

Pipe Thread Types and Designations

Overview: Different types of screw threads have evolved for fastening, and hydraulic systems. Of special concern are plastic-to-metal, taper/parallel threaded joints in hydraulic circuits. A discussion and recommendations are provided to create an awareness of different types of threads and how they are used.

Evolution

In the nineteenth century, many different types of screw threads were required for hydraulic and pneumatic circuits as well as fastening components. As a result, manufacturers started to devise their own fastening systems. This resulted in compatibility problems. The English mechanical engineer and inventor, Sir Joseph Whitworth devised a uniform threading system in 1841 to address the incompatibility problem. The Whitworth thread form is based on a 55 degree thread angle with rounded roots and crests.

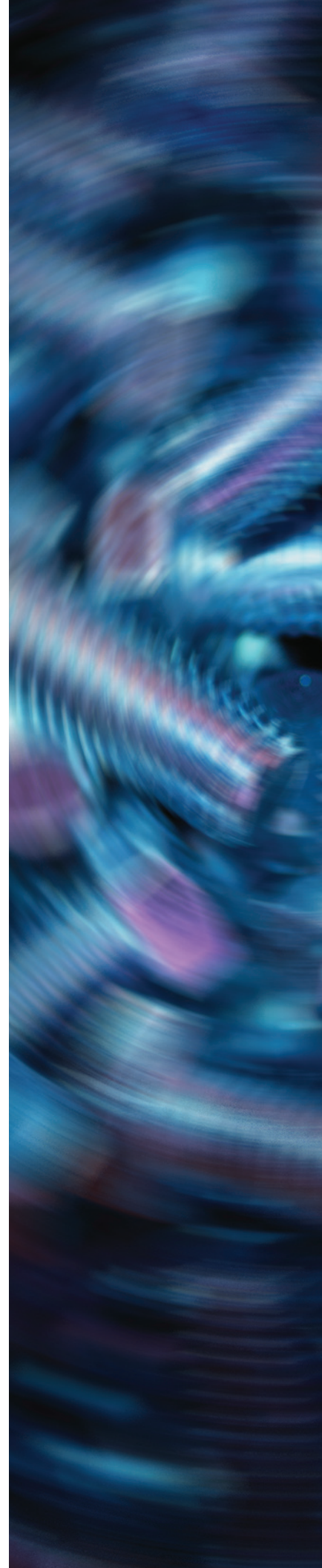
In America, William Sellers set the standard for nuts, bolts, and screws which became the National Pipe Tapered Thread (NPT) in 1864. His 60 degree thread angle, in common use by early American clockmakers, enabled the American Industrial Revolution. These thread forms later became the American National Standard.

The Whitworth thread form was selected as a connecting thread for pipes, which was made self sealing by cutting at least one of the threads on a taper. This became known as the British Standard Pipe thread (BSP Taper or BSP Parallel thread). The Whitworth thread is now used internationally as a standard thread for jointing low carbon steel pipes.

The best known and most widely used connection where the pipe thread provides both the mechanical joint and the hydraulic seal is the American National Pipe Tapered Thread, or NPT. NPT has a tapered male and female thread which seals with Teflon tape or jointing compound.

Pipe threads used in hydraulic circuits can be divided into two types:

- a) **Jointing threads** – are pipe threads for joints made pressure tight by sealing on the threads and are taper external and parallel or taper internal threads. The sealing effect is improved by using a jointing compound.
- b) **Fastening threads** – are pipe threads where pressure tight joints are not made on the threads. Both threads are parallel and sealing is affected by compression of a soft material onto the external thread, or a flat gasket.



Sizes

Pipe thread sizes are based on an inside diameter (ID) or flow size. For example, "1/2-14 NPT" identifies a pipe thread with a nominal inside diameter of 1/2 inch and 14 threads to the inch, made according to the NPT standard. If "LH" is added, the pipe has a left hand thread. The most common global pipe thread forms are:

NPT	American Standard Pipe Taper Thread
NPSC	American Standard Straight Coupling Pipe Thread
NPTR	American Standard Taper Railing Pipe Thread
NPSM	American Standard Straight Mechanical Pipe Thread
NPSL	American Standard Straight Locknut Pipe Thread
NPTF	American Standard Pipe Thread Tapered (Dryseal)
BSPP	British Standard Pipe Thread Parallel
BSPT	British Standard Pipe Thread Tapered

Plastic injection molded thread forms are manufactured to ANSI B2.1 and SAE J476 standards.

