

STANLEY PLANES AND SCREW THREADS

by John Bates

**Part One: Metal Screw Threads - Origins
and technology clearly explained**



A Special Publication by TTTG Inc
Copyright February 2006, The Traditional Tools Group Inc

What is TTTG?

TTTG was formed to encourage the preservation of traditional technical skills.

TTTG was formed to encourage research into Australian Industrial history.

TTTG is interested in all traditional technologies.

TTTG is interested in all traditional hand and machine tools.

Membership of TTTG is by subscription.

Membership of TTTG is open to all interested individuals.

Benefits of joining TTTG include.

TTTG holds meetings with guest speakers and tool auctions.

TTTG conducts skills based Workshops.

TTTG publishes a Newsletter.

TTTG publishes Tool Catalogue Reprints.

TTTG publishes Special Publications.

TTTG website www.tttg.org.au

Postal Address:

The Secretary TTTG (Inc.)

PO Box N240 Grosvenor Place

Sydney NSW 1220

AUSTRALIA

Enquires:

Mike Williams (02) 9144 6356

Bob Crosbie

r.crosbie@bigpond.com

Subscription Rates:

Sydney and Overseas \$30

Out of Sydney, other States and Australian Pensioners \$25



FOREWORD

by Bob Crosbie, President of TTTG Inc

Anyone who starts using or collecting old planes soon has to face the problem of finding replacement parts. With luck, parts from another similar plane might fit. A number of plane manufacturers copied the market leader. For most of the twentieth century, this was Stanley “Made in USA” or Stanley “Made in ENG”. For all practical purposes, parts from planes made by Record (UK), Turner (Australia) and by a few other manufacturers are interchangeable. However, the planes made by smaller manufacturers may look like the Stanleys but the parts are rarely the same.

Usually the threaded parts present the greatest difficulties. First time old plane owners faced with the problem of replacing missing parts invariably seek one or both of two solutions. The obvious path is to try to buy the missing part. With plane blades, this is sometimes possible.

Threaded components pose greater difficulties. Even if the plane maker is still in business this often results in frustration. Increasingly the reply is “No longer made” or “No such thing”. Specialist retailers usually give more polite but still negative replies combined with a sales pitch for a new high quality high price plane. Lateral thinkers soon discover the second path; that is to start buying incomplete or broken old planes and to cannibalise them for spare parts. How many addictions to collecting have resulted? Should TTTG form Plane Collectors Anonymous?

This quest for screw threads to fit old planes has created a “plane myth” consensus that Stanley and the other mass producers of planes used non-standard threads in their products. In the last few years this topic has been debated in the pages of TTTG News and on the TTTG and HTPAA websites www.ttg.org.au and www.htpaa.org.au .

John Bates entered this debate as the owner of one Stanley plane and an interest in metrology. Taking notes of the loose measurements mentioned in the discussion he put micrometer and thread gauge to the threads in his plane. He then asked plane owners for measurements. With a little deductive reasoning he converted the “about so many and a half threads” and “about something and a half diameters” responses he received into precise data. John then researched old Thread Charts.

John’s conclusions are in these two TTTG Special Publications. The first provides the technical and historical background. The second identifies the threads used in Stanley planes. I believe that this pioneering research will generate further analysis of the screw threads used in the vast range of metallic planes manufactured for a century.

INTRODUCTION – PART I

Life has many little mysteries. In the world of traditional tools and tool collecting the one that is perhaps most frequently talked about concerns the type and size of threaded parts used in the metal bench planes made by the Stanley Works (throughout the article references to the Stanley Works include the Stanley Rule & Level Company).

It would be fair to say that most people enjoy a good mystery and I am no exception. Therefore, it seemed quite natural that this inclination together with my love of machinery and machine history should draw me into the debate. The outcome is this article on the origin and production of the screw threads of the Stanley plane.

The article comprises two distinct but intimately related parts. The first looks at the various methods used in the production of screw threads, some of the economic and tolerance factors involved as well as the tools and techniques employed. Part two goes beyond these production issues and examines the social, economic and technological conditions and circumstances in the period leading up to and following the time that Stanley released its now famous metal bench planes onto the American market.

Furthermore, the article attempts to cover a very wide sweep of ground. It begins as one would expect with the screw then moves through the practice of screw thread production; thread geometry and metrology; current screw thread standards and their development; and ends with a review of the economic, social and cultural conditions that helped shape and drive America's industrialisation from 1850 into the early 1900's.

Dividing the article into two helped to emphasise the juxtaposition between the somewhat cloistered world of the factory workshop and the milieu in which the US began its development into the world's economic powerhouse. It also facilitated and assisted in its publication: the TTTG Newsletter being of quite modest proportions.

So why am I delving into such things? Well not because I believe that the 'old ways' are necessarily better than the new. However, I do feel that a better examination of some elements of past practice (and the kind of thinking that lay behind it) would be generally beneficial to those who use, restore and/or collect hand tools. I also see my efforts as a token contribution to the history of technology.

Without a standard, the repair and replacement of screwed parts is an extremely complicated, not to mention time consuming and costly process. Hence, the use of screws in any mass-produced product demands the use of ‘standard’ screw threads and a system of ‘fits’ or tolerances to ensure that components can be readily assembled. In other words, the parts must be interchangeable.

Such practical necessities are the reason that I cast grave doubt on any suggestion or theory that The Stanley Works used ‘non-standard’ screw threads in its hand planes in order to frustrate its competitors and/or force customers to buy ‘genuine’ replacement parts. This point is discussed more fully in Part II.

