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(19) (CA) # CANADIAN PATENT

(54) FLOOR NAIL

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FLOOR NAIL

ABSTRACT OF THE DISCLOSURE

This invention provides a fastener which includes a shank having a piercing point on one end, helical threads of which the outer diameter is greater than the maximum diameter of the piercing point, and a head on the other end. The thread angle of the threads is such that the threads are self-tapping and self-threading when the fastener is driven by means of an axial force.

This invention relates generally to a fastener element, and has to do particularly with a fastener element which is adapted to attach a first layer to a second layer. More particularly, this invention has to do with a fastener element especially suited for attaching rigid sheet material such as plywood flooring to metallic floor joists such as steel floor joists.

Recently, steel floor joists have been developed for use in the construction industry. Such joists, forming part of the sub-floor,are not solid members but rather are formed usually in a C-shape. Floor plating materials, such as plywood sheets, are then fastened to the upper flat surface of the C-shaped joist. The actual thickness of the steel in the joist is relatively thin, and can be pierced by certain high-strength fastening members, such as the heat-treated spiral shanked Ardox (trade mark) nails, or by the conventional self-drilling tapping screws used with an automatic depth setting screwgun.

When the steel floor joist was initially developed, one of the most critical problems to be overcome was that of squeaking floors, particularly when plywood flooring was used. The heat-treated spiral shanked nails mentioned above are generally incapable of clamping the plywood tightly enough and holding it sufficiently securely to prevent squeaking. In section, the Ardox nail is usually square or octagonal, with the corners of the section winding helically about the axis of the nail. Thus the corners of such a nail are not really "threads" in the ordinary meaning of that word. It is thought that the inability of the Ardox nail to clamp the plywood sufficiently tightly is related to the large lead of the helically progressing corners of the section, as well as by the fact that the holding becomes frictional rather than by the threading of the nail into the joist.

The self-drilling tapping screws used with the common screwgun appear to function satisfactorily, because the screw drills itself through the steel of the joist and then the threads pull the plywood down tightly against the joist. Although this method is being presently used and results in a satisfactory flooring with minimal squeaking, it has the disadvantage that the screws must be manually placed in the screwgun one at a time and then drilled into the joist. This operation takes approximately twice as much time as the hand-nailing of plywood to wooden joists.

Recently, a department of the applicant company has performed a time study of a steel floor joist system with self-drilling tapping screws as compared to an identical wood system. The following table shows the comparative time required to install the subfloor in the steel system and the wood system.

STEEL:	Move Material	Cut Material	Fasten Material	Misc.	Total
1st Floor	10.0	11.4	226.0	-	247.4
2nd Floor	54.5	33.5	253.7	-	341.7
Total	64.5	44.9	479.7	-	589.1 = 9.8 hrs.

WOOD:	Move Material	Cut Material	Fasten Material	Misc.	Total
1st Floor	10.0	11.0	94.0	2.0	117.0
2nd Floor	55.0	15.0	154.0	-	224.0
Total	65.0	26.0	248.0	2.0	341.0 = 5.7 hrs.

The foregoing table makes it evident that the length of time taken to apply a subfloor with a steel joist system is almost twice as great as the length of time for a wooden system. In view of this fact, it is obvious that the cost of applying a subfloor in a steel joist system could be significantly reduced if the length of time taken to apply the subfloor could be brought closer to that required for a wooden system.

Aims of this Invention

In view of the foregoing, this invention addresses self to the provision of a fastening element which, when used with a steel joist system, may considerably accelerate the process of applying a subfloor.

This invention further addresses itself to the provision of a fastener which has clamping characteristics similar to that of self-drilling tapping screws, but which can be applied in a shorter time and at a correspondingly reduced cost.

This invention further addresses itself to the provision of a fastening member capable of manual driving and which is capable of securing plywood to a steel joist with minimum squeaking.

This invention further addresses itself to the provision of a fastening element which not only satisfies the preceding desiderata, but which is also capable of use in a pneumatic or power nailer.

