# About R8, ER, and 5C collets and their use

– one user's experience and suggestions

R8, ER, and 5C collets all work by pulling or pushing the collet into a tapered hole, which in turn causes the collet to contract and secure the workpiece or tool being held by the collet. Collets are essentially tapered cylinders with a hole for the part or tool to be clamped. The collet is split in a few locations around its perimeter such that it compresses or tightens against whatever is being held in the collet when the collet is forced into a tapered hole that precisely fits the taper of the collet.

## R8 Collets

An R8 collet has three splits 120° apart around the side and is used almost exclusively for securing tooling into a mill spindle. A drawbar is used to pull the collet into the spindle taper, and this causes the collet to contract around the tool or material in the collet. R8 collets are available in sets of common imperial and metric sizes. Practically, speaking, since R8 collets are used almost exclusively to hold tools such as end mills, so you don't need the full 25-piece imperial set if you are using imperial tools since they come in shank sizes that are multiples of 1/16" diameter. The 1/32" collets that fall in between the major 1/16" divisions would be used very infrequently. An R8 collet has a very narrow range of compression – typically limited to 0.005-0007". If you plan to hold metric tooling in an R8 collet, you will need metric collets that correspond to the diameter of the tool. Given the narrow range of clamping, odd-sized tooling (e.g., 8.5mm) should be held in an ER collet rather than R8 collet.

Shown below are typical R8 collets – note the three splits around the perimeter of the collet and the tapered nose. In use, a drawbar is tightened into the small end of the R8 collet (nominally threaded 7/16 x 20), causing the collet to be pulled up and into the spindle taper, which in turn causes the nose section of the collet to compress around the tool.

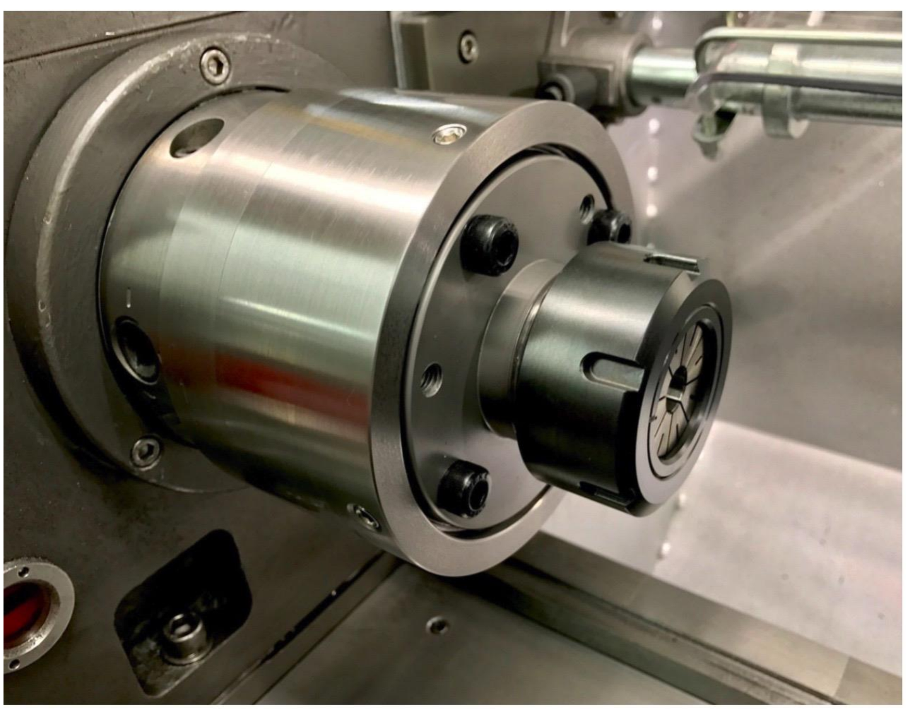
## ER collets

ER collets are useful for holding BOTH tooling and workpieces. They have a clamping range of ~1mm. Although typically employed to hold round materials or tooling, ER collets that hold hex-shaped (bar) stock are available (Maritool is a one such source). An ER collet is secured via a collet nut using a spanner wrench that presses the collet into the chuck's tapered hole. That same nut is designed to latch onto the collet so that the collet will be pulled out of the taper when the nut is unscrewed, thus releasing the collet's grip on the part or tool.

An ER collet is tightened and loosened at the nose of the collet chuck by turning the collet nut. When the nut is tightened, the collet compresses around the cylindrical part or tool the full length of the collet, not just at the nose-end of the part like the 5C variety discussed below. I my experience, the most critical aspect for precision ER setups is buying a very high quality ER collet nut made by Rego-Fix (the originator of the ER system in Switzerland) and high quality ER collets. This video is worth watching to understand a few of the common misconceptions about use of, and interaction between the ER collet and ER collet nut.