THE SCREW: A BRIEF INTRODUCTION

The origin of the screw thread is obscure, but it is logical to assume a number of craftsmen discovered it independently. There is evidence that screws were used for fastenings on personal armour, for parts of ancient cannon, and on the early printing press (see RYBCZYNSKI).

At first, the construction of the screw thread depended upon the eye and skill of the craftsman. However, from the eighteenth century, technical advances and technological change fuelled a growing demand for more screws, both in their accuracy and quantity. By midway through the first half of the nineteenth century, this demand had increased to the point that screws had to be mass-produced in factories. However, the lack of thread standardisation was a constant obstacle to efficient production and made interchangeability of fasteners problematical.

The English engineer Joseph Whitworth saw the pressing need for standardisation and responded by designing a system of standard screw threads based on a flank angle of 55 degrees. He presented his new standard in 1841 in a paper to the Institution of Civil Engineers, but it was not widely adopted in Great Britain until the 1860's.

Then in 1864, the noted American engineer William Sellers proposed an alternate standard for screw threads; his was based on a 60-degree thread form. It was eventually adopted as the US Standard and evolved into the American Standard Coarse (NC) and the Fine (NF) Series. A major advantage of Seller's thread was that its flat roots and crests made the screw easier to manufacture than the Whitworth standard that required rounded roots and crests. From the outset, Sellers did not like the shape of Whitworth's thread; one of his primary objections being that it took three kinds of cutters and two kinds of lathe to make a Whitworth screw. His 60 degree thread was easier to make and measure because it is part of an equilateral triangle. Likewise, his recommendation that the top of the pyramid should be flat was because that form is much easier to make than a ‘fancy’ rounded top. Sellers claimed his thread would need just one cutter and one lathe; and so it would be easier, quicker and, most importantly, cheaper, to make.

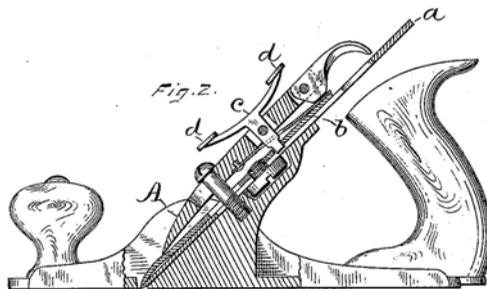
Production issues aside, there was little to choose between the two rival standards on any scientific basis. But by 1883, the American railroads were the largest corporations in the USA and practically all of them were using the Sellers screw thread. This forced the suppliers to those railroads to stock that thread. As with so many aspects of culture, weight of numbers decided that Seller's thread, and not Whitworth's, would be the standard across America.

For horological and instrument work the Thury thread, developed at a conference in Geneva in 1877, was used and was the basis for the British Association (BA) thread. The S.I. (Système International) metric thread was initiated by the International Conference in Zurich in 1898. This was generally accepted by Continental countries as the basis for their own thread standards.

The Unified thread series - adopted around 1948- is a 'modern' development introduced by the International Standards Organisation (ISO) which was formed in 1946. But 'standards' were about long before the ISO or Whitworth. The difference was that these earlier standards were not International, indeed for the most part they were confined to the output from a single firm or works. In the mid-1860s Charles Holtzapffel (1847: volume 2, 665) observed that, "No inconvenience is felt from the dissimilarities of screws, so long as the same screwing tools are always employed in effecting repairs in the same works".

Clearly, such a pragmatic position may be explained as a reflection of the state of the engineering, manufacture and trade in 1846. And at that time Mr Whitworth's screw threads were merely a suggestion. I might add that Holtzapffel goes on to discuss the taps, dies and hobs which his father used between 1794 and 1800! The significance of all this to the present discussion is that, by and large, all the major developments in the design of the metal bench plane took place after the first screw thread standards were introduced into the US. However, more on these historical matters later. Let us now turn to the practice of making screw threads and a review of the terminology used.

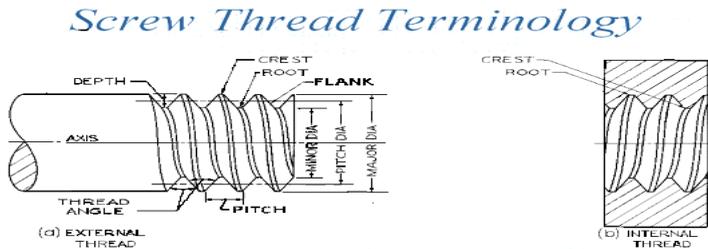
FIGURE 2: Sketch taken from F M Bailey's design for bench plane – US Patent No. 350613 of 1886



THE TERMINOLOGY OF THREADS

Throughout the text in the next few sections various terms are used, each of which may have a meaning which varies from the reader's understanding of that term. Thus Figure 3 below and the following glossary are intended to serve as much as a reference for myself as to avoid or resolve confusion for the reader. Being Australian and schooled in the ways of my country's British colonial past, the glossary provided gives priority to British and Australian interpretations and names in preference to those used in the United States.

FIGURE 3: Screw thread terminology



ACTUAL: SIZE – the measured size

ANGLE OF THREAD - the included angle between the flanks, measured in an axial plane section.

BASIC SIZE – the theoretical size and that from which the limits of size are derived by application of allowances and tolerances

CREST - the prominent part of a thread, whether internal or external; it may be either curved or flat in axial section

EFFECTIVE OR PITCH DIAMETER - on a parallel screw thread this is the diameter of an imaginary cylinder approximately mid way between the major and minor diameters which would pass through the threads at such points as to make width of the thread at these points equal

FLANK - the straight side that connects the crest and the root.

