Pipe Threads: Standards and Compatibility

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Have you ever been confused about pipe thread nomenclature? Have you wondered what is the difference between NPT and PT? What about BSPT? If you have asked these questions or similar ones, you're not alone and this paper is for you! Several different pipe thread designations are used around the world, and some are equivalent or compatible while others are not. A few of the most common types of pipe thread are listed below:

American National Standard (ASME)

- NPT
- NPSC

International Standard (ISO)

- G
- R
- Rp
- Rc

Historical British Standard (BS)

- BSPP
- BSPT

Historical Japanese Industrial Standard (JIS)

- PT
- PS
- PF

Figure 1—Typical threaded pipe connection with thread sealant.

In the U.S., American National Standard pipe thread is the most common, but other designations are also used. This is especially true of overseas companies (or their U.S. subsidiaries), where ISO, British Standard, and JIS pipe threads are often much more prevalent. Certain pipe thread designations are equivalent and compatible, some are not equivalent but partially compatible, and others are neither equivalent nor compatible. It can be confusing to determine what is true of a particular designation. This paper aims to eliminate this confusion.

Background

Regarding American National Standard pipe, ASME B1.20.1 covers the following series: NPT, NPSC, NPTR, NPSM and NPSL. All of these thread series specify threads with a 60° angle between the flanks (see Figure 2). Among these, NPT is the most common and indicates a tapered thread for both internal and external threads. NPT threads are designed to be fitted together wrench-tight and require a sealant for a pressure-tight seal (Ref. 10). NPSC threads are parallel internal threads, which are designed to be fitted wrench-tight with an external NPT thread. As with NPT/NPT connections, a sealant is required for a pressure-tight seal (Ref. 9). NPTR (tapered threads for railing joints), NPSM (straight threads for mechanical joints), and NPSL (straight threads for mechanical joints with locknuts) have the same thread profile dimensions as NPT or NPSC, but have certain modifications for specific applications (Ref. 10).

A separate standard, ASME B1.20.3, covers inch Dryseal pipe threads, which can create a pressure-tight connection without a sealant. The series covered by this standard are NPTF, PTF-SAE SHORT, NPSF and NPSI (Ref. 11).

ISO, British Standard, and JIS pipe threads are commonly used outside of the US. These thread standards all specify a 55° flank angle and specify two families of pipe threads: those for pressure-tight joints and those for non-pressure-tight joints. Pipe threads where pressure-tight joints are made on the threads are defined in ISO 7-1, BS EN 10226-1, BS EN 10226-2, and JIS B 0203. These standards all define identical thread series which are designated with R for external tapered thread, Rp for internal parallel thread, and Rc for internal tapered thread. For these connections, thread sealant is required to achieve a pressure-tight seal (Refs. 1, 2, 5, 7). ISO 228-1, BS EN ISO 228-1, and JIS B 0202 define pipe threads where pressure-tight joints are NOT made on the threads. These standards define identical thread series which are parallel for both internal and external threads and are designated with G. If a pressure-tight joint is required with these threads, then an external seal or gasket is required (Refs. 3, 6, 8).

With the latest standards listed in the previous paragraph, BS and JIS have adopted the same symbols as the ISO standard (namely R, Rp, Rc and G), but the historical symbols previously specified in the standards are still frequently used. In the British Standard, the historical symbols are BSPT and BSPP (Ref. 4). In the Japanese Industrial Standard, the historical symbols are PT, PS and PF (Refs. 7, 8). The characteristics of these series are shown in Table 1, which also defines the equivalent ISO thread series for each.

Standard(s)	Thread Designation	Thread Profile	Internal/ External	Flank Angle (deg)	Equivalent ISO Designation(s)
ASME B1.20.1	NPT	Tapered	Both	60	N/A
	NPSC	Parallel	Internal		
ISO 7-1 BS EN 10226-1 BS EN 10226-2 JIS B 0203	R	Tapered	External	55	
	Rp	Parallel	Internal		
	Rc	Tapered	Internal		
ISO 228-1 BS EN ISO 228-1 JIS B 0202	G	Parallel	Both		
BS (Historical)	BSPT	Tapered/ Parallel	Both	55	R, Rp, Rc
	BSPP	Parallel	Both		G
JIS (Historical)	PT	Tapered	Both		R, Rc
	PS	Parallel	Internal		Rp
	PF	Parallel	Both		G

Table 1—High-level overview and comparison of relevant pipe thread series. The series shaded grey are historical designations that are still in use.

