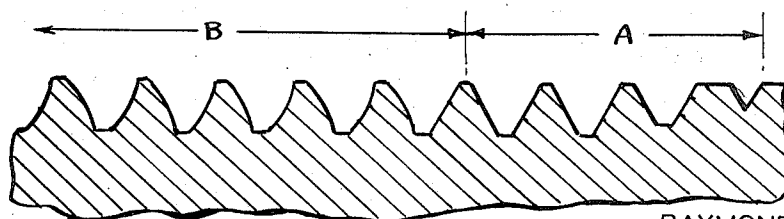


FIG. 16.



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LOCKING FASTENER

REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of applicant's U. S. application Ser. No. 91,730, filed Nov. 23, 1970 and now abandoned.

BACKGROUND OF THE INVENTION

Threaded fastener devices manufactured within usual commercial tolerances are usually characterized by at least a slight clearance between mating parts, unfortunately permitting them to shake loose under vibration unless an auxiliary device such as a lock-nut or a lock-washer is also employed. Even in the case when a relatively tight fit is specified between mating parts, the holding ability of the threads is usually unsatisfactory because of imperfection in the thread form in one or the other, or both, parts. Substantial contact will be attained between a few points of adjacent thread flanks when a screw is drawn up against a nut or workpiece, with other flank portions being held apart by the already engaged thread points.

Therefore, with a view toward elimination of auxiliary devices, various lock screws have been devised for producing a firm but limited contact between the threads of mating fastener devices. Typically, such lock screws are arranged to provide interference contact between certain portions of the locking screw and mating portions of the female thread. However, locking screw constructions as have been devised heretofore have had the disadvantage of tending to gall, break or freeze portions of the mating threads. As such, these prior constructions either produce relatively ineffective locking, or if sufficient interference is provided so that locking is assured, then galling or other damage occurs leading to breakage or permanent freezing of the parts together.

Another factor that has contributed to the unacceptable nature of prior art locking arrangement is their inability to accommodate the relatively wide industry accepted tolerances encountered with regard to mating threaded parts, and still provide effective predictable locking or holding action. In this regard, most forms or types of prior art locking screws employ a measure of interference between the male and female threads. However, since both the male and female thread configurations will vary within relatively wide tolerances, any attempt at predicting the degree of locking action is relegated to an educated guess, there being no certainty in the control of this factor.

With present day mass production methods, not only is it more difficult to form an internal thread than an external thread, but it is also significantly harder to maintain close dimensional tolerances with an internal thread. While all of the various thread dimensions may be important when attempting to control the locking action, depending of course, on the type of locking engagement to be effected, it is believed that a specific example will clarify this point.

Where flank-to-flank interference in one or both thread flanks is to be obtained, the pitch diameters of the respective mating threads can be a critical factor. In the screw thread art, the "pitch diameter" is defined as the diameter of an imaginary cylinder, the surface of which would pass through the thread profiles at such points as to make the width of the thread and that of

the groove equal. For example, with a conventional 5/16 inch nut and screw assembly, the industry standards will accept a pitch diameter for the nut that varies between 0.2764 and 0.2817 inches, a tolerance of 0.0053 inches. The industry accepted tolerances for the pitch diameter of the corresponding male screw member is 0.004 inches, the pitch diameter being between 0.2712 and 0.2752 inches. It must be emphasized that these dimensional tolerances are employed where no locking action is envisioned, and a clearance is to be maintained. In order to obtain a locking action of the flank-to-flank type with the nut and thread of the preceding example, the form or configuration of one or more of the thread turns on the male threaded member must be varied in some manner so as to bring the respective thread flanks into interfering engagement. However, the degree of flank interference that will be obtained will vary considerably, depending on whether the dimensions of the thread form on the nut are at the upper or lower end of the tolerance range.

Whether flank-to-flank interference is employed, or some other known type of thread interference is utilized, to be commercially acceptable, a locking arrangement must produce thread interference which falls within certain limits, depending of course on the intended use. If the interference is only slight, the locking action obtained may be insufficient for the user's purpose, and the threaded engagement may be loosened under vibration or prolonged use. On the other hand, if interference is excessive, galling of the threads may ensue and also, extremely high driving torques will be required to engage the mating elements properly. Therefore, it is extremely desirable that some measure of predictability and control of the degree interference be provided, and that this be obtained by present day mass production methods, without resort to precision machining or forming.

Unfortunately however, with conventional internally threaded members, the relatively wide tolerances encountered introduces a variable that will effect the degree of locking interference which preclude the obtaining of adequate predictability and control of the locking action. Accordingly, the present invention overcomes this problem, inherent in prior art locking arrangements by providing an externally threaded fastener which can effectively eliminate any variables due to the internal thread tolerances, and thus predictability and control of the locking action is obtained.

More specifically, the present invention provides an internally threaded fastener for use in a locking assembly wherein the threaded segment of said fastener includes a preparation portion, and a locking portion. The preparation portion includes a thread form preferably of the radially relieved type which is capable of reshaping the threads of the female member to a desired, predicted configuration. The thread turns on the locking portion are designed and configured to provide a desired type and degree of flank-to-flank interference when engaged with the internal threads of the female member subsequent to reshaping thereof by the preparation portion. As such, when the locking thread turns engage the reshaped internal threads, the interference, and correspondingly, the locking action obtained, is predictable and controllable. Therefore, the variances in the nut thread dimensions due to the industry tolerances no longer are factors which bear significantly on said locking action obtained.

The hereinafter disclosed embodiments of the present invention envision the elimination of the variables occasioned by the thread tolerances in several manners, as will be explained more completely with reference to the drawings. One form of the invention employs a preparation portion having a plurality of sizing thread turns of a general standard form or configuration. That is, the thread turns have relatively flat or straight flank profiles, which define the included angle of the thread form. These thread turns are of the radially relieved type designed to engage and cold work the internal thread of the female member, thereby reshaping the thread form of said member to a configuration determined by the relative form and dimensions of the sizing threads. In this regard, the sizing thread turns are provided with an effective pitch diameter that is at least as great, or greater than the maximum allowable pitch diameter that will be encountered with corresponding female members having an internal thread formed to the industry accepted tolerances. Therefore, no matter what the variance in the pitch diameter of the thread on the female member, it is assured that upon initial engagement said thread will be cold worked and reshaped to a desired configuration which, when engaged with the locking section, will give a predicted type and degree of locking action.

Another embodiment of the present invention envisions employment of a preparation portion wherein the relative dimensional differences between the sizing thread and the internal thread are of little or no significance. In this regard, the sizing threads on the preparation portion of the male fastener are provided with a specific configuration designed to deform or deflect the internal threads of the female member in a first axial direction. As such, the resulting thread form which is presented to the locking portion of the male fastener will have the flank displaced axially, which displacement will produce flank-to-flank interference. Since the final relative flank displacement which produces locking is, in fact, controlled solely by the relationships existing between the thread turns on the preparation and locking portions, respectively, any variances in the nut thread form are of little or no significance.

The form of locking action obtained pursuant to engagement of the thread turns on the locking portion with the reshaped internal threads of the female member may be of various known types. One novel form of locking, envisioned by the present invention, is the employment of a bulging flank configuration on either the locking portion of the male fastener, or the internal thread, or both, which will produce relative flank displacement, and the necessary interference to attain locking. Another form of locking is obtained by providing the thread turns on the locking portion with the standard thread form having the pitch diameter greater than the effective pitch diameter of the sizing threads, and correspondingly, greater than that of the reshaped internal thread turns to be engaged therewith. As such, flank-to-flank interference will be obtained along the opposed flanks of the locking thread turns.