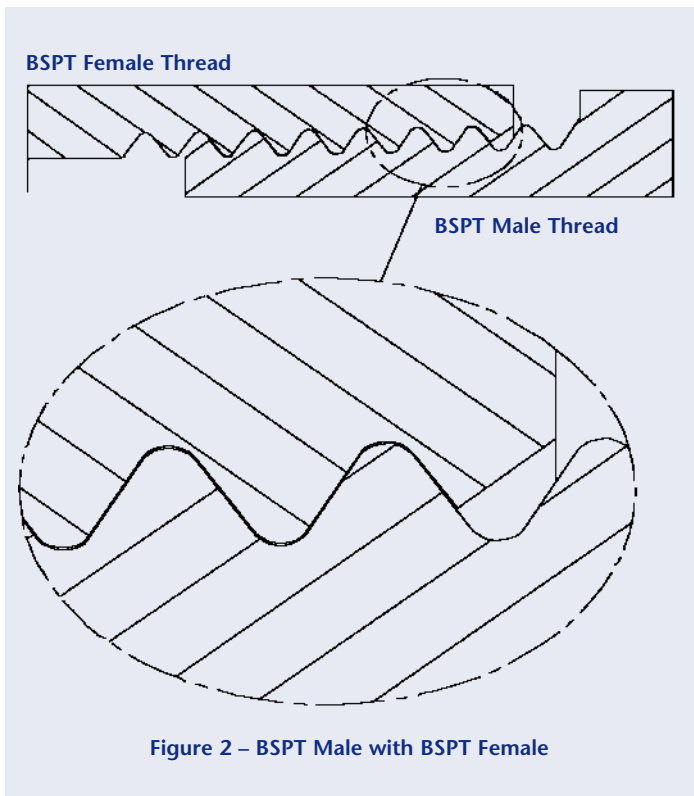
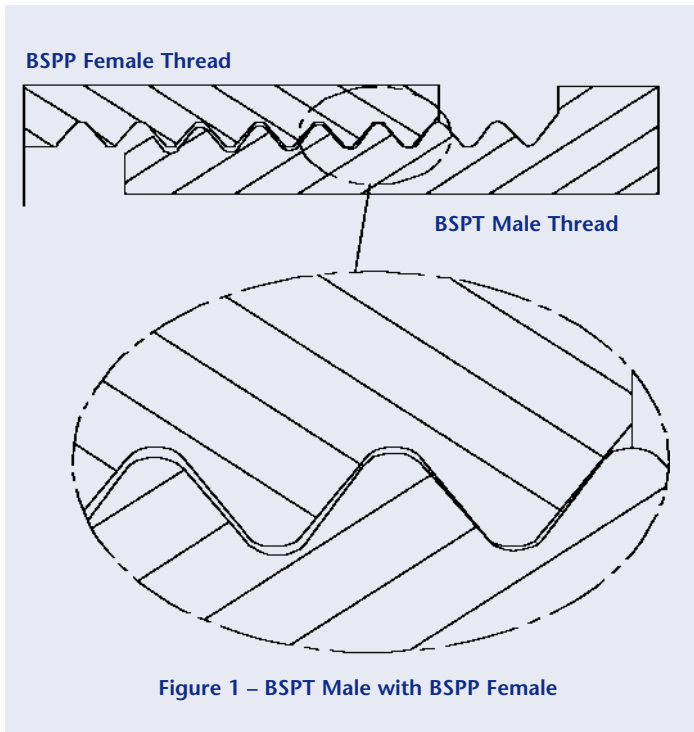
The word "tapered" in several of the above names points to the big difference between many pipe threads and those on bolts and screws. Many pipe threads must make not only a mechanical joint but also a leakproof hydraulic seal. This is accomplished by the tapered thread form of the male matching the thread form of the female tapered thread and the use of pipe sealant to fill any voids between the two threads which could cause a spiral leak. The bottoms of the threads aren't on a cylinder, but a cone; they taper. The taper is 1/16 inch in an inch, which is the same as 3/4 inch in a foot.