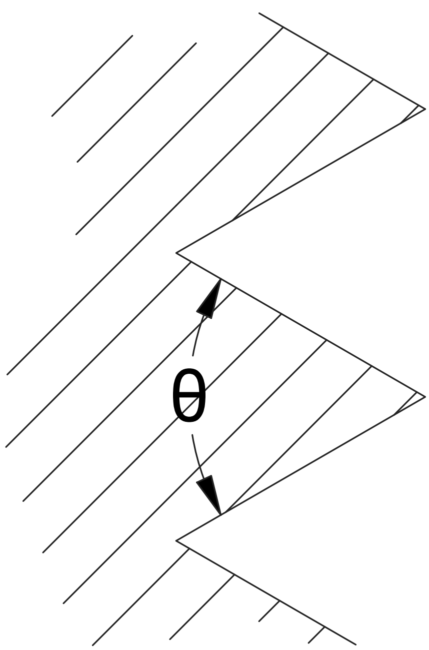

Figure 2—Diagram depicting flank angle, represented by θ.

To begin to address the confusion regarding pipe threads, it is helpful to take a step back and investigate some of the reasons for this confusion, some of which are listed below:

Different designations use the same nominal sizes (e.g., 1/2), even though they may have different thread profiles, dimensions, and tolerances.

Some of the designations have similar letters in the nomenclature but are not necessarily equivalent (NPT, BSPT, PT).

Certain historical designations are still extensively used, such as BSPP and BSPT.

Certain sizes of different thread standards can be screwed together, but not in a leak-proof manner. This means that physically fitting two threads together does not guarantee proper fit and leak prevention.

Different thread types require different sealing methods (sealant, O-ring, etc.).

Within each standard, the relationships between thread series are clear. Problems mainly arise from attempts to combine threads from different standards. The next section will address some of these problems and clarify which thread series are equivalent and compatible, and which are not.

Thread Compatibility

A compatibility chart of selected thread series is shown below in Table 2.

The cases of partial compatibility listed in Table 2 are mainly attributable to the tolerance difference between Rp and internal G threads, as shown in Figure 3. These two thread series have identical nominal dimensions but have different tolerances on the pitch diameter. The internal G thread has a +/0 tolerance above the nominal value while the Rp thread has a ± tolerance (Refs. 5, 6).

For the Partial$_1$ case, this means that there will not be issues threading parts together, but the use of a thread sealant is especially critical.

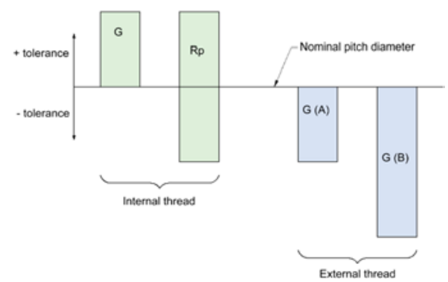

Figure 3—Comparison between pitch diameter tolerance of G and Rp series.

The bigger issue arises in the Partial$_2$ case. External G threads come in two classes (A and B), which both have a 0/- tolerance, and therefore there is no interference risk when threading into an internal G thread. However, when attempting to thread into an Rp internal thread, it is possible that the external thread pitch diameter will be larger than the internal thread pitch diameter. In this situation, it would be extremely difficult, if not impossible, to physically thread the external thread in.

		Internal Thread					
		NPT	NPSC	Rp, PS	Rc, PT	G, BSPP, PF	BSPT
External Thread	NPT	Yes	Yes	No	No	No	No
	R, BSPT, PT	No	No	Yes	Yes	Partial$_1$	Yes
	G, BSPP, PF	No	No	Partial$_2$	No	Yes	No

Table 2—Compatibility between selected thread series, with equivalent series grouped together.

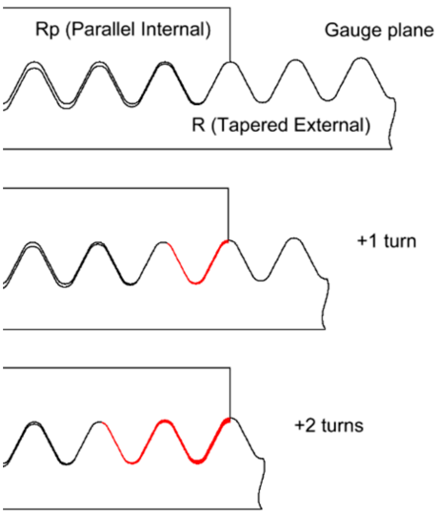

Figure 4—Diagram showing the connection between R 1/2 and Rp 1/2. The red area indicates where plastic deformation leading to a seal occurs.

Another important topic is the relationship between NPT and the ISO thread series. These two families of threads have different flank angles and root shapes and are not compatible with one another (see Table 2). However, it is sometimes possible to physically thread these two series together due to similar thread pitch and pitch diameters. This is especially true of the sizes designated 1/2 and 3/4 because the thread pitches of these sizes are exactly the same for both standards (Ref. 9). Although it may be possible in certain circumstances to physically thread these two series together, a pressure-tight seal is unlikely and certainly not guaranteed.

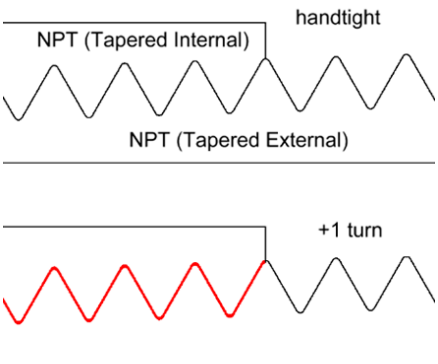

Figure 5—Diagram showing a 1/2-14 NPT connection. The red area indicates where plastic deformation leading to a seal occurs.