It must be emphasized that the type of locking engagement obtained with the present invention may vary, and various known forms of thread locking systems may be employed. The critical feature is the reshaping of the internal thread of the female member prior to locking engagement so as to eliminate any vari-

ables occasioned by the thread tolerances encountered.

As to the preparation section, the thread form employed can be any of those known in the art and used in self-tapping fasteners wherein the internal or female thread is cold formed or cut. With the present invention, the cold forming operation is preferred, and as such, a radially relieved thread configuration for the preparation section has been illustrated in the drawings. This thread form is of a trilobular design, such as disclosed in detail in U.S. Pat. No. 3,195,156, issued to Harvey F. Phipard, on July 20, 1965. It must be kept in mind that other known types of cutting threads or radially relieved cold forming threads may be utilized. It is important only that the threads on the preparation section be capable of effecting the desired reshaping or sizing of the internal threads to eliminate the variables due to nut thread tolerances.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side, elevational view, partially in section and partially broken away, illustrating a fastener member and locking arrangement according to the present invention employed in holding two members in assembled relation;

FIG. 2 is a partial, longitudinal sectional view of the male fastener member and the nut of the locking arrangement of FIG. 1, illustrated in an enlarged scale and in disassembled relation;

FIG. 3 is a partial, longitudinal, sectional view on still a larger scale of the male fastener member and nut of FIGS. 1 and 2, in assembled relation, and illustrating the type of locking action obtained thereby;

FIG. 4 is a longitudinal, partial, sectional view of a fastener member having a thread configuration constructed in accordance with another form of the present invention;

FIG. 5 is a side view, partially broken away, of a locking screw according to one form of the present invention;

FIG. 6 is a longitudinal cross section of FIG. 5 locking screw engaged with a female member;

FIG. 7 is a side view, partially broken away, of another locking screw arrangement according to the present invention;

FIG. 8 is a longitudinal cross section of the FIG. 7 locking screw engaged with a female member and illustrating the locking action obtained;

FIG. 9 is a side view, partially broken away, of yet another locking screw according to the present invention;

FIG. 10 is a transverse cross section through a locking screw according to one form of the present invention together with a female member engaged thereby illustrating of a tri-lobular configuration;

FIG. 11 is a longitudinal cross section of a locking screw according to FIG. 9, together with a female member engaged thereby, as taken, for example, at 11-11 in FIG. 10;

FIG. 12 is a similar longitudinal cross section of still another locking screw according to the present invention, together with a female member engaged thereby;

FIG. 13 is a plan view of a thread-rolling die of the present invention, and of the type used to produce fasteners such as illustrated in the foregoing FIGS. 1-12; and

FIGS. 14-16 are sectional views taken along the line 14-14 of FIG. 13, and illustrating die constructions

according to the present invention capable of producing the fasteners of FIGS. 5, 2, and 4, respectively.

DETAILED DESCRIPTION OF ILLUSTRATED EMBODIMENTS

Referring to the drawings, and initially to FIGS. 1-4, there are disclosed two embodiments of the present invention, wherein a standard thread form is employed in the preparation portion of the fastener. The embodiment of FIGS. 1-3, differ from that of FIG. 4, in the thread form utilized on the locking portion of the fastener, and correspondingly, in the type of locking action obtained.

Considering now FIGS. 1-3, in FIG. 1, a fastener arrangement in accordance with a first embodiment of the invention is shown in an assembled relation. Said arrangement includes an externally threaded male element or screw 10, having a driving head 12 and a shank portion 14 with a thread form 17 and a tapered work entering end 16.

The unthreaded segment of the shank, is designated 13 and is known in the art as the "grip." The grip 13 extends through aligned apertures 11 in the illustrated plate members 15, such that said plate members 15 are maintained in abutted relation by the fastener head 12 and a nut 26 engaged with the thread form 17.

The locking action between the nut 26 and the thread form 17 attained by the present invention, and detailed hereinafter, maintains the nut in position and assures that same will not work loose.

FIG. 2, illustrates a preferred arrangement of the thread form 17 for the fastener 10, with the nut 26 shown in disassembled relation thereto. Thread form 17, includes a preparation portion "A" and a locking portion "B," the former including a plurality of sizing thread turns 17A, capable of cold working and reshaping the internal thread 27 of nut 26, the locking portion having one or more thread turns 17B for effecting a locking action with the said reshaped internal thread 27. This locking action is illustrated in FIG. 3, and will be discussed in detail hereinafter.

With specific reference to FIG. 2, the thread 17 illustrated therein is of a generally standard form. That is, the following flank 22 and the lead flank 24 are substantially straight or flat in profile, and define an included angle of 60°.

As mentioned previously, the thread turns 17A on the preparation portion "A" are of the radially relieved type, and preferable tri-lobular, as illustrated in FIG. 10 and thereby capable of resizing the internal thread of nut 26. In this regard, the thread crests 23 and thread roots 25 define helices of a somewhat irregular configuration, as a plurality of circumferentially disposed lobes are provided due to the tri-lobular configuration. This configuration is that as taught by the aforementioned U.S. Pat. No. 3,195,156, and is discussed in detail hereinafter with reference to FIG. 10. The thread turns 17B on the locking portion "B" of the screw 10, may be either of a tri-lobular form, or of a circular cross section. With the tri-lobular form, the radial relief provided reduces the driving torque; however, with a circular form, an increased locking action will be obtained, although the driving torque may be higher. In either case, the thread will be rolled, and the final cross sectional form of the thread turns will be controlled by the initial configuration of the blank, as is well known in the art.

More specifically, considering the operation of the fastener 10, the sizing thread turns 17A on the preparation section, although of the radially relieved type, have a given effective pitch diameter or pitch line indicated by the datum line 28. It must be kept in mind that in the illustrated form threads 17A are tapered, to provide a lead-in and gradual reshaping action. Therefore, the term "effective pitch diameter" as employed herein and designated 28, denotes the maximum pitch diameter of the thread turns 17A, i.e., that of the thread turns or turns on portion "A" having the greatest crest height. Should a straight thread form be employed for thread turns 17A, as is within the scope of this invention, then the standard pitch diameter and the effective pitch diameter would coincide.

The internal thread 27 on nut 26, will also have a given pitch diameter, indicated by datum line 29, which falls within a prescribed range or tolerance. In forming the fastener 10, the standard industry accepted tolerances for a corresponding internal thread 27 is taken into consideration, and the effective pitch diameter 28 of the sizing thread turns 17 on the preparation section "A" is adjusted such that same is at least as great, and preferably greater than the maximum allowable pitch diameter 29, permitted pursuant to said standards. Accordingly, as the sizing thread turns 17A engage the internal thread 27, said internal thread will be worked and reshaped to a desired configuration determined by said radially relieved sizing thread turns 17A.

Thread turns 17B on the locking portion "B," are preferably formed as a straight thread having a pitch diameter, indicated by datum line 30. The pitch diameter 30 is selected such that it is greater than the effective pitch diameters 28 of sizing thread turns 17A, by a predetermined value indicated at 32, in FIG. 2. Accordingly, relative to the thread turn 17A having the maximum crest height, respective portions on the thread flanks 22 and 24 of thread turns 17B will be disposed radially upward a distance equal the difference in the respective pitch diameter, i.e. distance 32.