General Description of this Invention

Accordingly, this invention provides a fastener which includes a shank having a head on one end and a conical portion on the other, the apex of said portion constituting a piercing point for the fastener, the conical portion having a base diameter, the shank including a smooth cylindrical portion adjacent the conical portion, and a threaded portion adjacent the head, the axial section of the fastener exhibiting an abrupt, angled transition between the conical portion and the smooth cylindrical portion, the threaded portion having from seven to nine relatively small "U"-type threads with rounded ends and a relatively small included angle between the thread sides, the outer thread diameter being greater than the diameter of said smooth cylindrical portion, the latter being the same as the base diameter of said conical portion, the thread angle of said threads being between about 35° and about 55°, such that the fastener is self-tapping and self-threading, the included cone angle of said conical portion being between about 23° and about 35°.

General Description of the Drawings

Three embodiments of this invention are illustrated in the accompanying drawings, in which like numerals denote like parts throughout the several views, and in which:

Figure 1 is an elevational view of a fastener element constructed in accordance with the first embodiment of this invention;

Figures 2 and 2A are partial elevational views of a fastener element in accordance with the second and third embodiments of this invention respectively;

Figure 3 is a sectional view through a flooring-and-joist combination, showing the two components of the flooring secured together by a fastener element constructed in accordance with the first embodiment of this invention;

Figure 4 is a tracing made from a photograph of a polished section through an actual test sample in which a fastener constructed in accordance with the first embodiment of this invention is driven through and holds together a layer of plywood sub-floor and a metal joist, the polished section being taken through the fastener as well as through the two layers;

Figure 5 is a sectional view similar to Figure 3, on a smaller scale, showing three stages in the application of the fastener constructed in accordance with the first embodiment of this invention;

Figure 6 an elevational view of a fastener element constructed in accordance with this invention, showing the locations of section planes; and

Figures 7 and 8 are, respectively, sectional views to a larger scale taken along the lines 7-7 and 8-8 in Figure 6.

Particular Description of the Drawings

Referring to Figure 1 of the drawing, the fastener element 10 is seen to include a head 12, a first shank portion 14, a second shank portion 16 and a piercing point 17. The piercing point 17 is in effect the apex of a conical portion 18 located adjacent the second shank portion 16.

As can be seen, the first shank portion 14 has helical threads 19 with a thread angle α of substantially 45°, although this angle is not considered to be critical.

Depending upon the size of each thread, there may be from 6 - 10 separate threads around the first shank portion 14, although again this is not critical. In the particular embodiment illustrated there are eight separate threads around the first shank portion 14.

As seen in Figure 1, the second shank portion 16 is smoothly cylindrical.

If desired, the entire fastening element may be case hardened by conventional techniques to give it increased strength in order to ensure that it will pierce the steel joist layer.

The threads in the first shank portion 14 of the shank may be relatively rough or rounded threads, as they are not intended to engage an internally threaded, pre-tapped member. Threads commonly known as "U" type threads may be utilized. "U" type threads are well known in the fastener art, and in profile have rounded ends and a relatively small included angle (about 40°) between the thread sides, hence the resemblance to the letter "U".

It is essential to this invention that the outside diameter D1 of the threads 19 in the first shank portion 14 be greater than the external diameter D2 of the conical second shank portion 16. The minimum thread diameter (i.e. the diameter measured at the "trough" of the thread) is not critical, but ordinarily would be slightly less than the diameter D2, since this would be the natural result of the standard rolling technique by which threads are rolled into an extruded length of nail stock.

The head 12 of the first embodiment of this invention, shown in Figure 1, is a plain flat head, and a fillet 19a is provided under the head 12.

Figure 2 shows the second embodiment of this invention, which differs from the first embodiment only in that the head 20 of the second embodiment is rounded at its upper surface.

The third embodiment of this invention is shown in Figure 2A, and differs from the first embodiment only in that it includes a countersink 21 under the flat-topped head.

Figure 3 shows the fastening element of the first embodiment of this invention in tight engagement with plywood flooring shown in section at 22 and with the upper plate 24 of a steel joist member, also shown in section.

The fastening element 10 in Figure 3 has been driven either manually or mechanically into the tight engagement shown. It will be seen that the lower surface 26 of the steel joist plate 24 has a rough edge portion 28 where the piercing has taken place, and it will also be noted that the head 12 of the fastening element 10 has been driven down to a slight crushing engagement with the plywood flooring sheet 22, so that the latter may be held in tight, non-squeaking engagement with the joist plate 24.

Attention is now directed to Figure 4,which, as stated earlier, is copied from an actual photograph of a polished section through a joint utilizing the fastener of the first embodiment of this invention.