MAJOR DIAMETER (of parallel thread) – the diameter of an imaginary cylinder, coaxial with the screw or nut, which envelopes the thread with helical contact on the crests of the screw or at the roots of the nut

MINOR DIAMETER (of parallel) – the diameter of an imaginary cylinder, coaxial with the screw or nut, which makes continuous helical contact at the roots of the thread on the screw or at the crests of the thread on the nut

NOMINAL SIZE – the designation that is used for the purpose of general identification

PITCH – the axial distance between corresponding points on adjacent thread forms

ROOT - the bottom surface joining the flanks of the two adjacent surfaces of the thread whether internal or external, it may be either curved or flat in axial section

MEASURING SCREW THREADS

‘Measuring’ anything always raises questions of certainty or uncertainty; that is how confident we are, or how confident do we need to be, that our measurement is a true reflection of the thing measured. The precision with which we undertake manufacture or measurement should be no more than that needed to satisfy the service requirements of the product. Any more precision is a waste of time, effort and money. Some wag once summed up the futility of unnecessary precision in measurement in the saying; “measure it with a micrometer, mark it with a piece of chalk and cut it with an axe”.

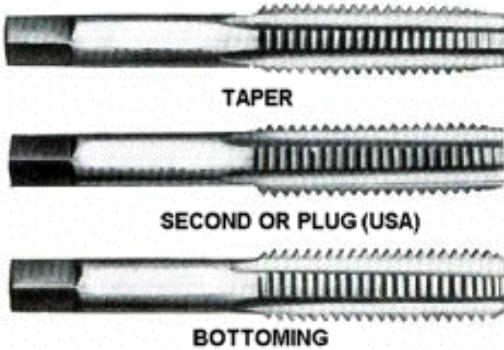
We have all picked up a screw, nut, or whatever and, simply by sight, been able to make some judgement about the ‘size’ of the thread. It is surprising just how often a sufficiently ‘accurate’ assessment of the thread size can be made just by looking at it! But the challenge that the screw threads on Stanley planes presents is one that demands something more sophisticated than ‘it looks right’. Indeed the experience of some TTTG members clearly shows that, the screw that looks right simply will not fit or fits quite poorly. Try as we might, the ‘right’ screw is nowhere to be found.

Now running a micrometer over the crests of the thread tells us a little about the screw. Nevertheless, this alone will not be enough to identify the thread size or type reliably. Further tests such as by using a thread gauge improves this situation, yet still leaves us with only rudimentary knowledge of some critical characteristics of the screw such as its pitch diameter, but more on this subject a little later.

MAKING A SCREW THREAD

Screw threads can be made by hand or machine. There are several methods of making them using machinery, they can be cut individually on a screw-cutting lathe or on a plain lathe using hand chasers and they can be mass-produced by cutting, grinding or rolling. Automatic lathes for the mass-production of screws were built in America during the Civil War (SINGER: volume 5, 646). The tools used for making screw threads by hand are taps (for screwing holes) and dies (for screwing bars). I will mostly confine the discussion to hand threading methods.

Taps: Joseph Clement (1779-1844) reportedly produced the first fluted taps of the kind with which we are now all familiar (ROLT: 100). Taps are used to cut the internal or female thread. These tools are typically made in sets of three. No.1 is called the taper tap; No.2 called the second, middle or intermediate tap (known as the plug tap in the USA); and No.3 is called the plug or bottoming tap. With the British Association or BA thread, the No.2 or second tap is always omitted.



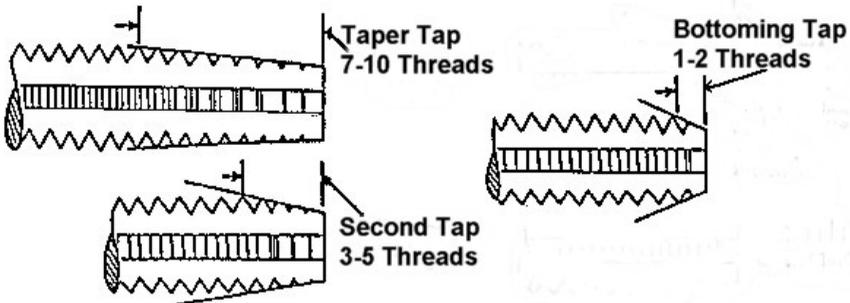
The No.1 or taper tap has a long chamfer of about eight threads.

TAP & DIE CHAMFER - the taper at the thread end of a tap or the throat of the die, made by cutting away the crests of the first few threads so as to distribute the work of cutting over several threads and also act as guide in starting the tap or die.

For dies: the stamped-size side is 45 degrees and back side is 60 degrees. For taps: the chamfer is relieved to facilitate cutting and the TAP is classed Taper (T), Second (S) or Bottoming (B), according to the length of chamfer, approximate sizes are:

- Taper tap 4 degrees per side (7 to 10 threads)
- Second tap 8 degrees per side (3 to 5 threads)
- Bottoming tap 22 or 23 degrees per side (1 to 2 threads)

The Second tap is also referred to as 'Intermediate'. The name 'PLUG' is commonly used to indicate a Bottoming tap. In America it is used to indicate a Second tap. To avoid confusion the terminology that should be used as stated by British Standard BS949:1979 is 'Bottoming' tap.



When hand tapping, except in shallow or blind holes, this tap is typically used to start the thread. The long chamfer helps to align the tap much better than a No.2 or No.3. The taper tap will make a complete thread in a through hole of normal depth; that is, a hole of about 1.5 times the diameter of the tap.

The No.2 or second tap is often used for preliminary tapping of blind holes. All its threads are full except for the first five or six.

The No.3 tap has complete threads all along the tap but for the first one or two threads. In the past, it was considered the most accurate as it was usually more thoroughly tested than the other two taps. This is no longer the case today and all taps of the same class are of equal accuracy. All three taps may be used on through holes or deep blind holes.