Because of the taper, a pipe thread can only screw into a fitting a certain distance before it jams. The standard specifies this distance as the length of hand tight engagement, the distance the pipe thread can be screwed in by hand. It also specifies another distance – the effective thread, this is the length of the thread which makes the seal on a conventional machined pipe thread. For workers, instead of these distances, it is more convenient to know how many turns to make by hand and how many with a wrench. A simple rule of thumb for installing tapered pipe threads, both metal and plastic, is finger tight plus one to two turns with a wrench. Torque installation values can be determined per application, but due to the variations involved in pipe joints such as dissimilar materials of male and female threads, type of sealants used, and internal variations in product wall thickness, a standard torque specification cannot be generically applied.

This table shows the distances and number of turns called for in the standard. A tolerance of plus or minus one turn is allowed, and in practice threads are often routinely cut shorter than the standard specifies. All dimensions are in inches.

American Standard Taper Pipe External Thread

Nominal size	Actual OD	Threads per inch	Length of engagement (tightened by hand)	Length of effective thread
1/8	0.407	27	0.124 ≈ 3.3 turns	0.260
1/4	0.546	18	0.172 ≈ 3.1 turns	0.401
3/8	0.681	18	0.184 ≈ 3.3 turns	0.408
1/2	0.850	14	0.248 ≈ 3.4 turns	0.534
3/4	1.060	14	0.267 ≈ 3.7 turns	0.546
1	1.327	11.5	0.313 ≈ 3.6 turns	0.682



Taper/Parallel Threaded Joints

Despite the standards created to maintain uniform fittings, tapered pipe threads are inexact and during the course of use and repair the threads can become damaged and susceptible to leakage. The area where the crest and the root of the thread meet can form a spiral leak path no amount of tightening will eliminate.

A pressure tight joint is achieved by the compression in the threads resulting from tightening. This compression and sealing occurs in the first few turns of the internal thread. As wrenching takes place, material from both the male and female threads deform into each other. This ensures full thread contact which minimizes spiral leakages. Variations between injection-molded plastic and machined metal thread forms can occur due to different manufacturing processes.

Pipe threads were originally designed as machined thread forms. With the use of thermoplastics and plastic injection molding in the manufacture of plastic pipe thread forms, mold shrinkage and plastic sink make it difficult to insure leak free joints. For this reason, the use of a Teflon based sealant is recommended on all plastic pipe threads. The most common form of sealant is Teflon tape wrapped 2 to 3 turns around the male thread before assembly. Liquid Teflon based sealants are also used successfully to ensure a pressure tight seal. It is always important to use care when applying sealants to avoid introducing the sealant material into the system flow path.

The following sections show examples of how different threads are used and issues that can arise in attempting to create a leak free connection.

When a BSPT tapered male thread is tightened into a straight female thread (BSPP) the seal can only be made at the base of the female port with 1 or 2 threads. See figure 1. Sealing is compromised by the lack of thread form control in BSP specifications. Variation in crests and roots may cause a mismatch in the thread and create a spiral leak. Thread sealant is required to seal this combination.

Using both tapered male and female BSPT threads would offer a better chance of sealing since you are now matching the taper of the male and female