The section through the fastener shown at 30 is not an axial section, but is taken through a plane spaced slightly from the central axis of the fastener. It will be noted that the upper plate 32 of the joist 34 has been bent and deformed downwardly by the pressure of the fastener 30 during its forced insertion. It will also be noted that the threads of the fastener 30 have in fact simultaneously tapped the plate 32 and threaded themselves through the plate 32, so that there is a positive engagement of the threads with the tapped hole through the plate 32. The same tapping and theading takes place in the plywood layer 36, as can be seen.

While the cylindrical shank portion 16 has been shown in Figure 1 to be of a substantial length as compared to the conical portion 18, the particular length or ratio of lengths is not considered to be critical. It is considered that the length of the cylindrical shank portion 16 can be shortened to the point where it is substantially negligible, provided the pointed end of the fastener (constituted in Figure 1 by the apex of the conical portion 18) widens progressively to a substantially smooth and round section before the threads 19 begin. The reason for this latter requirement relates to the necessity of first "punching" or piercing a substantially round hole in the layer prior to the point in time when the self-threading and self-tapping threads 19 come into contact with the pierced hole. Thus, the action of the fastener is two-fold: firstly a hole is "punched" or pierced by the pointed end (on which no threads are formed), and secondly that punched or pierced hole is tapped by the self-threading threads 19 as the fastener screws itself into the pierced or punched hole. Thus, it is obvious that the fastener will undergo some rotation about its axis during that portion of the driving operation when the threads 19 are in contact with at least one of the layers.

While a substantial length of unthreaded cylindrical shank is not considered essential to the broad concept of the invention, nonetheless in a preferred form of the invention the provision of a certain length of unthreaded shank portion can have an additional advantage, as will now appear from the following description with reference to Figure 5.

Figure 5 shows three fasteners 40, 42 and 44, at different stages of being driven through a double layer constituted by a plywood sub-flooring layer 46 and a metal joist layer 47.

The fastener 40 is simply shown in position for a first driving blow in a hand-driving operation with a standard hammer.

Fastener 42 is shown after the first blow of the hammer, the latter being assumed sufficient to drive the fastener through the plywood sub-floor layer 46 so that the piercing point ends up close to or touching the upper surface of the metal joist layer 47. It will be noted that the length of the fastener 42 from the piercing point to the beginning of the threads 19 (i.e. including the smooth cylindrical portion 16) is substantially the same as or only slightly larger than the thickness of the plywood sub-floor layer 46. Naturally, since there are no threads on the smooth cylindrical portion 16 of the shank of the fastener 42, the fastener 42 does not undergo any rotation and is not subject to rotational forces during this first hammer blow. The second hammer blow is intended to be of sufficient force to drive the fastener into the position of fastener 44 in Figure 5. During the second hammer blow, the point pierces the metal joist layer 47, and the smooth cylindrical portion 16 establishes a relatively smooth pierced hole in the metal joist layer 47 prior to the engagement of the threads 19 with that pierced hole. It will be clear that, over most of the movement of the fastener 44 during the second hammer blow, the threads 19 will be in engagement with at least one layer. The threads first come into engagement with the plywood sub-floor layer 46, and this begins rotational movement of the fastener during its descent. This means that, by the time the threads come into contact with the metal joist layer 47, the fastener is already rotating to some extent, and this will aid the process of self-tapping which occurs between the threads and the metal joist layer 47.

Conversely, if the threads 19 were to extend all the way down to the base of the conical portion 18 of the fastener 44, such threads would come into contact with the metal joist layer 47 almost immediately after the initial impact of the hammer in the second hammer blow, and this could mean that the fastener 44 would not have had sufficient time to begin rotating before this engagement takes place. This would mean that the threads could be forced through the pierced hole in the metal joist layer 47 during the initial non-rotating movement of the fastener, and this could tend to "strip" the threads through the pierced hole in a manner similar to a reaming action, as opposed to a rotational tapping movement through the metal joist layer 47.

Furthermore, if the threads 19 were to extend all the way down to the base of the conical portion 18 of the fastener 44, the threads would be forced through the pierced hole in the metal joist layer 47 without the benefit of the bell-like curved portion of the joist layer which is shown immediately surrounding the shank of the fastener in Figure 4. The piercing point and the cylindrical portion of the fastener ordinarily create this bell-like portion prior to the engagement of the threads therewith, and it is believed that the gradual engagement thereby afforded improves the threading action of the threads through the metal joist layer 47.