Below is a photo of an ER40 style collet. Note that the splits around the perimeter of the collet originate from both ends of the collet in a staggered manner. This is how the collet contracts in a cylindrical manner when it is forced into the taper of a collet chuck.

On a lathe, an ER40 collet chuck mounted on the spindle can be used to hold small diameter material for machining operations. ER40 collets have a maximum capacity of 26mm, or just over 1". Shown below is my ER40 collet chuck with D1-4 backing plate, mounted on my PM1340 lathe - I made my own ER40 collet chuck setup which is documented here, or you can buy an ER40 collet chuck with D1-4 backing plate from Shars, or from other manufacturers if higher precision is required:



This is a time-laps video that illustrates the use of the ER40 collet chuck on my PM1340 lathe.

In addition to use on a lathe spindle, an ER collet chuck with an R8 or Morse taper end can be employed on a mill or lathe to rigidly hold tooling that might otherwise spin in a drill chuck - such as an end mill or other tooling or indicators with a cylindrical mounting shaft. (A drill chuck will not grip an end mill tight enough to prevent the tool from spinning in the chuck.) The ER40 collet chuck is also a good way to hold odd-sized tooling (e.g., 8.5mm) in an R8 spindle.

This is what an ER40 collet chuck for an R8 mill spindle looks like:

This is the ER40 collet chuck with MT3 arbor end that would fit the tailstock on a typical 12-14" lathe, or in rotary table with MT3 taper.

ER40 collet blocks are available for work holding small diameter round parts on the mill - the part is secured in the ER collet and then the blocks are then secured in a mill vise or the jaws of a conventional lathe chuck. This is one way you can hold cylindrical materials in a mill vise, and then rotate the collet block in the vise to perform successive operations that are clocked at 60°, 90°, 120°, or 180°. Shown below is a photo of a square and a hexagon ER40 collet block.

This is a video demonstrating the use of a square ER40 collet block to hold a round part in a milling vise. The part has a 3/4" round shaft secured in the ER collet, while the mill is used to drill and tap for a set screw with the collet block secured in the mill vise. A second operation rotates the collet block 180° in the vise so there are two opposing set screws around the circumference of the part being worked on.

Using a hex ER collet block is one way to take a round shaft (that's perhaps threaded on the lathe) over to the mill and machine a hex-head on the end of the shaft. The same ER40 collet blocks can be mounted in a conventional 3- or 4-jaw chuck on the lathe. This can be useful when taking the same part back and forth between the mill and the lathe, when you also need to keep the part consistently clocked (rotated) between operations on different machines.

An ER collet is secured via a nut using a spanner wrench that presses the collet into the chuck's tapered hole. That same nut is designed to click onto the collet so that the collet will be pulled out of the taper when the nut is unscrewed, thus releasing the collet's grip on the part or tool. An ER collet is always tightened and loosened at the nose of the collet chuck. An ER collet has a ~1mm clamping range - no more. And it compresses around the cylindrical part or tool the full length of the collet, not just at the nose-end of the part like the 5C variety. The most critical aspect for precision ER setups is buying a very high-quality ER collet nut made by Rego-Fix (the originator of the ER system in Switzerland). This video is worth watching to understand a few of the common misconceptions about ER collet use.

