A Brief History of Screwthreads

Archaeologists tell us that the forerunner of the modern screw can be found in artifacts dating to early Greek and Egyptian times. Hero of Alexandria certainly used them in his automatons and devices. Sporadic use of screwthread attachments and mechanisms appear from ancient times through the beginning of the Renaissance. The most common form in the latter historic times is that of a thin bar of metal twisted by a smith into a helix much like today's hammer-drive screws and nails. The second most common form of screwthread is one that was cut using gravers and saws. This was the state of screwthread technology through to the beginning of the 18th century.

Firearm manufacture needed strong and consistent screwthreads. As firearms changed from being the domain of specialized military groups, most commonly found as Royal bodyguards such as the famed Musketeers, into a weapon of the common soldier, the need to reduce the cost of manufacture grew in importance. It was one thing to spend a fortune protecting the regent and another thing altogether to spend a fortune protecting a yeoman. The two complementary areas where these costs could be reduced lay in boring the barrel and screwthreads to assemble a firearm. As the solution to these two items lay with the development of rotary turning equipment (i.e. lathes), it should come as no surprise that these two technologies developed together.

A major improvement in lathe technology took root towards the end of the 17th century in the northern Germanic states. Arguments may be made on behalf of several persons and locations for creation of this innovation. The application of a ratchet to the traditional *sapling flexure* drive to provide unidirectional rotational power and the incorporation of a flywheel provided to maintain constant spindle speed created the foundation for a true industrial lathe. The obvious application of this new technology to firearms caused those who possessed it to try and keep it secret. As so often is the case, the attempt to classify this new technology as a secret failed. Then, about 1750, Antoine Thiout created a useable lathe leadscrew. These two technologies were the true foundation of the industrial revolution.

Many attempts to create low-cost mating screwthreads began. The problem is less trivial than we, with the solutions ready in our handbooks, visualize. Thiot's solution worked moderately well when applied to hand-fit mated screw/nut combinations, but it failed in broad application. Ernst Löwenhertz, the Germanic competitor to Ben Franklin in many areas of practical science, created the first reliably functional screwthread circa 1762 in Prussia. Löwenhertz calculated that the optimum form for a screwthread had a 53°45" included space angle between the flanks of a screw's external thread along its axis. Eli Whitney learned of this advance while spying for the Continental Congress under cover provided to him by letters issued by Gilbert du Motier, the Marquis de Lafayette and other French supporters of the American cause. Whitney "made off" with a set of taps and dies while spying. This led directly to his famous demonstration of interchangeability that figured so prominently in the American Revolution.

Löwenhertz's threadform development was notable several ways. He was the first to find that an external (male) thread is weaker than its mating internal (female) thread. His use of the 53°45" angle was an attempt to make the external thread equal in strength to the mating internal thread. What he did not know was how stress and strain are distributed across the volume of a material. That had to wait for Simeon Poisson and his work at the *Ecole Polytechnic* in the 1820's that resulted in the definition now known as *Poisson's ratio*. Löwenhertz threads are still in use as part of the DIN standards. Joseph Whitworth simplified Löwenhertz's threadform by making the included angle 55° exactly and developing relationships to define *classes* of fit in 1841. This is the *British Standard Whitworth* (identified as BSW) that only started falling out of favor during the latter half of the 20th century. Making use of Poisson's work, Whitworth screwthreads have the male thread 90% as strong as their mating female threads.

The 19th century saw a multitude of screwthread forms and sizes. Many have rightly disappeared from the scene. Others are still used in specialized applications such as boilers, quick-release mechanisms, optical assemblies, cannon breeches, and the like. While the well-trained designer should study these less common screwthreads and understand their application, our focus here is on the most commonly used thread forms and the standards behind them.

World War I brought an immediate need for interchangeability of screwthread forms and fits across national boundaries. The American-British-Canadian (ABC) Council of Industry settled on the 60° screwthread form, established simple fit guidelines, and codified standard thread pitches for each diameter screw. This evolved into the Unified National Thread standard in the United States under the American Standards Association (ASA) in the 1920's. The ASA became the American National Standards Institute (ANSI) in 1958 in the wake of the *Sputnik* crisis. This system uses two separate progressions of major diameters for screwthreads. Number sizes (0000 to 0 to 14) are used for screws smaller than ¼ inch. Fractional sizes are used for screws ¼ inch or larger.