It can thus be seen that, for a particular application in which a relatively thick and relatively soft layer is to be fastened to a relatively thin and relatively hard under-layer, the provision of the unthreaded substantially smooth cylindrical portion 16 of the shank of the fastener provides an additional advantage, so long as the length of the fastener from the piercing point to the beginning of the thread is about the same as the thickness of the relatively soft and relatively thick layer. Naturally, this portion of the fastener can be considerably longer than the thickness of the last-mentioned layer, but this additional length of the smooth portion would be essentially wasted. Furthermore, it is essential that the threaded portion of the fastener be long enough to be able to extend through both layers, as shown with fastener 44 in Figure 5. Thus, to permit the shortest workable fastener length for a given application with a first thickness of metal joist layer and a second thickness of a comparatively soft panel layer, the length of the threaded portion of the fastener must be at least as great as the combined first and second thicknesses just mentioned, while the length of the fastener from the point to the beginning of the threads should be long enough that, during the second hammer blow described above with reference to Figure 5, the fastener will begin to rotate before the threads engage the pierced hole in the metal sub-layer.

A number of failure tests have been carried out with the fastener of this invention, the details of two of which will now be given in detail.

In the first set of tests, a piece of one-half inch plywood was hand-nailed to a 0.060 inch steel joist, with a washer around the fastener to distribute the load over a broader area. The fastener in all tests measured exactly 1-3/4 inches from the piercing point to the underside of the head, and relative dimensions were as shown in Figures 1 and 5 of the drawings. The fastener was case-hardened, phosphate treated, had eight separate threads, and had a thread angle of 45^{o}.

The following are the results of failure tests on five separate fasteners, the failure test being carried out by pulling the plywood away from the joist at a loading rate of

5 inches per minute, thereby to determine the failure load for the nail in the steel joist.

Test No.	Failure Load (lbs.)	Remarks
1	750	-Nail pulled straight out - no rotation.
2	775	-Nail pulled straight out - no rotation.
3	740	-Nail pulled out with slight rotation.
4	770	-Nail pulled out with about 10^{o} rotation.
5	760	-Nail pulled straight out - no rotation.
Average failure load - 759 lbs.		

The second set of tests was identical to that set forth above, except that the joist had a thickness of 0.075 inches. The size, condition and shape of the fastener is the same, as is the loading rate.

Test No.	Failure Load (lbs.)	Remarks
1	740	-Plywood failed by cracking down the middle at the nail.
2	770	-Plywood failed by cracking down the middle.
3	710	-Plywood failed by cracking down the middle. Nail almost came out, but did not rotate.
4	865	-No plywood failure. Nail rotated slightly.
5	870	-Plywood pulled over washer and nail. Nail came out about 1/16 inch.
Average failure load - 791 lbs.		

It will be noted that failure for the joist of thickness 0.060 inches involved the nail pulling out of the joist either with or without rotation. By comparison, the failure for the joist of thickness 0.075 inches involved, in all but one case, failure in the plywood rather than in the grip between the nail and the joist. It will be particularly noted that, with the 0.075 inch joist, the dislodgment of that grip required loads greater than 865 lbs. in two instances. By comparison, with the joist of thickness 0.060 inches, the grip was dislodged in each case by application of a load not greater than 775 lbs.

This suggests that the load required to dislodge the grip of a hand-nailed phosphate treated fastener of the foregoing relative and absolute dimensions in a 0.060 inch steel joist is in the area of about 750 lbs., while the load required for a 0.075 inch joist is in the area of 860 lbs. It is assumed that Test No. 3 for the 0.075 inch joist was an exception in that the grip between the nail and the joist was considerably weaker than in the other four tests on the same thickness of joist.

The foregoing failure loads are extremely high when compared with the normal expected failure load of a 2 inch common nail in a wood joist, the latter being about 150 lbs.

It is believed that the higher pull-out values of the fastener for the 0.075 inch joist, as compared to the 0.060 inch joist, is related to the fact that the "lips" which are deformed downwardly by the piercing point and smooth cylindrical portion of the fastener are stiffer in the 0.075 inch joist because they are thicker. These "lips" are what are threaded, and because the 0.075 inch lips are stiffer they offer more resistance to the cutting force of the threads, and hence are cut deeper.