Directing attention now to FIG. 3, the locking operation obtained upon engagement of the reshaped internal thread 27 with thread turns 17B is illustrated. In this regard, the overall form of the reshaped internal thread 27, and correspondingly the resultant pitch diameter 29, are controlled by the dimensions of the sizing thread turns 17A. As such, the pitch diameter 30 of the thread turns 17B will exceed the pitch diameter 29 of the thread 27, by an amount approximately equal to the previously discussed distance 32. As a result of this difference in pitch diameter, and due to the controlled form of the reshaped internal thread 27, the lead and following flanks 22 and 24 of thread turns 17B, will be displaced upwardly relative to the corresponding flanks 68 and 74 of said internal thread 27. Upon engagement, as shown in FIG. 3, interference in the form of flank-to-flank engagement will be obtained, with the respective flanks of the internal thread 27 being deformed to correspond to the shape of thread turns 17B.

In FIG. 3, the configuration of the lead and following flanks 74 and 68 of the internal thread are illustrated in dotted outline, while the flanks 22 and 24 of the thread 17B are in solid outline. As such, it can be seen that along each flank interface a prescribed degree of interference, designated by reference character 40, is obtained. The degree of interference 40, thus achieved,

produces the locking action imparted to the engaged threads 17 and 27.

From the preceding, it can be appreciated that due to the resizing accomplished by thread portion 17A the relative form of the internal thread 27 will be consistent, upon engagement with the thread turns 17B, regardless of the variances in the form of said thread 27 before engagement. Thus, the degree of interference 40 and correspondingly the locking action obtained depends upon the relative dimensional difference between thread portion 17A and 17B, which can be selected and varied in the design and forming of external thread 17. It follows then that a manufacturer of fasteners can, by utilization of the present invention, predict and control the locking action obtained during use of the fasteners 10.

In FIG. 4, an alternate configuration for the thread form 17 is disclosed and to avoid repetition and confusion wherever possible, reference characters identical to those used in FIGS. 1-3 are employed. Basically, the configuration and operation of the thread turns 17A on the preparation portion "A" are the same as discussed above with regard to FIGS. 1-3. The primary difference with this embodiment lies in the form of the thread turns 17B and type of locking action thus obtained. While these features of the thread form 17B of this embodiment, as discussed briefly in conjunction herewith, a more detailed discussion of the type of locking action will be given with regard to FIGS. 5-12. It should be noted, that in this embodiment the effective pitch diameter of the sizing thread turns 17A and that of the locking thread turns 17B are the same, being designated 28. While the thread profile of thread turns 17A is of a standard form, the thread turns 17B are of an irregular shape having lead flanks bulged outwardly in an axial direction, with the opposite following flank being depressed in the same direction by a generally similar amount.

The above mentioned irregular shape of the locking thread turns of this embodiment, is best understood with reference to the thread profile designated 17B. The dotted outline of a thread profile corresponding to that of thread 17A, is superimposed over said thread profile 17B. From this it can be seen that the net result is that the respective lead and following flanks 24 and 22, have been displaced in an axial direction toward the sizing thread portion "A," with the maximum amount of bulge taking place approximately along the pitch diameter 28.

In operation, the thread 17 is fabricated such that the effective pitch diameter 28 is as great, or greater than the maximum allowable pitch diameter of a corresponding nut (not shown) to be engaged therewith. Upon engagement of sizing thread turns 17A with said nut, the internal thread will be reshaped to a specified configuration determined by said sizing thread portion A. Subsequently upon engagement of the irregular shaped thread turns 17B with the reshaped internal threads of the nut, said internal threads will be deflected and a preselected and determinable flank interference will be obtained along the interface of the lead flank 24, which produces the locking action. Due to the depressed nature of the following flank 22, little or no interference will be encountered, along this interface.

Thus, as was the case with the embodiment of FIGS. 1-3, with the present form of the invention, the locking action can be predicted and controlled by adjusting the

relative dimension of the thread turns 17A and 17B. Also, due to the sizing operation preferred by the preparation portion 17A any variables that might be encountered due to nut thread dimension variances are eliminated.

The embodiment of the invention illustrated in FIGS. 5 and 6, differ from those previously discussed, in that only a locking thread formation is employed, there being no sizing or preparation portion to rework the internal thread of the nut and eliminate the variable due to the industry accepted tolerances. In this instance, the fastener illustrated employs a type of locking thread similar to that discussed briefly with regard to FIG. 4, with the exception that the following flank is bulged and the lead flank depressed, opposite to that as shown in FIG. 4. Here again, wherever possible, fastener elements have been designated by the same reference character employed previously, with the addition of a prime designation (') to all of the reference characters employed in FIGS. 5 and 6.

Referring to FIG. 5, a screw indicated generally at 10' is shown having a driving head 12', shank 14', and a tapered work entering end 16'. The driving head 12' represents only one form of driving end since the screw may be a headless stud or a set screw. The screw shank is provided with a straight thread formation 17' adjacent the tapered work-entering end, while the remainder 13' of the shank between the thread formation and the driving head 12' is unthreaded, and may be termed the grip. It is understood the last-mentioned shank portion 13' is intended for extension through an apertured structural member or the like secured against a workpiece or nut by the head of screw 10'.

A following thread flank 22' in thread formation 17' bulges axially outwardly, e.g. it is convexly curved in cross section, in a direction toward driving head 12' for at least one thread convolution. The leading flank 24' is then depressed or relieved. For example, the leading flank is deflected concavely in a direction away from the work-entering end for at least one thread convolution. The aforementioned bulge and relief on the opposite sides of each thread cross section are relative to the crest and root portions of the thread formation, or relative to straight lines describing the positions of conventional straight flanks between crest and root. Normally, the bulging and corresponding depressions are present throughout at least several convolutions of the thread form.

With a thread form circular in cross section, the thread crest 23' and thread root 25' will comprise uniform helices adapted to have a predetermined mating relation with a given female thread, for instance, a standard 60° included angle thread. The flank deviations of the present invention, which are substantially axial of the screw, are maximum approximately along the pitch line 30' of the screw with the thread cross-sectional widths along the pitch line being approximately half of the thread pitch. Thus, the outwardly bulging condition of the thread flank 22', for example, will correspond to a substantially equal amount of relief or depressed condition of the opposite flank 24'.

As hereinafter more fully explained, the screw of FIG. 5 is adapted for deflecting or swaging an already existing female thread in a nut or workpiece to provide firm flank engagement with such female thread, and tension between a following female thread flank and the head of the screw. As the outwardly bulged follow-

ing flank 22' engages a female thread, it deflects the female thread into a shape corresponding with that of the following flank 22' thereby establishing a firm pressure area against the following flank of the female thread.

FIG. 6, further illustrates the locking operation of the screw 10' with a nut 26'. It is understood that the screw 10' has advanced in the direction of arrow 77', i.e., from the left to right in the drawing, into a previously threaded nut 26'. The thread flanks bulge in a direction opposite to the direction of advance of the screw. It is further understood that the female thread, before insertion of the screw, is typically round in cross section and standard, having been previously tapped, and has the same pitch as the male thread on screw 10'. Its thread is suitably one providing a standard clearance fit with a standard screw having the same crest and root dimensions as the present screw. The screw thread according to the present invention may be round in cross section, departing from the standard thread form principally as regards the bulging and relieved thread flanks. The clearance between male and female parts can be as great as will still provide substantial pressure contact between the same male and female flanks as herein described, that is, the axial bulge should exceed the maximum tolerance for both external and internal threads of the general class comprising the screw and the nut or workpiece, plus any allowance therebetween, permitted for a conventional clearance fit. Alternatively, the screw thread may be slightly oversize in dimension as regards the thread of the nut as hereinafter described in connection with subsequent embodiments.