In addition to the varying taper of the tap as noted above, taps also come in various styles of flute. For the majority of situations that the home machinist will encounter a 'standard' straight fluted hand tap is all that will be needed. UN-series taps are readily available in H2 and H3 tolerance.



Experience suggests that the intermediate tap is the pick of the litter; a real workhorse, and treated carefully it is quite capable of doing the work of both the taper and the bottoming taps tolerably well. Indeed, taps in some less common styles are only available in the intermediate form. Hence, I use the 'inter' for all normal cutting.

However, my tapping experience is confined to the workshop environment; Clynt Sheehy, TTTG Treasurer, was thoughtful enough to remind me that the taper tap may be the better option in some cases particularly in effecting field repair work or in other

situations where it would assist in keeping the thread square to the hole. In Clynt's case his nemesis proved to be a stripped sump plug hole in a 1966 Holden where the 'inter' proved difficult to use in situ producing an out-of-square thread and a leaky seal.

It should also be noted that all taps must have some chamfer or taper lead as they simply would not be able to cut a thread without it; even reamers are ground with a nose relief.

Spiral point 'gun' taps are so named because their cutting action throws or shoots out the chips ahead of the tap like the 'shooting' action of a gun. Their use is most definitely not confined to gun repair or gun manufacturing and they are ideal for through-hole machine tapping.



Dies: Dies are used for cutting the external or male thread. There are several types of dies, of which two are particularly important. The first is the circular die sometimes called a button or spring die (pictured). The second type is the split die that, as the name implies, is a two-piece construction.

The dies are made in a standard range of outside diameters to fit the appropriate diestock. These diameters are 13/16, 1, 1½, 2, 3 and 4 inches. In use the split or button die is placed in the diestock and then adjusted using three screws located in the circular section of the stock. The middle screw is provided with a pointed end designed to fit into the slit or cut made in the die. The purpose of this slit is to allow the die to be adjusted slightly larger or slightly smaller as the need or required 'fit' may demand. Screwing the middle screw into the cut before tightening the other two screws makes the die larger. Reversing this procedure makes the die cut slightly smaller.

Always try to put equal pressure on the outer two screws; this reduces the risk of breaking the die. Split dies are also available with an integral adjusting screw, which allows the die to be preset and checked before use and so minimises the possibility of a poor fit.

Carbon steel vs. High Speed Steel: Today most taps and dies are made from high speed steel (marked HSS or HS) though some carbon steel products are still sold. Few cutting tools of comparable size are expected to do more work than taps. For example, the feed rate is governed solely by the pitch of thread, swarf in many cases cannot be removed from the cutting zone, and the cross-sectional area of the tap is often small when compared to the work that it must undertake. My advice is to buy the very best quality you can afford as this will produce better results in use and cost less in the long run. When buying taps or dies check that the tool is marked HS or HSS and

avoid carbon steel like the plague.

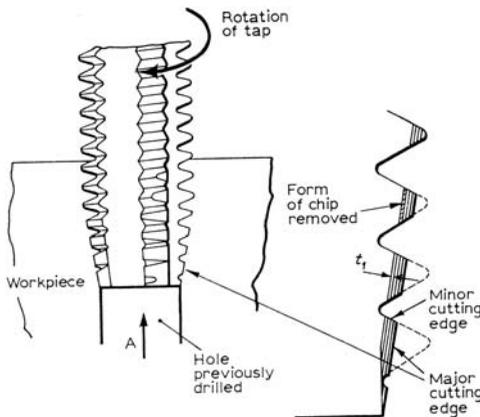


Die nuts: Finally, a caution about die nuts (pictured); these tools should NEVER be used to cut a full depth of thread on a piece of bar stock. They are only designed to standardise or true existing threads or to ease a dirty or damaged thread. A die nut is particularly useful dealing with a bruised thread after a set of studs has been fitted and the stock and dies can no longer be manipulated. Nevertheless, enough said on this topic.

DRILL AND TAP AND THREAD

I always like to drill a hole before attempting any tapping operation. If nothing else, it is of great assistance in locating the tap. This may be a surprise to some people, but drills are primarily 'roughing' tools and will tend to create over-sized holes. In fact, tests have shown that even when drilling under 'ideal' conditions the degree of probable oversize will be from about 0.0015 inch for a hole to suit a No.0-80 machine tap, up to 0.0060 inch for a 1-inch diameter by 14 threads per inch tap hole.

Under less than ideal conditions, that is no centre-drilled hole and no drill bushing to guide the drill, considerably more oversize may be expected. Thus, for holes from 1/8 to 1/4 inch, an oversize of 0.0050 inch is typical and for 1/4 to 3/4 inch diameter holes this will usually increase to 0.0060 inch.



By now you may have begun to suspect that tapping threads is not as straightforward as some would have us believe. Even the 'generally accepted' 70-75% depth of thread is rather difficult to produce, and for the most part unnecessary for the home machinist. This is especially true in certain 'small' sized taps of the UNC standard, since the

smaller taps in coarse pitches are expected to remove too great a percentage of metal in relation to their core dimensions and strength.

Tapping torque or turning force increases greatly with a fuller thread and tests have

shown that three times as much power is required to produce a 100% thread depth as for one of 75%. A fuller thread involving a deeper cut also brings a larger volume of chips to be carried in the flutes and increased difficulty in applying lubricant. With 50% depth of thread only 30% of the basic thread area has to be removed by the tap and with 75% thread depth only 60% of this area.