While a thread angle of 45° has been referred to in this specification as providing satisfactory results, it is considered that thread angles in the general range from about 35° to about 55° may be utilized without altering the basic characteristics or grip strength of the fastener.

The included cone angle of the conical portion 18 is shown in the drawings to be in the region of 23° to about 30°. The preferred included cone angle of the portion 18 (i.e. the angle which, if rotated about its bisector, would yield the cone) is that shown in Figure 1, namely about 25°. However it is considered that a range of from about 23° to about 35° will produce a satisfactory fastener.

A'

It has been stated earlier in this disclosure that threads commonly known as "U" type threads may be utilized for the fastener herein described. Figures 6, 7 and 8 are useful to illustrate the profile configuration of threads of this kind. Figure 6 shows the floor nail, with two section lines drawn. Section line 7-7 is taken perpendicularly to the direction of the fastener itself, and results in the view shown in Figure 7, which is of course to an expanded scale. Section 8-8 is one which is taken so that it cuts across the particular thread 53 at right angles thereto, and cuts across adjacent threads at progressively sloped angles thereto.

Referring first to Figure 7, which is a section taken perpendicular to the direction of the fastener, each of the individual eight threads proceeds across the planar section at the helix angle of 45^{o} which means that in Figure 7 each thread appears to have a similar profile, but the profile shown is not the true thread profile that would be seen in a section taken perpendicular to a given thread. Instead, the thread profiles in Figure 7 are somewhat expanded, due to the fact that the section for the thread is angled to the actual trace direction of the thread. The expansion is something on the order of 1.4 (i.e. the square root of 2), given a helix angle of about 45^{o}.

Conversely, Figure 8 shows for at least one or two of the threads which are located toward the viewer in Figure 6, the actual and correct thread profile. The thread identified in Figure 6 by the numeral 53 is marked on Figure 8, and it can be taken that the profile there shown is the true thread profile. Again, the accuracy of the section for the thread 53 is due to the fact that it is taken at right angles to the actual thread direction at the point of crossing with the sectional plane. As previously stated, this does not hold for all threads. The plane along which section 8-8 is taken, which is sloped at about 45° to the fastener, becomes progressively more and more oblique to the various adjacent threads as these progress further and further around the girth of the floor nail. Thus the threads other than the thread 53 and possibly the two immediately adjacent to thread 53 cannot be taken to represent the true perpendicular sections.

An examination of the thread 53 reveals that it is of the "U"-type category, as opposed to the standard 60° triangular thread. The "U"-type thread differs from the standard thread in two important particulars. In the first place, the "U"-type thread has a rounded end rather than a sharp peak. Another characteristic of "U"-type threads is the rounded base between adjacent threads and the fact that at no location anywhere on the thread does the wall become flat or linear. The curvature of the profile across adjacent threads curves smoothly by reverse bends to define the profile. Another characteristic of "U"-type threads is the relative narrowness or "pointedness" of the threads as compared to the standard 60° triangular threads. Since the profile of the threads at no location becomes flat or straight, they do not lend themselves to angular measurement. Nonetheless, it can be said that the average included angle is in the region of about 40°.

In both Figures 7 and 8, which are adapted from actual photographs of a floor nail which has been cut, ground and polished in accordance with the section lines shown in Figure 6, the outer ends of several of the teeth

D

are shown to be somewhat irregular. This irregularity occurred in the photographs and has been reproduced in the figures. It should be understood that the gaps or irregularities are merely a form of roughness which results from the procedure by which the threads are formed. Normally, the material of the threads is raised up from the shank of the floor nail blank by the rolling procedure, and it is quite common to find irregularities and lack of exact symmetry in "U"-type threads formed in this manner, particularly when enlarged sections are examined. In Figures 7 and 8, some of the threads have had their true rounded profile dotted in at the outer extremity, to give some idea of the ideal shape.