As illustrated in FIG. 6, male threads 52', 54', and 56' have each deflected the female thread of nut 26' to produce a depressed, relieved or concave following flank, and a bulging leading flank, by a deflecting or swaging action. Thus bulging following flank 62' of screw thread 54' has produced a relieved following flank 68' on the female thread by swaging action, urging metal of the female thread to the left along pitch line 30'. Therefore, a bulging female leading flank 74' is produced which nearly "fills in" the relieved leading flank 76' of screw thread 56'. Similarly, a bulging leading female flank 64' is established adjacent relieved screw flank 66'. As a result of the male thread relief on the leading flank thereof, a space is thus provided for reception of the metal of the female part which has been moved to the left by the swaging action, and binding or galling is thereby avoided. A deflection of the female thread may be restricted to remain within the elastic limits of the material from which nut 26' is constructed, but this is not necessarily the case. The original or undeflected position of the female thread is illustrated by the straight, dashed lines 69' and 75' in FIG. 6.

At the location of contact between the bulging screw thread flank and the relieved female thread flank, e.g., along adjacent flanks 62' and 63' in FIG. 6, intimate engagement is necessarily present, since screw thread flank 62' is responsible for the exact formation of female flank 68'. In other words, appreciable interference is present along the interfaces of the flanks 62' and 68', with an interference also being present at least at the top and bottom of the following screw flank 64', i.e., at points 70' and 72'. The intimate and extensive flank contact is provided, however, without deforming the female thread to an extent or at a location where galling might take place.

As can also be seen, the pressure against the female 68' 68' is in the direction of screw head 12'. Thus, as the screw is drawn up tight, the following female flank 68' is placed in tension toward the screw head.

Referring to FIG. 7, still another embodiment of the invention is shown. This embodiment is similar to the two previously discussed embodiments of FIGS. 1-4 in that the fastener, designated 110, is provided with a sizing or preparation portion "A" and a locking thread portion "B." Similarly, with the fastener 110, the preparation portion "A" will reshape the internal thread of the nut, thus eliminating any variables in thread form occasioned by the nut thread tolerances that may be encountered due to industry accepted standards or tolerances. However, it should be noted that these variables are eliminated in a manner somewhat different than that employed with the fasteners of FIGS. 1-4.

More specifically, the fastener 110 will deflect the internal thread of the nut to attain a desired deflection or swaging of the thread to axially displace the thread flanks. This should be compared with the reforming of the threads to a standard profile with enlarged thread dimensions as was done by the fastener of FIGS. 1-4. The deflected internal thread is then engaged with the thread turns of the locking portion to attain the desired locking action.

As such, a fastener 110 is provided, having a driving head 112 or other form of driving end, a shank 115, and a work-entering end 116. The thread formation on the screw is divided into two portions, the preparation thread portion A, the end of which is tapered toward work-entering end 116, and the locking thread portion B. The remainder 117 of the shank or the grip, which may extend through an apertured structural member or the like, is shown broken away.

A leading thread flank 118 in preparation portion A bulges axially outwardly, e.g., is convexly curved in cross section for at least one thread convolution in a direction axially away from driving head 112. The following flank 120 is then relieved; for example, the following flank is depressed concavely away from the screw's driving head. The described condition is desirably present throughout portion A. The second thread portion B suitably comprises a substantially standard thread form having substantially flat or straight flanks. In any case, as viewed in FIG. 7, the thread flanks in section B are located to the left of the position of thread flanks in section A, if the thread crest and root portions in the two sections were juxtaposed for comparison.

The thread on screw 110 desirably has substantially the same lead throughout the thread formation. Thus, the bulges and depressions in the thread are relative to substantially standard, uniform crest and root helices which are maintained approximately the same through the thread formation and adapted to have a predetermined mating relation with the female thread, e.g., a standard clearance fit with a standard nut thread. The flank deviations from the standard screw are maximum along the pitch line of the screw. Also, the width of the screw thread cross section is desirably maintained equal to approximately half the thread pitch.

The preparation portion A of the FIG. 7 screw deflects or swages the existing thread in a nut or workpiece in a direction axially away from driving head 112, as portion A is driven into the nut or workpiece. After the female thread is deflected to the right by thread portion A of the screw, the second thread portion B en-

gages the female thread and the following flank thereof establishes pressure against the following flank of the female thread which was theretofore deflected by preparation portion A. The previously deformed following flank of the female thread is thus placed in tension between the following flank of thread portion B and driving head 112, as driving head is tightened. The flank-to-flank contact thereby established is appreciable more extensive than in the normal screw and nut combination.

FIG. 8 illustrates locking of screw 110 with a nut. In FIG. 8, only one thread, 150, of a preparation thread portion A is illustrated, while a pair of threads, 146 and 148, correspond to portion B in FIG. 7. It is understood that the female thread is typically standard and formed to conventional, accepted tolerances, as in the previous embodiment, suitably provide a standard fit with a standard screw having the same crest and root dimensions as the present screw. The screw thread may be round in cross section and may be slightly oversize in dimension as regards the dimension of the thread of the nut, as hereinafter described. The general configuration of thread portion B exemplified by threads 146 and 148 corresponds to a standard or typical male thread adapted for engaging the nut thread. Thus, the flank-to-flank angle for threads 146 and 148 is 60 degrees, and the crest and root portions 129 and 136 have a conventional relation to the pitch line 30.

As illustrated in FIG. 8, preparation thread 150 having a bulging leading flank 118 has deflected the female thread to produce a relieved or concave leading flank 154 by a swaging action, deforming the flank 154 to the right. The original or undeflected position of the female thread is illustrated by dashed lines 153 at the right in FIG. 8. In the course of reaching the position illustrated in FIG. 8, thread 150 has similarly deflected the preceding female thread axially to the right. Thus, flank 156 will have been similarly deflected to the right during at least the previous revolution of the screw. The female thread is displaced from left to right producing bulging following flank 158, e.g., which is convexly rounded away from the screw's driving head, early "filling in" the relieved flank 120 accommodating the material from the female thread swaged to the right.

When thread 148 moves into the previously distorted female thread, it tends to deflect the female thread to the left in FIG. 8. Therefore, the following flank 162 of the internal female thread will necessarily be in intimate contact with the following flank 160 of the screw since the screw thread portion A swages the final surface configuration of the female thread. Inasmuch as a flat screw thread flank from section B has not yet encountered female thread flank 158, to force material to the left, some gap or space will remain between the leading flank 159 on the screw thread, and flank 156 of the female thread. Then as hereinbefore mentioned, thread 148 swages remaining female threads to the left. The material swaged to the left along the pitch line produces a female flank 165 for nearly "filling in" along the straight leading flank of screw thread 146.

As a result of the swaging of the female thread to the right and then the re-forming of the same to the left, appreciable interference is produced along the faces of flanks 160 and 162, for example. Since the form or degree of deflection upon engagement with the screw thread 14B is determined solely by the preparation portion A, regardless of the original dimensions of said fe-

male thread, the tolerances employed in forming said female thread will have no effect on the locking action. The female following flank, for example flank 162, is placed in tension between following flank 160 of the male thread and the head 112 of the screw. Locking is accomplished primarily on the flank area by bending of the female thread along the pitch line, and regions of the threads where galling or breaking would more likely occur, are avoided. Thus, the crest and root portions of the male thread are not materially deflected from their normal position, and there is therefore less tendency for the female thread crest and root portions to be broken or damaged. Galling is also avoided, as hereinbefore mentioned, as a consequence of the following flank relief on thread portion A. The fastener results in desired tension and reduced driving torque as compared with prior locking screws. In this embodiment, increased working of the female thread, with the female threads being returned substantially to their original position for locking, results in increased locking strength and high removal torque.