Hence, many difficulties in tapping practice are as a direct result of attempting to tap too great a percentage of thread. Thus the smaller the diameter and the coarser the pitch of tap the lesser the percentage of thread that need be tapped. While percentage of thread is also dependent on the material, in no case should the depth of thread ever exceed 83%. When hand threading the cutting action of the tap or die may be facilitated or improved if the tool is 'humoured' whenever the resistance is felt too great.

Selecting the tapping drill: a rule of thumb to find the correct size tap drill for use with American standard threads is the major diameter of the screw minus one divided by the number of threads per inch.

For example, the drill for a ½-13 UNC tap would be $(0.500 - 1) / 13 = 0.423$. The nearest fractional drill under 0.423 is 27/64 (0.421) inch. In the case of a No.12-24 tap the following drills will yield the percentage of full thread as noted - No.19 (59%), 4.1 mm (70%), No.20 (71%), No.21 (76%), 4.0 mm (81%) and 5/32 (83%). The benefit of having available a wide selection of drills is immediately obvious.

Tapping blind holes: blind holes, such as those on the Stanley bench planes for the tote and knob studs, are quite often tapped in two operations. The first is typically at least a half to one thread deeper than the second so that the finishing tap need not remove a great amount of metal when it reaches 'bottom'. If you look at the threaded hole in your Stanley you may be able to see this; if not you will be able to measure it because the fixing screw will seize before it reaches the bottom of the full depth of the hole.

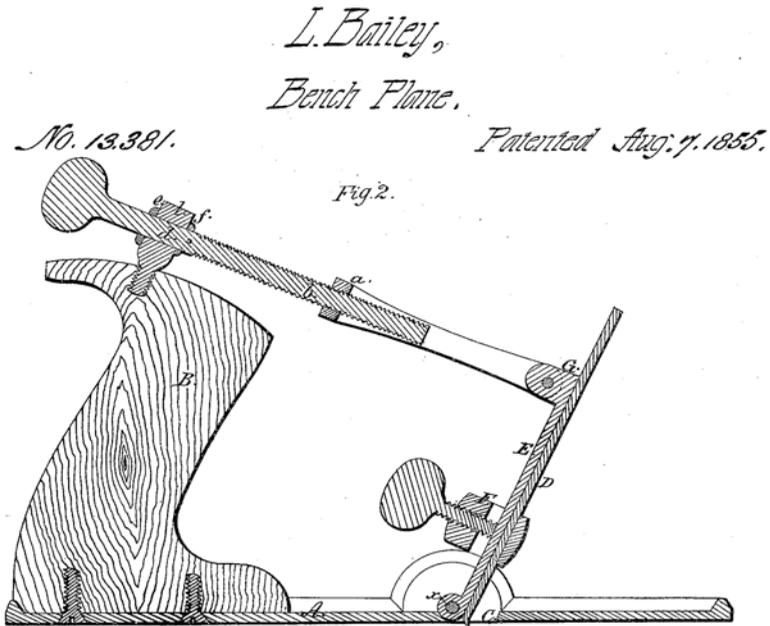
Die-cutting a thread will be greatly assisted if you ensure that the end to be cut is faced square and has a chamfer of around 45 degrees cut down to the minor diameter of the required thread. Such preparation will go a long way to providing an easy start for the die and lessen the likelihood of the die cutting out-of-square.

Always use a thread lubricant. It eases the load on the tool thus prolonging its life, increasing the time between sharpening, improving chip removal and producing a better surface quality on the thread. I use 'Tap Magic' for everything, but it is particularly good when tapping aluminium alloys. Most types of brass can be cut or tapped dry.

MACHINE SCREWS

So why use machine screws rather than 'regular' fractional size screws? Simply because in the USA when Stanley started making woodworking tools and especially for sizes below ¼ inch diameter machine screws were readily available. These screws were part and parcel of the standardised thread forms introduced into American industry by William Sellers in 1864.

FIGURE 4: Sketch taken from L Bailey's design for bench plane – US Patent No. 13381 of 1855



The Bailey plane patents relating to the Stanley 'Bailey' bench planes post-dated this event by about 20 years. At that time the standard machine screws series also included an extra coarse pitch type that would have been ideally suited to threading in iron plane castings.

Perhaps a point of historical clarification is required here. There is no doubt that Bailey was himself manufacturing a range of planes as early as 1855 and certainly before 1858. However, these designs were for wooden-bodied planes (see for example US Patents Nos. 21311, 67398 and 72443) or, in the case of US Patent No. 13381 (see Figure 4), suggested a design quite different to the metal-bodied bench planes later produced by Stanley. Whilst, in the mid 1880s, Bailey manufactured a range of metal planes, his patents (except for the scraper plane, fig 4) show his patented mechanicals

on a wooden stock similar to the later, so-called, “transitional” planes. Thanks to Clynt Sheehy for drawing this to my attention and providing the relevant patent dates.

Machine screws are in reality small hand taps except that they are made to the machine screw system of sizes. In that system No.0 is the smallest and equals 0.060 inches. Each subsequent size increases by regular increments of 0.013 inches. Taps are still furnished up to and including the No.14 size.

For The Stanley Works, adopting machine screw sizes for its fasteners was simply following standard practice, with the added advantage that the extra coarse threads offered the following benefits:

1. easier/faster assembly; provides better start and less chance of a cross-thread
2. nicks and burrs from handling were less liable to affect assembly
3. less prone to strip when threaded into lower strength metals
4. easier to tap in brittle materials and or materials that crumble easily

If you need further evidence then consider this, those ‘non-standard’ No.12-20 and the 9/32-24 taps can still be purchased in America today (see Rutland Airgas Catalog 2005, p.106 at www.shoprutlandtool.com).