D

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A fastener which includes a shank having a head on one end and a conical portion on the other, the apex of said portion constituting a piercing point for the fastener, the conical portion having a base diameter, the shank including a smooth cylindrical portion adjacent the conical portion, and a threaded portion adjacent the head, the axial section of the fastener exhibiting an abrupt, angled transition between the conical portion and the smooth cylindrical portion, the threaded portion having from seven to nine relatively small "U"-type threads with rounded ends and a relatively small included angle between the thread sides, the outer thread diameter being greater than the diameter of said smooth cylindrical portion, the latter being the same as the base diameter of said conical portion, the thread angle of said threads being between about 35° and about 55°, such that the fastener is self-tapping and self-threading, the included cone angle of said conical portion being between about 23° and about 35°.

2. The fastener claimed in claim 1, in which the thread angle is substantially 45°, and in which the number of separate threads is eight.

3. In combination:

a metal joist layer having a first thickness,

a panel layer having a second thickness and juxtaposed in contact with and against said metal joist layer,

and a fastener securing the panel layer to the metal joist layer, the fastener including a shank having a head on one end and a conical portion on the other, the apex of said portion constituting a piercing point for the fastener, the conical portion having a base diameter, the shank

C

including a smooth cylindrical portion adjacent the conical portion, and a threaded portion adjacent the head, the axial section of the fastener exhibiting an abrupt, angled transition between the conical portion and the smooth cylindrical portion, the threaded portion having from seven to nine relatively small "U"-type threads with rounded ends and a relatively small included angle between the thread sides, the outer thread diameter being greater than the diameter of the smooth cylindrical portion, the latter being the same as the base diameter of said conical portion, the thread angle of said threads being between about 35^{o} and about 55^{o}, such that the fastener is self-tapping and self-threading, the included cone angle of said conical portion being between about 23^{o} and about 35^{o}, the length of the fastener from the piercing point to the junction of the threaded portion with the smooth cylindrical portion being substantially the same as said second thickness, the length of the threaded portion of the fastener being at least as great as the combined first and second thicknesses, the fastener securing said layers together with its head against the panel layer remote from the metal joist layer and with said threaded portion extending through both said layers.

4. The combination claimed in claim 3, in which the thread angle is substantially 45^{o}, and in which the number of separate threads is eight.