Referring now to FIG. 9, still another embodiment of the present invention will be described with reference to a screw indicated at 210 having a driving end 212, a shank 214, and a work-entering end 216. In this instance, the thread formation on the screw is divided into three portions: a preparation thread portion A which is generally tapered toward work-entering end 216, a transition or identification thread portion B, and a locking thread portion C. The remainder of the shank between locking thread portion C and driving end 212, i.e., the grip, is shown broken away. It is understood that this part of the shank is again intended for extension through an apertured structural member or the like secured against a workpiece or nut by screw 210.

The preparation portion A of this embodiment functions in the same manner as that discussed with regard to FIGS. 7-8 to eliminate female thread variables which might effect locking. A leading thread flank 218 in preparation portion A bulges outwardly or is convexly curved in cross section in a direction axially away from driving end or head 212 throughout at least one convolution, and desirably throughout thread portion A. The following flank 220 is then depressed or relieved, for example the following flank is depressed concavely away from the screw's driving end or head. Transition thread portion B suitably comprises a substantially standard thread form having substantially flat or straight thread flanks. However, the locking portion C comprises a thread formation wherein the thread flanks deviate from standard threads in an opposite direction from the thread flanks in preparation portion A. Thus, a following flank 222 bulges or is convexly curved in cross section throughout at least one thread convolution toward driving end or head 212. The leading flank 224, on the other hand, is correspondingly relieved or concavely depressed in the direction of the screw head. The same configuration is preferably followed substantially throughout all convolutions of portion C.

It should be noted that the thread on screw 210 desirably maintains substantially the same lead throughout the thread formation. Thus, the aforementioned bulging regions of portions A and C, and the corresponding relief on the opposite sides of each cross section, are relative to substantially standard and uniform crest and root helices maintained approximately constant

throughout the thread formation and adapted to have a predetermined mating relation with a female thread. The flank deflections in directions substantially axial of the screw are maximum approximately along the pitch line of the screw, and merge gradually with the substantially undeflected crest and root portions of the same thread formation. Moreover, the cross-sectional width of the thread along the pitch line generally remains approximately half the thread pitch whereby a bulge on one thread flank will correspond to a substantially equal relief on the opposite side of the same thread cross section.

The screw of FIG. 9 suitably deflects or swages an already existing female thread in a nut or workpiece first in a direction axially away from driving head 212 as preparation thread portion A is driven into the nut or workpiece. The thread preparation thereby accomplished renders the subsequent locking operation more certain and consistent between male and female members having considerable variations in tolerance. The preparation makes sure that the female threads are in position for subsequent optimized engagement on the opposite side thereof by the male locking thread. Thus strong flank-to-flank contact is assured throughout 360 degrees as the screw deflects the female thread in an opposite direction toward driving head 212 when locking portion C engages the female thread. The following flank 222 establishes a firm pressure engagement against the adjacent flank of the female thread which was itself theretofore deflected by preparation portion A. The previously deformed flank of the female thread is placed in tension between the following flank of thread portion C and driving head 212, as driving head 212 is tightened against a member secured against the nut or workpiece by screw 210. The flank-to-flank contact throughout 360 degrees established in thread portion C is extensive and optimizes the locking or holding ability of the screw in the total tolerance of the tapped nut.

With the embodiments discussed to this point, and those of FIGS. 11-12 to be detailed hereinafter, the thread form of either the preparation section A, the locking section B, or both, may be of a standard, round cross section, or of the radially relieved type. Where a considerable amount of reshaping is anticipated, the radially relieved type of thread form is especially desirable for the preparation portion A, as it will reduce the driving torque during deformation of the internal thread. Conversely, with regard to the locking portion B, the greatest locking action will be obtained with a circular thread form. Therefore, a manufacturer can adjust the form of the respective thread portions A and B to suit the intended use to which the fastener is to be employed.

While various types of radially relieved threads are known such as disclosed in U.S. Pat. No. 3,426,642 and the aforementioned U.S. Pat. No. 3,195,156, a preferred thread cross section exhibiting radial relief is illustrated in FIG. 10. While the cross section of FIG. 10 is of particular value for the screw of FIGS. 1-4, and 9, since the work accomplished in reshaping the female thread is appreciable, nevertheless, the same cross section can be used if desired for the other screws disclosed.

Referring to FIG. 10, a screw of the radially relieved type referred to above engages a female thread in a female member here comprising a nut 226, illustrated as

partially broken away. The thread formation on the screw is of arcuate polygonal cross section, and in particular of arcuate, triangular cross section, a form which is termed tri-lobular as set forth in U.S. Pat. 3,195,156. Line 228 indicates the peripheral or crest edge of the screw thread, line 229 the root of the thread, and dotted line 230 represents a cross section of the pitch cylinder of the thread. The pitch cylinder is not round, but is of arcuate, polygonal cross sectional configuration. The line 232 represents the root of the thread in the nut 226.

The radius of circular line 232 corresponds to the distance between the screw axis 234 and the outermost points of screw thread lobes 236, 238, and 240. Only these lobes 236, 238, and 240 are in relatively complete contacting engagement with the female thread. The relatively broad sides 242, 244, and 246 will be supported out of engagement to provide the aforementioned radial relief. Accordingly, frictional resistance between the screw and the nut is reduced. The lobes 236, 238, and 240 merge smoothly and gradually with arcuate sides 242, 244 and 246 therebetween with the arcuate radii or curvature of sides 242, 244, and 246 being appreciably larger than the arcuate radii of curvature of lobes 236, 238, and 240. The degree of eccentricity depicted for the tri-lobular configuration in FIG. 10 is by way of illustration only and may be greater or less than shown. The screw according to the present invention is preferably hardened more than the nut 226.

FIG. 11 further illustrates the locking operation of the FIG. 9 screw with a nut or workpiece. For the purposes of convenient illustration, the transition portion B here comprises a single thread 248 preceded by a preparation thread 250 and followed by a locking thread 252. It is understood that screw 210 as illustrated has advanced in the direction of arrow 277 from left to right into nut 226. It is also understood that the longitudinal cross section viewed in FIG. 11 may be considered as taken at the lobe of the screw thread, i.e., at 11-11 in FIG. 10 if the screw has the FIG. 10 transverse cross section, at which location approximately a tight fit occurs. Such fit would be uniform around the screw in the case of a round screw.

Typical pitch diameter tolerances for a previously tapped nut and screw in accordance with FIG. 11, and in the case of a particular example of 5/16 inch -18 thread size, are given as follows:

	Min.	Max.
Nut, standard class 2B (example 5/16"-18)	0.2764	0.2817 inch
Lock Screw	0.2817	0.2837 inch

In the case of a lock screw having the FIG. 10 cross section, the pitch diameter is measured at the lobes. Of course, the same dimensions may apply to a round screw. It is to be understood that for a nut of the above given dimensions, the comparable standard dimensions for a round screw, standard class 2A size 5/16 inch -18 threads per inch, are 0.2712 inch min. and 0.2752 inch max.