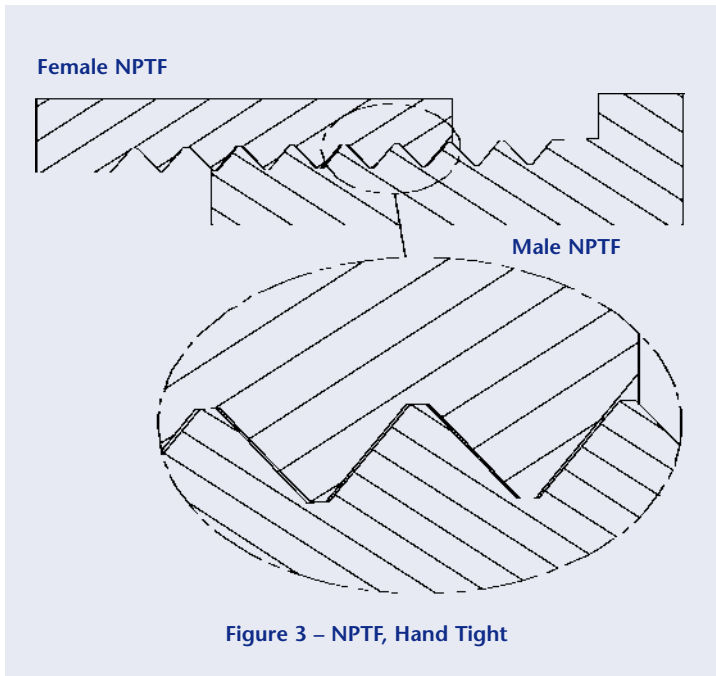


Figure 3 – NPTF, Hand Tight

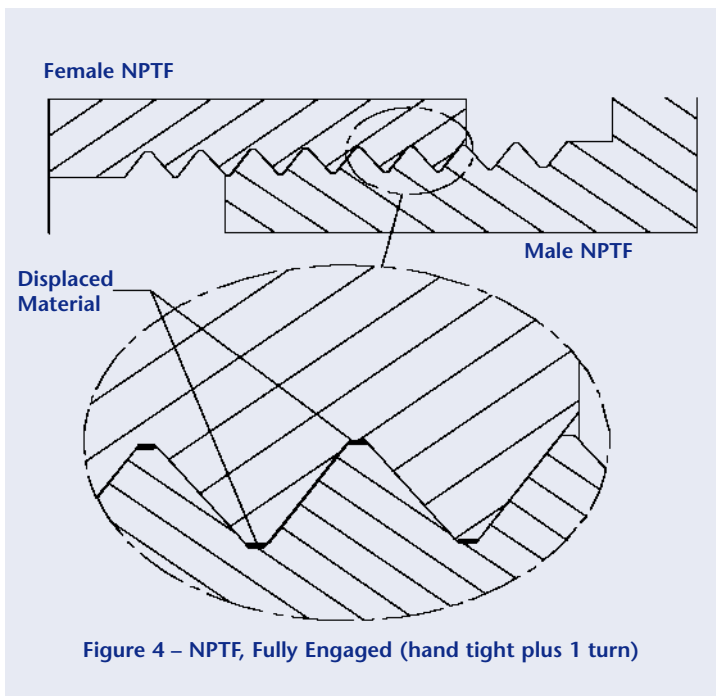


Figure 4 – NPTF, Fully Engaged (hand tight plus 1 turn)

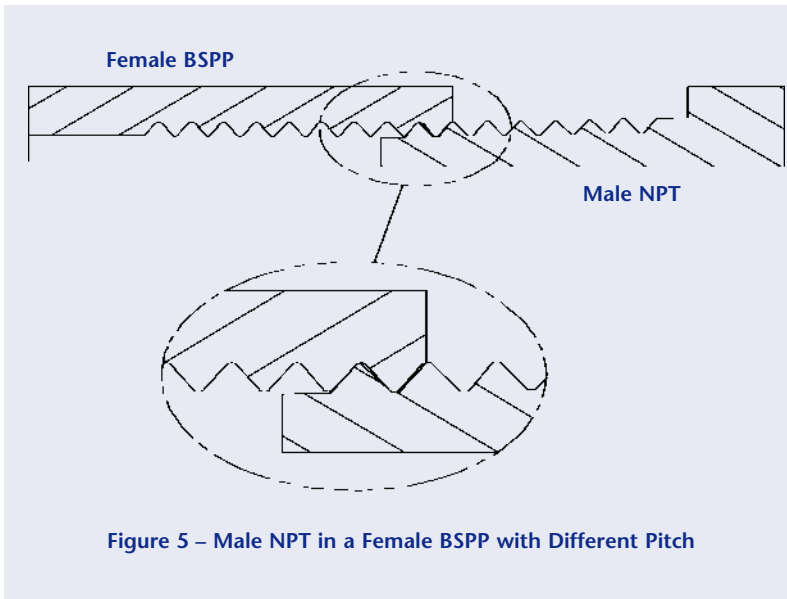
thread. See figure 2. This offers more threads a chance of sealing against spiral leakage. Crest and root control is still missing, but with thread sealant, a pressure tight joint would be easier to accomplish.