Generally speaking, Unified National screws are available in Number sizes from 0 to 12. The Number screw size system is based on a major diameter of .0600 inches being size 0. Each size larger than #0 adds .0130 inches to the major diameter (i.e. a #10 screw has a major diameter = 10 * .0130 + .0600 = .1900 inches). Number sizes 7, 9, and 11 were removed from use in the 1920's leaving sizes #0, #1, #2, #3, #4, #5, #6, #8, #10, and #12 in common service. The #14 size screw is not commonly available. #0 screws are only available in the UNF pitch. Sizes #1 through #10 screws are available in UNC and UNF pitches. Size #12 screws are available in UNC, UNF, and UNEF pitches. Each size smaller than #0 subtracts .0130 inches from the major diameter (i.e. a #00 screw has a major diameter = .0600 – 1 * .0130 = .0470; a #000 screw has a major diameter = .0600 – 2 * .0130 = .0340 inches; while a #0000 screw has a major diameter = .0600 – 3 * .0130 = .0210 inches). Number sizes smaller than #0 have mostly disappeared in favor of (metric) Unified Miniature Threads.

Fractional screw sizes are generally limited to ¼ through $^5/_8$ (by $^1/_{16}$ths), ¾ through 1-¼ (by $^1/_8$ths), and 1-½ through 2 (by ¼ths). They are commonly available in UNC and UNF pitches. UNEF pitches are available, but not commonly stocked. Standards for screws up to 6 inches major diameter exist, but are rarely readily available.

In the wake of World War II, users of metric screwthreads began standardizing sizes and pitches. At the beginning of this effort (1946), there were dozens of regional and national standards. They have been reduced to: US-ISO, British Standard (BS), French-ISO, Deutsches Institut für Normung (DIN), and Japanese Industry Standard (JIS). While the five major systems of standards have much in common, they also have areas of exception that are enough to drive the casual observer to hard liquor.

The World War I effort that created the Unified National thread system is something that should be put forward when people say that bureaucracy can do no good. The work done in pursuit of a usable standard has never been equaled. The analysis was done to assure that there is a 15% gain in mechanical properties when moving from UNC pitch to UNF pitch and again from UNF pitch to UNEF pitch! This was a specific goal established by the leaders of the ABC Council of Industry. No such consideration was given to metric thread sizes and pitches. In point of fact, the committee working on metric screwthread standards spent more time arguing about which nation's standard would be adopted to the point where, in 1968, there were five different "standard" pitches for a 6mm (M6) screw. As they finally started creating metric "standard" and "fine" pitches all practical arguments were lost. As a result, where such designations (standard and fine) exist in a given screw size, the gain in mechanical properties is usually in the 3% range. If a gain of 3% is going to help you, your design is marginal at best!

Anyone needing to use metric threads today should get copies of: ISO 68-1 (*General Purpose Metric Threads, Basic Profile*), ISO 261 (*General Purpose Metric Screw Threads, General Plan*), ISO 262 (*General Purpose Metric Screw Threads, Selected Sizes for Screws, Bolts, and Nuts*), ISO 965-1 (*General Purpose Metric Screw Threads, Tolerances, Principles and Basic Data*), and ISO 965-2 (*General Purpose Metric Screw Threads, Tolerances, Limits of Sizes*). ISO 965-3 contains specific tolerance and allowance information of note to design engineers, but it is not generally useful in the shop. Similarly, ISO 965-4 and ISO 965-5 contain information as to plating and finishing of metric screws that is only required for people in that business.

While there is progress being made to standardize metric screwthreads, it is all too often uneven and ill-considered. Designers and users of metric screwthreads must always be asking **which** metric "standard" is being applied. The day may come where all metric screws of a given size have common and interchangeable pitches. This issue has been getting better over the past few decades. The thing that can**not** be added to the standards for metric screwthreads today is a progression of pitches in a given size that would allow significant improvements in mechanical properties to be gained by changing pitches. The point at which such considerations could be incorporated into the standards has passed.

One final note, we here in America are undergoing an ill-considered and ill-advised period of *privatization* of national standards information. This started in 1984 when our National Bureau of Standards (NBS) was gutted into the National Institute for Standards Technology (NIST). As this process plays out, we are seeing taxpayer-paid-for research in taxpayer-paid-for publications turned into *private intellectual property*. This has happened to screwthread standards. Most people who care have all the information they need in *Machinery's Handbook*. If you need more or more detailed information on the subject, copies of the (public domain) *FED-STD-H28 Screw Thread Specifications* are available as PDF documents several places around the internet. If you have or can foresee a need for such information, you should grab a copy now before they are removed from public access.