These preferred tolerances set forth above thus indicate the screw thread lobes suitably produced from a tight to an interference fit. While these tolerances are typical and preferred, it is understood the present invention is not limited to a tight or interference fit at the lobes of a screw. It is further understood that the fe-

male thread is initially typically standard and round in cross section. Also, the general form of the male threads, for example in the screw transition thread portion corresponds proportionately to a typical male thread for engaging such internal or female thread of the standard nut. Thus the included angle between the flanks of thread 248 in the transition thread portion in FIG. 11 is typically 60°.

As illustrated in FIG. 11, wherein a tight fit is assumed for purposes of illustration, preparation thread 250 having a bulging leading flank 218 will have deflected the female thread to produce a relieved or concave leading flank 254 by a deflecting or swaging action, deforming the flank 254 to the right as illustrated. The original or undeflected position of the female thread is illustrated by dashed lines 255 at the right in FIG. 11 for comparison. Also, in the course of reaching the position illustrated in FIG. 11, thread 250 will have similarly deflected the preceding female thread axially to the right, or away from the screw's driving head. Thus, flank 256 will have been similarly deflected to the right during at least the previous revolution of screw 210 illustrated. The female thread will have been displaced from left to right producing the bulging following flank 258 which is convexly rounded in a direction away from the screw's driving head, substantially "filling in" the relieved flank 220 of screw thread 250. Thus, the width of the nut thread along the pitch diameter 230 remains the same as before deflection.

However, when transition thread 248 moves into the previously distorted female thread, it may tend to deflect the female thread to the left in FIG. 11. Thus, the following straight flank 262 on the female thread. It will be apparent that the following flank 262 will necessarily be in rather intimate contact with the aforementioned following flank 260. However, since a flat transition screw thread has not yet encountered female thread flank 258 to force material to the left, a gap or space 257 will remain between the leading flank 259 of thread 248 and flank 256 of the female thread.

Locking thread 252 is effective for displacing the female thread flank to the left, for example to the left of dashed line 266 in FIG. 11, the dashed line being indicative of the original position of the female thread. Bulging following flank 222 of locking thread 252 deflects the female thread toward the driving head of screw 210, producing a relieved concave flank surge 268 in the female thread. At this thread location, and at the location of following threads of the locking thread portion, intimate engagement between adjacent flanks, i.e., screw flank 222 and nut flank 268, is substantially maximized. An appreciable area of interference is produced along the faces of flanks 222 and 268, with interference also being present at least at the top and bottom of following screw flank 224, i.e., at points 270 and 272. The interference is produced without galling or undesired freezing of the parts together.

While a gap is present between leading flank 224 of thread 252 and adjacent flank 264 of the female thread, this gap is characteristic of only the first locking thread convolution which encounters the female thread. Since each female thread remains substantially constant in width along the pitch line 230, female threads between locking thread 252 and the screw driving head will "fill in" the relieved leading flank of the screw thread. Thus, following flank 222 of thread 252

will urge the next adjacent female thread cross section to the left along the pitch line, and so on.

Intimate and extensive flank contact is thus provided by deflecting the female thread first in a direction axially away from the screw's driving head without deforming the female thread to the point where galling between the screw and the nut might take place. Then, the female thread is deflected in the opposite direction toward the driving head, preferably past its original location, resulting in optimized flank contact and tension between the female thread flank and the screw driving head when the screw is tightened. The possible displacement of the female thread produced by the preparation screw thread portion, and the locking screw thread portion to provide this firm flank-to-flank contact has a greater deflection value than could be accomplished in one step. In other words, the female thread could not have been satisfactorily deflected all in one direction, e.g., toward the screw head, by a distance equaling the maximum practical deflection that can be herein easily accomplished subsequent to female thread preparation by the screw's preparation thread portion. Locking is also accomplished with a change or reformation of the female cross section, but only by bending the female thread along pitch line 230. As hereinbefore mentioned, the crest and root portions of the female thread are substantially unaffected by deviation along the pitch line, whereby undue interference at a location frequently associated with galling or breaking of the nut or screw thread is avoided. Also, as in the previous embodiments, not only is premature or undesired freezing of the mating parts eliminated, but driving torque is reduced. The relief opposite a bulge in a thread cross section is instrumental in reducing torque and also in avoiding galling. The total axial bulge (of a preparation thread plus a locking thread) should exceed the maximum tolerance for both external and internal threads of the general class comprising the screw and nut or workpiece, plus any allowance therebetween, permitted for a conventional fit. The fastener has been found to provide a low driving torque to attain a desired tension while maintaining maximized removal torque in the total tolerance of a tapped nut.

An additional advantage of the various embodiments of the present invention relates to the decreased nut spreading or dilating, based upon a smaller thread pressure angle. The standard thread pressure angle is 30 degrees as illustrated, for example, in the case of transition thread 248 in FIG. 11. However, as a result of the deflection of the female thread produced by locking thread 252, the thread pressure angle is reduced, this angle being measured approximately between a tangent to the thread flank and a line perpendicular to the screw axis. In the case of a particular screw, this angle was approximately 25° as illustrated for thread 32 in FIG. 11. Therefore, the components of force directed radially outwardly when the screw's driving head is tightened is reduced, whereby nut spreading is minimized.

Another embodiment of a locking screw according to the present invention is illustrated in cross section in FIG. 12, together with the cross section of a female thread engaged thereby. In FIG. 12, primed reference numerals are again employed in referring to corresponding elements designated by unprimed reference numerals in FIG. 11. In the FIG. 12 embodiment, screw 210' is provided with a preparation thread portion ex-

emplified by thread 274, a transition portion, exemplified by thread 276, and a locking thread portion exemplified by thread 278. As in the previous embodiment, the screw's transition thread is of a substantially standard formation and would suitably engage the female thread with a tight or slight interference fit. Moreover, the screw threads may have arcuate polygonal shapes in transverse cross section as illustrated in FIG. 10, or may be round in cross section. Screw 210' as illustrated has advanced to the right as indicated by arrow 287.

The FIG. 12 embodiment differs from the previous embodiment in that the preparation and locking threads, instead of being convexly bulging and concavely relieved, are angularly bulging and angularly relieved with respect to pitch line 230'. However, the crest and root portions of the screw thread remain substantially standard and undisplaced as before. Radially outwardly from pitch line 230', leading flank portion 280 of preparation thread 274 makes a larger than standard angle with a line perpendicular to the screw axis. Thus, in a particular instance, this angle was 32° rather than the standard 30°. Leading flank portion 282 radially inwardly from the pitch line, on the other hand, makes a smaller than standard angle with the said perpendicular, this angle being 26 degrees in the particular example. As a consequence, the leading flank of preparation thread 274 bulges as in the previous embodiment. In order for the following flank of thread 274 to be relieved, following flank portion 284 radially outwardly from the pitch line is related to the perpendicular by an angle of 28° with flank portion 286 radially inwardly from the pitch line having an angular difference of 34° from the same perpendicular to the screw axis. In each case, the total flank-to-flank angle remains 60° in the case of the flank portions outwardly from the pitch line, or in the instance of the flank portions inwardly from the pitch line. These particular angular values are exemplary only.

In the case of locking thread 278, since the bulging region and relief are reversed between following and leading flanks, the aforementioned angles are similarly reversed as illustrated in FIG. 12. The operation of the locking screw 210' in deflecting and re-deflecting the female thread is substantially the same as hereinbefore described for the previous embodiment. The FIG. 13 embodiment is illustrative of the typical extent of flank bulge and relief provided on screw thread preparation and locking portions in this and the previously described embodiments. Thus, while the preparation and locking thread flanks in the FIG. 11 embodiment are smoothly curved, the angular measurements in FIG. 12 typify approximate angles which tangents to the flank surfaces in FIG. 12 near the crest and root of the screw thread would make with the aforementioned perpendicular line. The actual lineal deviation of the preparation and locking threads along the pitch line with respect to the screw driving head will, of course, vary with the size of the screw, and the clearance which would be present between the engaged female thread and a conventional male thread of the same general proportions as the present screw. The greater this clearance, the greater the deviation which will be desired for firm contact. Quite obviously the flank variations have been in order to more clearly illustrate the concepts involved.