WHAT ABOUT OTHER THREAD TYPES?

Some members have also written or asked about the use of Whitworth fasteners in planes and other hand tools.

Sir Joseph Whitworth first developed the British Standard Whitworth (BSW) thread form in 1841. The distinguishing feature of the BSW thread is that the angle between the thread flanks is 55 degrees and the thread has radii at both the roots and the crests of the thread. Its specifications are contained in BS84. The Unified thread superseded this thread form in 1948 that ultimately gave way to the metric thread form. A variant, the British Standard Fine of BSF thread form, is based upon the BSW form but has a finer thread. The BSF was first introduced in 1908 and is also specified in BS84.

Provided the thread pitch and diameter are the same, BSW and BSF threads can be interchanged with their UNC and UNF counterparts despite the differing flank angles. Tests carried out in the 1950s on ¼, 3/8 and 5/8 size threads showed that when nuts and bolts of different thread form were assembled there was no appreciable difference in the fatigue or strength performance compared with those assemblies with a matching thread form (see *Practical Engineering* Vol 30, No 758, September 1954, pp 319-20).

Square threads are now obsolete, but tap sets may still be purchased (in almost any size) if you have the financial resources to pay the cost of a special production run. A typical set of square or Acme taps would comprise two or three tools allowing a progressive cutting of the full depth of thread. However, in the production situation

time is money and to save dollars one-piece combination or ‘tandem’ taps are made to do the roughing and finishing cuts in a single pass.

ROLLED THREADS

An interesting point raised in the current debate concerns Stanley’s use of rolled thread fasteners on its hand planes. So why use screws with rolled threads? There are

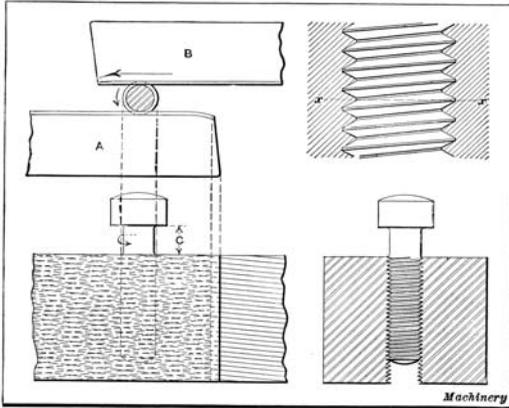


Diagram illustrating how Screw Thread is rolled

many reasons for using rolled thread screws, but the most important are related to mass production advantages. In addition, The Stanley Works clearly had a pretty good grasp of how to wring the maximum profit out of the production line.

Firstly, the surface finish of the thread is less rough than for screws with machine chased threads; typically as smooth as 12 or 14 microinches. By comparison, a chased thread is the roughest finish being

around 125 to 250 microinches. This smoothness assists mass assembly.

Second, thread rolling saves material and is thus cheaper. For a ¼-20 UNC thread the material saving is around 25%! This is simply because the thread is created by displacing or rearranging the screw blank material rather than by removing it. As noted by Terry Butcher, a past President of TTTG Inc., the blank has a smaller diameter than the finished thread. This is one indication that the screw has been manufactured by rolling. For a rolled thread the preferred material will typically be a straight carbon steel in the 1005 to 1095 range.

Finally, thread rolling has lower production costs. Small-diameter fasteners can be produced at rates of up to 3,000 pieces per minute by rolling.

This leads to another interesting question: Did Stanley produce its own threaded fittings, or did the company source them from other suppliers? I suspect that the lever cap screw would more likely than not have been made by Stanley in-house. However, each plane also has two simple studs; one securing the front knob and the other fixing the handle. As parts go these studs have nil intellectual property value, are very simple to manufacture and feature wide tolerances.

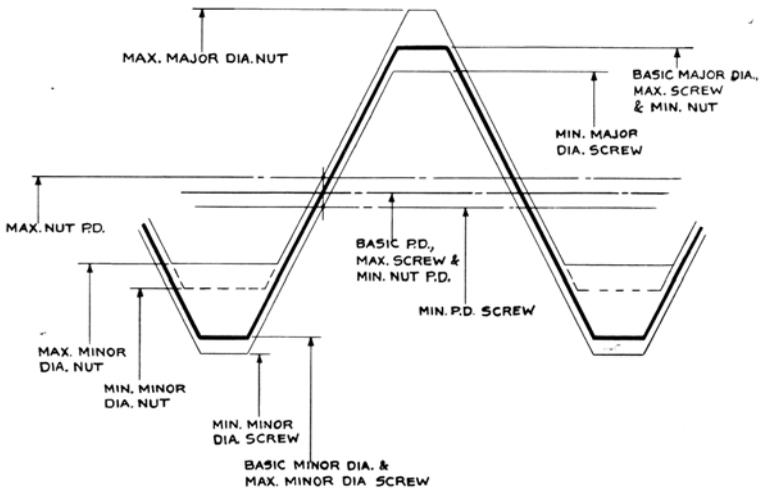
At a rate of even 250 pieces per minute (let alone 3,000) a single rolling machine could easily produce 150,000 studs in a day! Even early automatic screw-making lathes of the 1870's could turn out machine screws at between 80 and 150 pieces per hour (DERRY: 360) Now I have no precise information on this but my guess is that that The Stanley Works was never making enough planes to keep a thread rolling machine fully occupied. Even one old style automatic screw lathe would probably have exceeded the company's needs. Stanley did not become the commercial success it is by adopting inefficient work and production practices.

Hence, it seems more likely that Stanley out-sourced much of its production requirements for threaded parts and components. If that were so then this would be one more nail in the coffin of the non-standard thread theory.