A number of variations of the NPT thread have been introduced to overcome the problem of spiral leakage and are known as Dryseal threads (See SAE standard J476). The best known is the NPTF (F for Fuel). With this thread design, there are controls on the crests and roots of both the male and the female threads to ensure the crest crushes or displaces material into the root of the mating thread. The interference fit between the crest of one thread and the root of the other, along with the thread flanks matching, seals against spiral leakage.

Figure 3 shows an NPTF male tightened into an NPTF female hand tight. You can see the crests of both the male and female thread come into contact with the root before the thread flanks meet.

Figure 4 shows the NPTF male and female threads tightened approximately 1 turn past hand tight, and you can see the flanks meet and the crests are displaced into the roots. Although these threads are considered Dryseal, a Teflon tape or liquid is still recommended to aid in the assembly process. The Teflon works as a lubricant to avoid galling of the material when tightening the two threads together and also fills any voids that may cause leakage.

A variation of the Dryseal thread is the NPSF (National Pipe Straight Fuel). It is used for internal threads and a NPTF external thread can be screwed into it to provide a satisfactory mechanical connection and a hydraulic seal. The combination of a parallel and tapered thread is not regarded as ideal but is widely used. High-quality plastic quick disconnect couplings typically use NPT threads.



Another tapered thread is the British Standard Pipe taper, or BSP, covered by British Standard 21. BSP thread is commonly used for low pressure plumbing, but is not recommended for medium and high pressure hydraulic systems. This form uses the Whitworth thread with an angle of 55° and a 1 in 16 taper. It is not interchangeable with the American NPT thread, though at the 1/2" and 3/4" size, they both have 14 threads per inch.

Problems arise when threading a NPT male thread form into a BSP female straight thread form. The 1/16", 1/8", 1/4", and 3/8" sizes have a dissimilar pitch, which causes a misalignment of the threads. The flank angles of the threads are also different between NPT and BSP. NPT has a 60° thread where the BSP has a 55° thread.

Figure 5 shows a male NPT tightened into a BSPP. Because of the smaller size of the BSPP and the pitch difference, the NPT tightens with only a few turns.

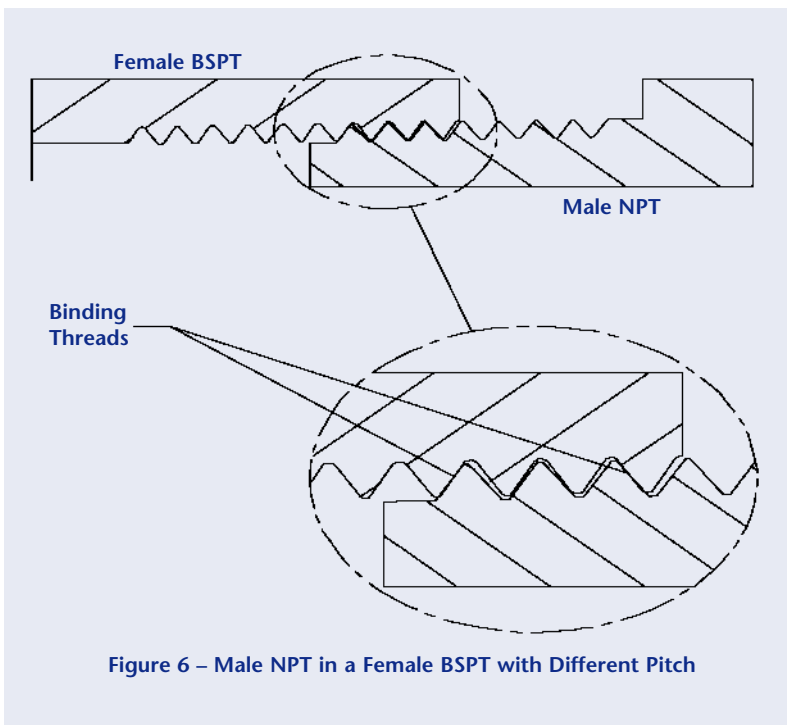


Figure 6 shows an NPT tightened into a BSPT. The BSPT being wider at the opening will allow the NPT thread to engage further, but pitch difference eventually causes a binding of the threads. Pitch and thread angle differences will allow spiral leakage.

The 1/2" and 3/4" sizes in the NPT and BSP are all 14 threads per inch, and the NPT will engage the BSP fairly well.