Although a preferred embodiment of the invention for most efficacious results comprises a screw with a

preparation thread portion, a transition thread portion, and a locking thread portion, it will be appreciated that a locking screw according to the present invention may alternatively comprise a preparation thread portion, wherein the individual threads bulge to the right, followed substantially immediately by a thread portion where the individual threads bulge to the left for producing the intimate contact between male and female threads. Or, as hereinbefore described, the screw may employ a locking thread alone.

Although screws are generally described herein as having a driving head, it is appreciated that a head as such is not necessary and may be eliminated. The locking screw may have any other form of driving means or driving end and may, for example, comprise a stud, set screw, or the like.

Referring to FIG. 13, there is illustrated in plan view a die 308 for forming a thread of screws manufactured according to one of the embodiments of the present invention. The FIG. 13 die is particularly designed for the screw of FIG. 9, in that it is divided into portions generally corresponding to the thread portions of said screw, that is, die portion A is employed for rolling the preparation thread portion A of the screw, and so on. The FIG. 13 die is illustrated in partial transverse cross section in FIG. 14 wherein the various thread-forming portions thereof are more clearly illustrated, and wherein it can be seen the die is substantially complementary to the FIG. 9 thread form. In FIGS. 15 and 16, die profiles are illustrated which are capable of forming the fasteners of FIGS. 1-3 and 4, respectively. The showings of FIGS. 13-16 are illustrative only and are not intended to be dimensionally accurate.

In accordance with one feature of the present invention, the die illustrated in FIGS. 13-16, is employed to roll threads in a manner somewhat different from the methods heretofore employed. Each die groove, for example, die groove 302 employed in the formation of a preparation thread portion, is of substantially unchanging cross section from the right-hand end of the die to the left-hand end of the die as illustrated in FIG. 13. The same is true for the grooves of the die which form the transition and locking thread portions. Since the screw form itself is desirably provided with transition portion B, which form is substantially duplicated on the die, the desired transition is provided whereby each die groove can be milled with the same cross section all along its length.

A given screw blank is formed into a screw by engaging the same between a die as illustrated in FIG. 13, and the surface of a complementary die of substantially similar construction positioned for forming or swaging the die thread form into such screw blank. The screw blank will be disposed at substantially right angles to the dies and at a predetermined angle with respect to the grooves thereof, as illustrated, for instance in outline form at 304 in FIG. 13. The screw blank will first engage the die at the left-hand side, and will be rolled between moving and stationary dies so the blank proceeds to the right. A given thread form cross section, as rolled upon the blank by the die, may vary as such blank is rolled from left to right. Thus, at a given distance from the screw head, the blank may first engage a portion 306 of the die adapted for forming a preparation thread therein. As the blank moves in a direction to the right, the same thread form cross section will successively be formed into a transition thread configu-

ration and then a locking thread configuration at the right-hand end of the die. Die construction is much simpler than multi-portion dies heretofore wherein a division between said thread-forming portions would be made intermediate the ends of individual thread-forming groove of the die, whereby, for instance, a given portion of the screw blank would encounter only thread-forming grooves of a given formation. The practice according to the present invention avoids the necessity of changeover in milling cutters or the like part way along a groove. Approximately the same crest and root spacings are maintained throughout.

The dies are desirably tilted slightly in a conventional manner so that thread forming is somewhat progressive. That is, the dies will be further apart when they first encounter the blank, and will gradually deepen their impression. Also, the blank employed is desirably provided with a slight up taper in the direction of the head so that the locking threads are slightly more pronounced than the preparation threads.

While we have shown and described several embodiments of our invention, it will be apparent to those skilled in the art that many changes and modifications may be made without departing from our invention in its broader aspects. We therefore intend the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

We claim:

1. An externally threaded male locking fastener for engagement with an internally threaded female member, said female member having an internal thread which is of a substantially circular cross-section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of thread turns of the radially relieved type, said plurality of thread turns having one flank thereof bulging outwardly at a first axial direction with the opposite flank of said thread turns depressed inwardly in said first axial direction, whereby upon engagement of said preparation portion, with the internal thread of a female member regardless of the industry tolerances employed, said internal threads will be reshaped and provided with uniform corresponding bulging and depressed flanks, deflected axially with regard to their initial configuration; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, said locking portion including a plurality of thread turns having a thread form which will upon engagement with said uniformly reshaped axially deflected bulging internal threads, produce a prescribed degree of interference along one or more of the engaged thread flanks, to lock said male and female members in assembled relation.

2. An externally threaded male locking fastener as defined in claim 1 wherein said locking thread portion includes a plurality of thread turns having relatively straight flank surfaces, disposed to engage said bulging flanks formed on said internal thread by the preparation portion, said engagement producing the desired flank interference.

3. An externally threaded male locking fastener as defined in claim 1, wherein said locking thread portion

includes a plurality of locking thread turns having one flank thereof bulging outwardly in a second axial direction opposite to said first direction, with the oppositely disposed flank of said locking thread turn being depressed, such that upon engagement of said locking thread turn with said previously reshaped internal thread, flank-to-flank contact will be obtained between the opposed engaged bulging flanks of said internal thread and said locking thread, respectively, producing the desired flank interference.

4. A locking screw according to claim 1 further provided with a transition thread section located between and joining said preparation thread portion and said locking thread portion and having an intermediate thread flank configuration.

5. A locking screw according to claim 4 wherein said transition thread section is characterized by a substantially straight flank cross section.

6. A locking screw according to claim 1 wherein said bulging flank is convexly rounded and wherein said relieved flank is concavely rounded.

7. A locking screw according to claim 1 wherein said bulging flank extends angularly outwardly to an apex proximate the pitch cylinder of said screw while said relieved flank extends angularly inwardly to an apex also proximate the pitch cylinder of said screw.

8. An externally threaded locking fastener member adapted to be engaged with an internally threaded female member, having an internal thread formation which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said fastener member including a driving head, a shank portion and a tapered work-entering end, with an external thread formed on at least a portion of said shank, said external thread including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of sizing thread turns of the radially relieved type and having a standard profile, said sizing thread turns having an effective pitch diameter which is at least as great as the maximum allowable pitch diameter of the internal thread of the female member to be engaged therewith, such that upon engagement, the sizing thread turns will reshape said internal thread to a prescribed configuration having a pitch diameter determined by said sizing thread turns, regardless of the internal thread tolerances encountered; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, and said locking portion including at least one full thread turn, one flank of which bulges axially outward with the opposite flank being depressed, whereby upon engagement with said reshaped internal thread flank interference will be obtained along said bulging thread flank to lock the respective male and female members in assembled relation.

9. An externally threaded male locking fastener for engagement with an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a

plurality of thread turns of the radially relieved type, said thread turns having an effective pitch diameter that is at least as great as the maximum allowable pitch diameter of said internal thread permitted by said industry tolerances, such that upon engagement of the preparation portion with an internally threaded member, regardless of the tolerances encountered, said internal thread will be reshaped and sized to a desired, predicted uniform configuration having a pitch diameter determined by said preparation portion; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, said locking thread portion includes a plurality of thread turns having a pitch diameter greater than the effective pitch diameter of the thread turns on said preparation portion, such that said locking thread portion will, upon engagement with said internal thread after reshaping thereof by said preparation portion, produce a prescribed degree of interference along one or more of the engaged thread flanks, to lock said male and female members in assembled relation.