TOLERANCES AND LIMITS

An essential principle in making screw threads is that the actual profiles of both the nut and bolt threads must never cross or transgress the theoretical or basic profile. Therefore, tolerances must be applied to ensure that this essential principal always applies in practice.

The setting of tolerances for screw threads is complicated by the complex geometric nature of the screw thread form. Clearances must be applied to the basic profile of the threads in order that a bolt thread can be screwed into a nut thread. However, in practice for the thread to be made tolerances must also be applied to the main thread elements.



SCREW THREAD "FITS"

Usually nut threads have a tolerance applied to the basic profile so that it is possible in practice for the nut thread profile to be equal to the theoretical profile. Bolt threads on the other hand usually have a gap between the basic and actual thread profiles. This gap is called the allowance on inch-based threads and the fundamental deviation on metric threads. The allowance is the prescribed difference between the design (maximum material) size and the basic size.

The TOLERANCE CLASS is a combination of tolerance grade and a fundamental deviation that is given to an internal or external thread. A tolerance class for an internal thread when combined with the tolerance class for an external thread gives the class of fit for the mating threads.

TOLERANCE GRADE The difference between maximum and minimum metal conditions for a tolerance applied to a screw thread. For metric threads the tolerance grade is given a number.

The FUNDAMENTAL DEVIATION is an intentional clearance between internal or external thread and the design form of the thread when the thread form is on its maximum metal condition. For metric threads the fundamental deviation is designated by letters, capitals for internal threads and small letters for external threads. Some tolerance classes have a fundamental deviation of zero. For imperial threads the fundamental deviation is called the allowance.

The CLASS OF FIT is a measure of the degree of fit between mating internal and external threads. Thread Classes are used to specify the amounts of tolerance and allowance. Three main Classes of Fit are defined for Unified screw threads: 1A, 2A and 3A for external threads and 1B, 2B and 3B for internal threads.

If you look at the markings on a ground thread HSS tap, in addition to the letter G that designates it as a ground thread tap, it has limit numbers. For example, GH3 indicates a ground thread tap with pitch-diameter limits of 0.0010 to 0.0015 inches above basic on sizes of 1 inch and under. The letter H designates high or above basic diameter while the letter L indicates low or below basic. These data are related to the tap limits only. There is a common misconception that, for example, a GH2 limit tap should be used to produce a Class 2 fit. This is not true. None of the data on tap limits in any thread series corresponds to the various classes of fit.

In fact, in the tap limit series, the largest number indicates the limit farthest from basic, whereas in the class of fit the smallest number indicates the greatest deviation from basic size. So for a No.12-24 thread, a Class 2 fit will require a class GH3 tap and a Class 3 fit would require a GH1 tap.

TOLERANCES FOR ROLLED THREADS

There are three general classes of blank size used in thread rolling. Those a little larger than pitch diameter (Class 1); those approximately equal to the pitch diameter (Class 2); and those a little smaller than the pitch diameter (Class 3). Class 3 blanks are for threads from ¼ to ½-inch diameter and about 0.002 to 0.003 less than the basic pitch diameter. The blanks for Class 3 threads below ¼-inch diameter are about 0.001 to 0.0015 inches smaller than the basic pitch diameter.

DISCUSSION

So armed with a little knowledge what can we make of the screws and tapped holes that Mr Stanley has handed down to us?

To begin I would suggest that it is far too optimistic to expect that any fastener used on a Stanley plane will measure to gauge. By this I mean that you should not expect to pick up a ¼-inch screw and measure 0.250 inches across the major diameter. More likely it will measure 0.240 inches and still be within its production limits.

CLASS OF FIT	MAX. PITCH DIA. bolt (in)	MIN. PITCH DIA. bolt (in)	MAX PITCH DIA. nut (in)	MAX. OUTSIDE DIA. bolt (in)	MIN. OUTSIDE DIA. bolt (in)
Class 1 Rough work	0.2160	0.2109	0.2226	0.2489	0.2367
Class 2 Standard	0.2175	0.2139	0.2211	0.2489	0.2408
Class 3 High quality	0.2178	0.2165	0.2188	0.2500	0.2419
Class 4 Aircraft	NA	NA	NA	NA	NA
Class 5 Wrench or interference	0.2193	0.2186	0.2183	NA	NA

SOURCE: Machinery's Handbook

I consulted Machinery's Handbook and found that a loose fit, or Class 1, is recommended as the commercial standard for any work where the threads must assemble readily and a certain amount of shake or play is not objectionable. Free fits,

or Class 2 threads, include threaded work of ‘ordinary’ quality of finish and semi-finished nuts and bolts (see Table 1).

The vast bulk of commercially made nuts and screws are Class 2 fasteners. My examination of the fasteners found on Stanley hand planes such as the studs holding the tote and front knob indicate that they are made to a Class 1 finish. I will try to clarify this a bit further using Terry Butcher’s comments from the October 2004 *TTTG Inc. Newsletter* (No. 79) as an example.

Firstly, a No.12 machine screw has a ‘nominal’ major (i.e. outside) diameter of 0.2157 inches. However, its ‘basic’ major diameter, assuming it to be a Class 1 screw, can vary between 0.2147 and 0.2055 inches. So the screw that Terry measured as 0.212 inches would be within the tolerance specified for a Class 1 screw of that size. Jim Davey, a long-time member of TTTG and a restorer and ‘tuner’ of Stanley planes, also measured the screws for the tote, knob and frog. He came up with 0.214, 0.208 and 0.206 inches, each one different to Terry’s but all are within the size limits for a Class 1, No.12-20 machine screw.