Figure 4 shows an engagement between an R thread and Rp thread (which are designed to mate with each other). As the external thread is tightened beyond the gauge plane with a wrench, plastic deformation leads to sealing. Similarly, a complete seal on the threads occurs with an NPT connection, as shown in Figure 5. Remember that both connections require a sealant to guarantee a pressure-tight seal.

When an R external thread is threaded into an NPT internal thread (see Figure 6), problems begin to arise. In this case, the difference in flank angle and root/crest shape mean that portions of the threads will begin to experience excessive plastic deformation while other areas (mainly at the roots of the internal thread) will still have clearance between the threads. This can lead to a phenomenon known as "spiral leakage" (Ref. 4).

The situation is even worse when an external NPT thread is threaded into an internal Rp tapped hole or fitting, as shown in Figure 7. In this case, the gaps remaining between portions of the two threads are even more pronounced despite excessive interference in other areas. Whatever the combination may be, a connection between an American National Standard thread (e.g., NPT) and an ISO thread (e.g., Rp or G) is not recommended and should not be used.

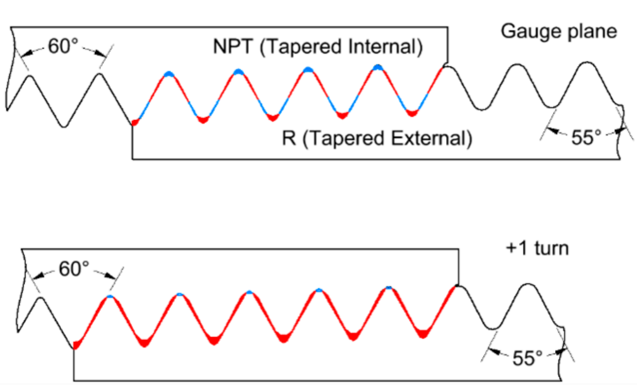

Figure 6—Diagram showing a connection between R 1/2 and 1/2-14 NPT. The red areas indicate where plastic deformation occurs and the blue areas indicate where clearance is present in between areas of interference. Note the small regions of clearance in the roots of the NPT thread at +1 turn.

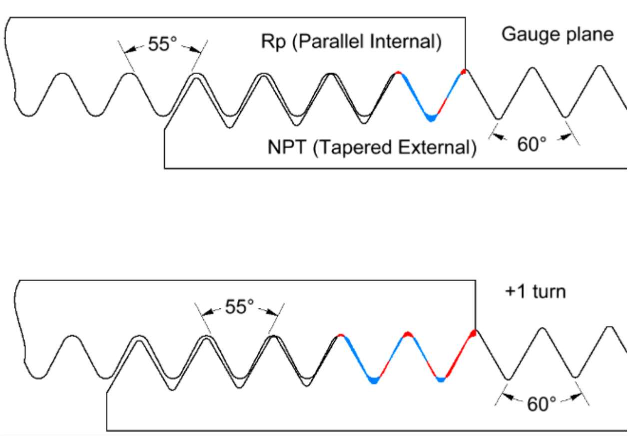

Figure 7—Diagram showing a connection between 1/2-14 NPT and Rp 1/2. The red areas indicate where plastic deformation occurs, and the blue areas indicate where clearance is present in between areas of interference.

Conclusion

The preceding information on pipe thread compatibility is critical for anyone who is designing, inspecting, or assembling a threaded connection. For applications where maintaining pressure or sealing is necessary, one must ensure that the correct threads are being used. It is not safe to assume that a connection is adequate just because the threads can be screwed together. For this reason, controlling plug and fitting inventory is crucial because different thread series often cannot be easily distinguished from one another.

When using 55° flank angle threads (i.e., ISO, BS, and JIS thread designations), the best approach is to specify the G or R series instead of BSPP/BSPT or PT/PF/PS. The G and R designations are not only the correct designations according to the latest ISO, BS, and JIS standards, but also help to eliminate confusion and misinterpretation. In particular, extreme caution must be taken when working with the old British Standard designations. “BSP” is often used to indicate BSPP, but this is not always the case. Similarly, BSPT on an internal thread would most likely indicate a tapered internal thread (i.e., Rc) but may actually refer to a parallel internal thread (i.e., Rp). Be sure to clarify with vendors exactly what thread series is being supplied and use the G and R designations on all new designs wherever possible.

In addition to the items brought up in this paper, there are a variety of other variables to consider when designing, inspecting, and assembling pipe threads. The material of both parts, the internal pressure, the sealant used, the type of fluid inside, and other factors can all have a substantial impact on the threaded connection. That being said, this paper will equip you with the basic knowledge you need to handle threaded connections with confidence.

PTE

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