10. An externally threaded male locking fastener for engagement with an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of thread turns of the radially relieved type said thread turns having an effective pitch diameter that is at least as great as the maximum allowable pitch diameter of said internal thread permitted by said industry tolerances, such that upon engagement of the preparation portion with an internally threaded member, regardless of the tolerances encountered, said internal thread will be reshaped and sized to a desired, predicted uniform configuration having a pitch diameter determined by said preparation portion; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, said locking thread portion including a plurality of thread turns having one flank thereof bulging axially in a first direction with the opposite flank of each said turn depressed inwardly in the same direction, such that said locking thread will, upon engagement with said internal thread after reshaping thereof by said preparation portion, produce a prescribed degree of interference along one or more of the engaged thread flanks, to lock said male and female members in assembled relation.

11. In combination, an externally threaded male member and an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of sizing thread turns of the radially relieved type, said sizing thread turns having an effective pitch

diameter that is at least as great as the maximum allowable pitch diameter of said internal thread, such that upon engagement, said sizing thread turns will reshape and size said internal thread, eliminating all variances due to tolerances and producing a thread form of predicted uniform configuration and pitch diameter, regardless of the internal thread tolerances encountered; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, said locking portion including at least one thread turn having a pitch diameter greater than the effective pitch diameter of said sizing thread turns, by a preselected value, such that upon engagement of said reshaped internal thread with said locking thread turns, a predicted flank-to-flank interference will be obtained, which interference will maintain said male and female members in assembled relation.

12. In combination, an externally threaded male member and an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of sizing thread turns of the radially relieved type, said sizing thread turns having an effective pitch diameter that is at least as great as the maximum allowable pitch diameter of said internal thread, such that upon engagement, said sizing thread turns will reshape and size said internal thread, eliminating all variances due to tolerances and producing a thread form of predicted uniform configuration and pitch diameter, regardless of the internal thread tolerances encountered; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, said locking portion including at least one full thread turn, one flank of which bulges axially outward with the opposite flank being depressed, whereby upon engagement with said reshaped internal thread flank, a prescribed degree of interference will be obtained along said bulging thread flank to lock the respective male and female members in assembled relation.

13. In combination, an externally threaded male member and an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of thread turns of the radially relieved type, said thread turns having one flank thereof bulging outwardly in a first axial direction with the opposite flank of said thread turns depressed inwardly in said first axial direction, whereby upon engagement of said preparation portion, with the internal thread of said female member, said internal thread will be reshaped to a desired, predicted configuration and provided with corresponding bulging and depressed flanks, deflected axi-

ally with regard to their initial configuration; and a locking thread portion position further from said work-entering end of the screw than said preparation portion, said locking portion including at least one locking thread turn having one flank thereof positioned to engage said reshaped, axially deflected bulging flank of said internal thread in interferring relation to produce a locking action.

14. In combination, an externally threaded male member and an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of thread turns of the radially relieved type, said thread turns having one flank thereof bulging outwardly in a first axial direction with the opposite flank of said thread turns depressed inwardly in said first axial direction, whereby upon engagement of said preparation portion, with the internal thread of said female member, said internal thread will be reshaped to a desired, predicted configuration and provided with corresponding bulging and depressed flanks, deflected axially with regard to their initial configuration; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, said locking portion including at least one locking thread turn having one flank thereof bulging outwardly in a second axial direction opposite to said first direction, with the oppositely disposed flank of said locking thread in turn being depressed, such that upon engagement of said locking thread turn with said previously reshaped internal thread flank-to-flank contact will be obtained between the bulging flank of said locking thread and that of said internal thread, respectively, producing flank-to-flank interference which maintains said male and female members in assembled relation.

15. In combination, an externally threaded male member and an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of thread turns of the radially relieved type, said preparation portion including a plurality of sizing thread turns having a generally standard profile and an effective pitch diameter at least as great as the maximum allowable pitch diameter of said internal threads, with engagement of said sizing thread turns with said internal threads reshaping said internal threads to a predetermined uniform configuration having a prescribed pitch diameter, regardless of the internal thread tolerances encountered; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, and having a thread form which will, upon engagement with said uni-

formly reshaped internal threads, produce a prescribed degree of interference along one or more of the engaged thread flanks, to lock said male and female members in assembled relation.

16. In combination, an externally threaded male member and an internally threaded female member, said female member having an internal thread which is of a substantially circular cross section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of thread turns of the radially relieved type, said thread turns having an effective pitch diameter that is at least as great as the maximum allowable pitch diameter of said internal thread permitted by said industry tolerances, such that upon engagement of the preparation portion with said internal thread, regardless of the tolerance encountered, said internal thread will be reshaped and sized to a desired, predicted uniform configuration, having a shape and pitch diameter determined by said preparation portion; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, and having a thread form which will, upon engagement with said internal thread after reshaping thereof by said preparation portion, produce a prescribed degree of interference along one or more of the engaged thread flanks, to lock said male and female members in assembled relation.

17. A combination as defined in claim 16, wherein said locking thread portion includes a plurality of thread turns having a pitch diameter greater than that of the thread turns on said preparation portion.

18. A combination as defined in claim 16, wherein said locking thread portion includes a plurality of thread turns having one flank thereof bulging axially in a first direction with the opposite flank of each said turn depressed inwardly in the same direction, such that upon engagement with said reshaped internal thread, said flank interference will be obtained along said bulging flanks.

19. In combination, an externally threaded male member and an internally threaded female member, said female member having an internal thread which is of a substantially circular cross-section and of generally uniform dimensions held within accepted, industry specified tolerances, said male member including a driving head, a shank portion, and a tapered work-entering end, with an external thread formation on at least a section of said shank, said external thread formation including, a preparation portion disposed adjacent said tapered work-entering end and including a plurality of thread turns of the radially relieved type, said plurality of thread turns having one flank thereof bulging outwardly in a first axial direction with the opposite flank of said thread turns depressed inwardly in said first axial direction, such that upon engagement of said preparation portion with the internal thread of said female member, regardless of the industry tolerances employed, said internal threads will be reshaped and provided with a uniform thread form determined by said preparation portion, said uniform thread form having corresponding bulging and depressed flanks, de-

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flected axially with regard to their initial configuration; and a locking thread portion positioned further from said work-entering end of the screw than said preparation portion, said locking portion including a plurality of thread turns having a thread form which will, upon engagement with said uniformly reshaped axially deflected bulging internal threads, produce a prescribed degree of interference along one or more of the engaged thread flanks, to lock said male and female members in assembled relation.

20. A combination as defined in claim 19 wherein said locking thread portion includes a plurality of thread turns having relatively straight flank surfaces, disposed to engage said bulging flanks formed on said

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internal thread by the preparation portion, said engagement producing the desired flank interference.

21. The combination as defined in claim 19 wherein said locking portion includes a plurality of locking thread turns having one flank thereof bulging outwardly in a second axial direction opposite to said first direction, with the oppositely disposed flank of said locking thread turn being depressed, such that upon engagement of said locking thread turn with said previously reshaped internal thread, flank-to-flank contact will be obtained between the opposed engaged bulging flanks of said internal thread and said locking thread, respectively, producing the desired flank interference.

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