TABLE 2:				
Measure of screws from a Stanley ‘Bailey’ No.4½ bench plane c.1950				
PART OF BENCH PLANE	PRODUCTION METHOD	NOMINAL SIZE (decimal inch)	MEASURED MAJOR DIA OF SCREW	MEASURED MINOR DIA OF TAPPED HOLE
Tote/knob screw	Rolled	No.12-20 (0.21570)	0.2110	0.18895
Frog screw	Chased or cut	No.12-20 (0.21570)	0.2170	0.18475
Lever cap screw	Chased	9/32-24 (0.28125)	0.27785	0.24895
Adjuster screw	Chased or cut	9/32-24 LH (0.28125)	0.28300	NA
Cap iron screw	?? unidentified	Unable to gauge	NA	NA

As an experiment I disassembled my Stanley ‘Bailey’ No.4½ (year of manufacture c.1950) and measured some of the threaded components. See Table 2 for the results. I measured the threaded holes using pin gauges so the measurement is the clearance between the actual crests of the finished threads.

The lever cap screw is an interesting beast for a couple of reasons. To begin with it is

not rolled as are some other threaded components, but appears to have had its head and thread finished on an automatic lathe of some type. I also suspect that the head was first shaped or upset and the blank loaded into the lathe for finishing.

Based on the plane parts that I examined, the quality of the handle/knob studs was poor in terms of profile and surface finish. The thread shows the split or twin peaks effect on the crests often found on lesser quality rolled fasteners. Still this level of quality is more than adequate to hold the parts together. The Stanley Works certainly did not waste time on unnecessary accuracy or surface finish.

This is by no means a scientific result. By this I mean it is not an adequate sample and therefore we should not be tempted to jump to conclusions based on this data alone. A goodly amount of the relevant data needed to help inform our debate is missing. For example, when was the plane I examined made? I understand that Stanley began making the No.4½ in 1884, but my plane was probably made after 1950! Did Stanley stick with the same size fasteners from the year dot? Possibly, but we know that the manufacturing method used to produce some parts, such as the tote studs, did change at some point in time; Jim Davey suggests this may have been around 1900. In addition, did Stanley use the same size screws on every model of Stanley's Bailey plane?

END OF PART ONE

REFERENCES

- ATKINSON, Norman: Sir Joseph Whitworth. Sutton, Stroud, 1996
- BATES, John “*Jo-Blocks: A Reprise*”, in TTTG Newsletter. No.68, December 2002
- BRITANNIA COMPANY: Screws and Screw-Making. Britannia Company, Colchester, 1891
- CALVERT, Monte A: The Mechanical Engineer in America, 1830-1910. Johns Hopkins, Baltimore, 1967
- COPE, Kenneth American Machinist's Tools: An illustrated directory of patents. Astragal, Mendham, 1993
- DAVIS, Donald W. The Stanley Works: A 125 Year Beginning. Newcomen Society of America, New York, 1969
- DERRY, T. K. and WILLIAMS, Trevor I. A Short History of Technology. Oxford, London, 1960
- DUMAS, M. Scientific Instruments of the 17th and 18th Centuries and Their Makers. 3rd edition, Portman, London, 1989
- HAWKE, David Freeman Nuts and Bolts of the Past: A History of American

- Technology, 1776-1860. Harper & Row, New York, 1988
- HISCOX, W. J. & PRICE, J. R: Factory Administration and Practice. 5th edition, Pitman & Sons, London, 1940
- HOLTZAPFFEL, Charles Turning and Mechanical Manipulation. London, 1847. Volumes 1, 2 and 3 reprinted by Tee Publishing, Warwickshire, 1993. ISBN: 1-85761-032-6
- HUME, Kenneth J. A History of Engineering Metrology. MEP, London, 1980
- MAYR, Otto and POST, Robert C (editors): Yankee Enterprise. Smithsonian Institute, Washington, 1981
- NORTHCOTT, W. Henry: Lathes and Turning. Longmans Green, London, 1868
- REULEAUX, F. The Constructor: A Handbook of Machine Design. (Henry H Suplee, translator) The Engineering Magazine, New York, 1906. pp.51-2
- ROE, J. W: English and American Tool Builders. original by Yale University, 1916; reprinted by Lindsay, Bradley, 1987
- ROLT, L. T. C. Tools for the Job: A history of machine tools to 1950. HMSO, London, revised edition 1986
- RYBCZYNSKI, Witold One Good Turn: A Natural History of the Screwdriver and the Screw. Scribner, New York, 2001
- SALAMAN, R. A. Dictionary of Woodworking Tools c.1700-1970. revised edition, Unwin Hyman, London, 1989
- SAUNDERS, C. H. Hand Book of Practical Mechanics. Charles Saunders, Boston, c.1894
- SINGER, Charles et al (editors) A History of Technology. Oxford, London, 1958
- SUROWIECKI, James 'Turn of the Century', in Wired. Issue 10.01, January 2002
- WEIDENSCHILLING, Paul The Sargent Tool Catalog Collection. Astragal, Mendenham, 1993. ISBN: 1-879335-42-5
- WHITBY, Philip Leonard Bailey and the Stanley Rule and Level Co 1869-1884. in Toolshops Auction Catalog, 1996

NOTES:

Patent drawings and data were obtained from the US Patent Office website at www.uspo.com

US Patent No.1 was issued on 13 July 1836 - it is interesting to trace trends America's inventiveness and industry by comparing the number of patents issued each year.

The author would be pleased to receive readers' views, comments and suggestions concerning this publication. These may be sent to John Bates C/O the Secretary TTTG Inc. PO Box N240, Grosvenor Place, SYDNEY NSW 1220, AUSTRALIA or emailed direct to reproturn@bigpond.com