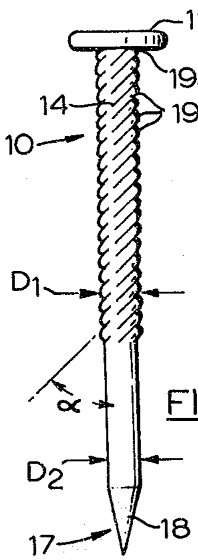


FIG. 1

FIG. 2

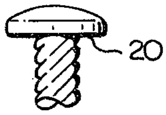


FIG. 2A

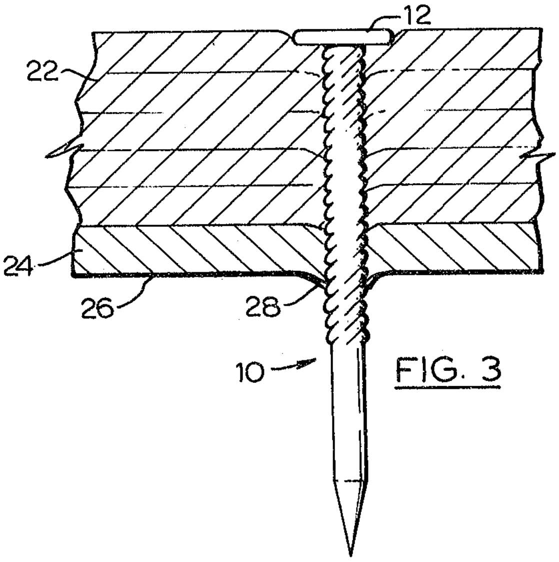


FIG. 3

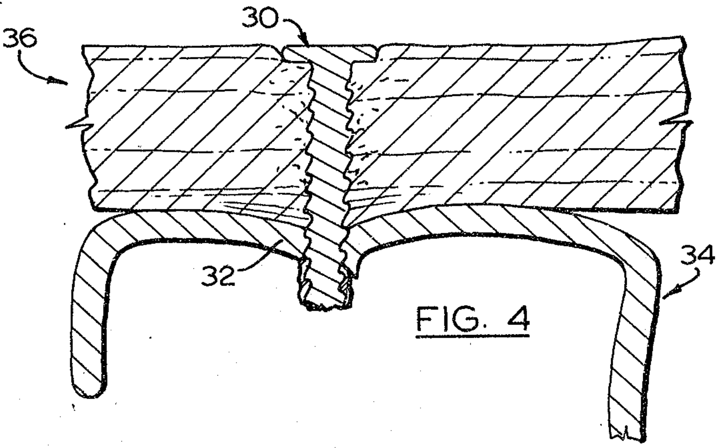


FIG. 4

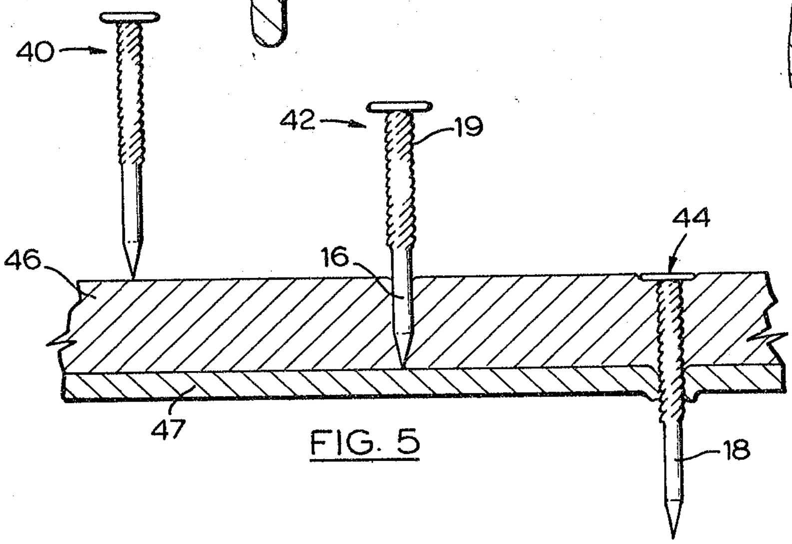


FIG. 5

Sim + McBurney

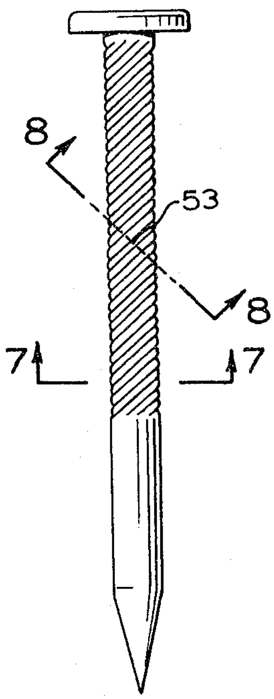
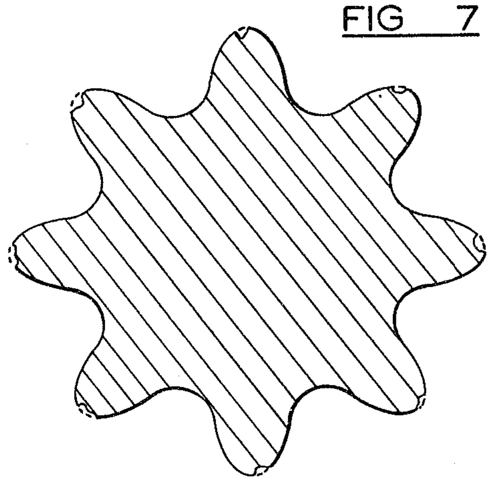


FIG. 6

FIG 7



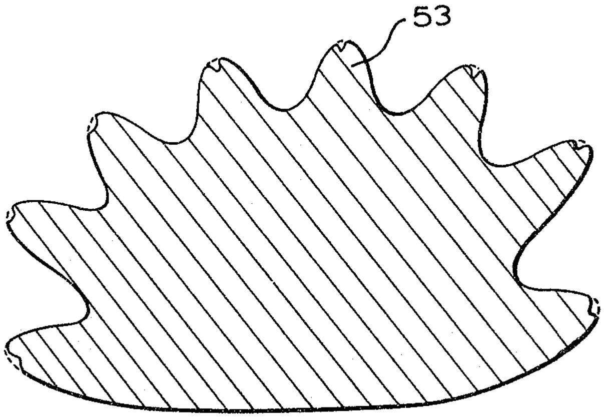


FIG. 8