Although these threads are the same pitch and engage well there are still issues with the thread form. The thread angles and the crest and root tolerances being different will allow spiral leakage as shown in figure 7. These threads might be used effectively together if an appropriate thread sealant is incorporated.

Many issues arise when plastic quick disconnect couplings, with their corresponding injection-molded pipe thread forms are plumbed into metal-piped hydraulic systems. Leaks and plastic thread form failures may occur if care is not taken. When investigating a metal-to-plastic pipe joint failure, two factors, chemical attack and over tightening, need to be considered.

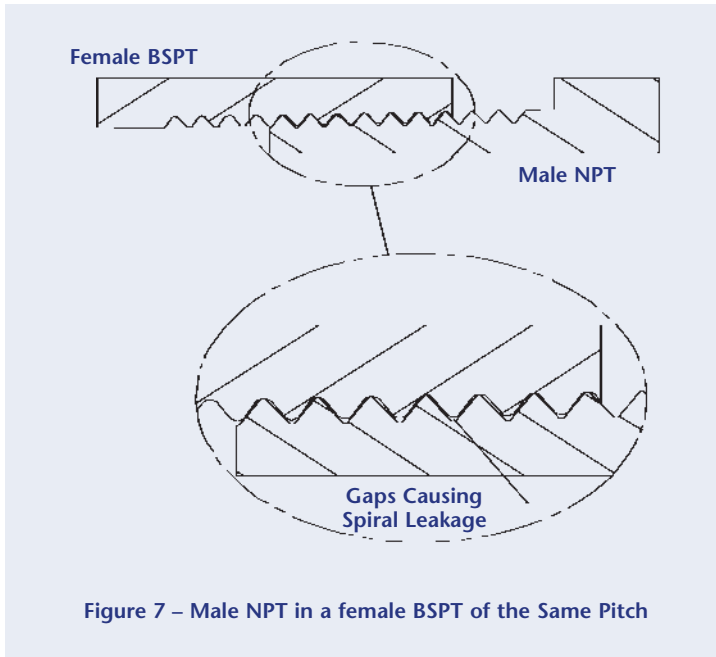


Figure 7 – Male NPT in a female BSPT of the Same Pitch

Chemical attack can occur when improper thread sealants are used. Thread sealing is an attempt to block the spiral leak path which occurs when the crests and roots of the thread forms do not match. Anaerobic thread sealants should be avoided when sealing plastic thread forms. These sealants contain chemicals which may attack plastics. Use of a Teflon-based pipe thread sealant is a better choice for plastic threads.

Over tightening of any plastic pipe thread will have adverse affects on the function of the joint. The major difference between plastics and metals is the behavior of polymers. Injection-molded plastic parts continue to deform if they are held under a constant load e.g. creep. Creep is the continued extension or deformation of a plastic part under continuous load. Typically the plastic material in an injection-molded plastic pipe thread form will creep from being over tightened into a female tapered port. The deformation of the part's internal features can lead to part failure.

Standard Pipe Thread Forms Colder Products Company Produces	
NPT (National Pipe Taper) Sizes:	BSPT (British Standard Pipe Taper) Sizes:
1/16 – 27NPT	
1/8 – 27NPT	1/8 – 28BSPT
1/4 – 18NPT	1/4 – 19BSPT
3/8 – 18NPT	3/8 – 19BSPT
1/2 – 14NPT	1/2 – 14BSPT
3/4 – 14NPT	3/4 – 14BSPT
1 – 11-1/2 NPT	

Virtually any thread configuration can be incorporated into a Colder coupling on a custom basis. Some examples of custom applications are NPSM (National Pipe Straight Mechanical), BSPP (British Standard Pipe Parallel), SAE flare fittings, and a variety of ISO (Metric) and American Unified screw threads.

With over 29 years experience in the design and manufacture of injection-molded plastic quick disconnect couplings, Colder Products Company knows about the shrink and sink of molded plastic parts and how they can affect the seal ability of pipe threads. Our NPT thread has been engineered to add more control to the plastic thread form to ensure a leak-proof seal.

This paper was researched, organized and written by Mark Schmidt, Colder Products Company Product Control Engineering. Mark works at Colder Products Company in St. Paul, MN. He can be contacted at askourengineers@colder.com.