## 5C collets

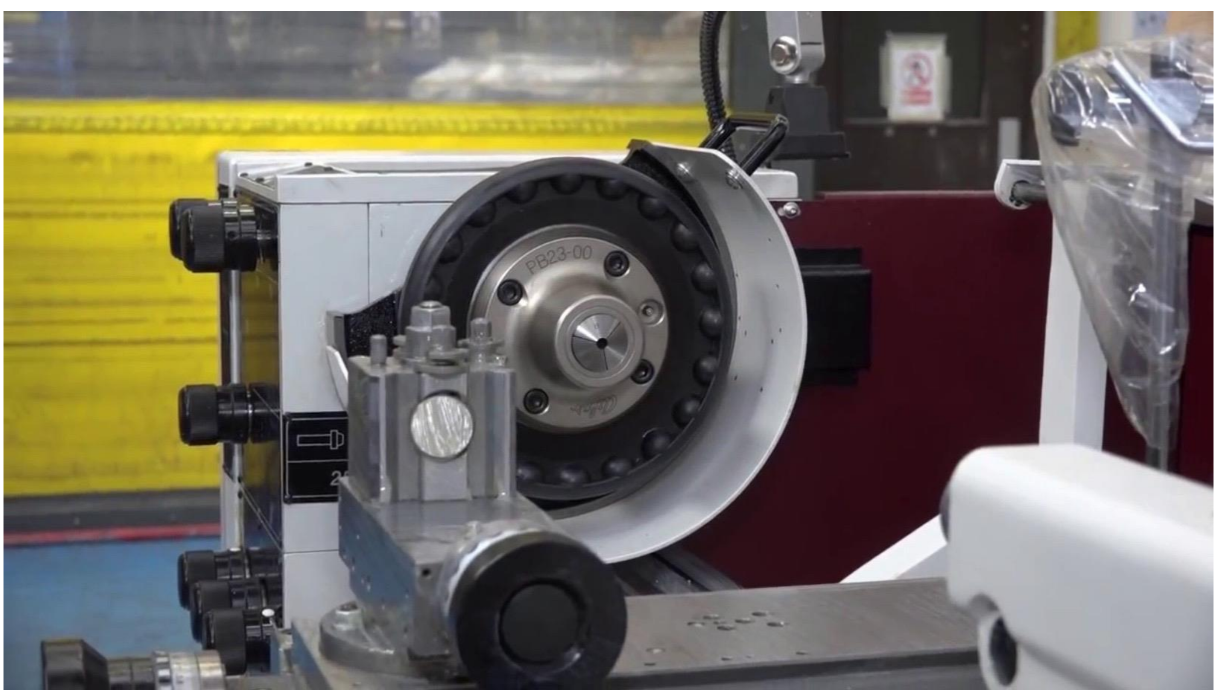
A 5C collet is only used for holding materials, not tools. It has a much smaller clamping range of a few thousandths of an inch, so you need a LOT of them to cover a 1" range. Unlike the ER collets, they only clamp on the material at the nose-end. The 5C collet does not compress cylindrically like ER collets, they pinch at the nose, and the clamping range is approximately 0.003". This is why you need so many to cover a given range. If you are routinely working with nominal-sized material, then a collection of nominally-sized 5C collets will suffice. But when switching between metric and imperial-sized raw stock, or needing to chuck up odd sized diameters, the ER collets have a distinct advantage.

On the other hand, one advantage of the 5C collet is that it can securely hold short pieces of material, where the ER40 collet requires at least 1" of material inside the collet to maintain a good grip and low runout (TIR). The photo below illustrates a typical 5C collet – note that it has three splits around the perimeter, and the drawbar attachment at the small end has a male thread for use with a tube-style drawbar.

For lathe use, there are three basic types of 5C collet chucks for spindle mount. These collet chucks adapt to the lathe spindle with the same style of mounting system that's used for a 3-jaw scroll chuck on the same lathe. The spindle mount could be Camlock, threaded, tapered, or some other configuration.

The most basic type of 5C collet chuck for a lathe is one that uses a chuck key to actuate the collet closure - rotating the chuck wrench actuates a built-in threaded sleeve that pulls or pushes on the 5C collet to compress or release the collet. That type is shown in the following photo.


Similar 5C collet chucks are available for the lathe that actuate the collet closure with a large wheel on the chuck-side of the spindle. The wheel type lathe collet chuck is shown below. The large black wheel can be gripped and turned by hand (assuming you have a spindle lock on the lathe) to actuate and compress or release the 5C collet in the taper of the collet chuck.



The third type of 5C lathe collet chuck actuates the collet a quick release drawbar mechanism on the left side of the spindle. That system is called a 5C collet closer – you'll find a decent video of how it works here. With this type of setup, the collet chuck attaches to the lathe spindle in the conventional manner. The following photo is a 5C collet chuck (on the right) with the collet closure mechanism that mounts to the left side of the lathe headstock and reaches through the spindle to the 5C collet with a tube-style drawbar on a quick-release lever mechanism. The system is designed such that the lever-closing mechanism remains stationary even when the lathe spindle is turning.


There are also square and hexagonal 5C collet blocks for holding round materials in a vise and indexing them at 60° or 90° similar to the ER40 collet blocks shown above. Here is a photo of square and hex 5C collet blocks. The black cylindrical item on the right is a quick-release collet closer and the handle actuates the collet from clamped to unclamped position.

There are special 5C collets that are essentially solid faced, not fully hardened, and can be machined to hold basically any profile you can machine into the collet - these are called "emergency" collets and are often used to hold oddball sizes of materials rather than stocking the 50+ collets you'd need to cover a ⅛-¾" range. This is a photo of one type - it is installed and clamped in a collet chuck, then the collet is machined to the required diameter with a drilling or boring operation (or a profile machined into the collet on a mill). The three pins keep the collet from fully closing when the collet is tightened and being machined, then once the collet is released, the three pins are removed so the collet can fully clamp on the workpiece it was machined to hold.


Some indexing systems, dividing heads and rotary tables are available with 5C collet chucks built into the device.

### Deciding between ER40 and 5C

Joe Pie has produced an informative video that could be useful different collet types.

When considering the trade-offs between ER40 and 5C collet systems, I decided to standardize on the ER40 collets. The following explains my rationale for going with ER40 instead of 5C.

The clamping range of a 5C collet is approximately 0.003". So for a standard 5C collet to be useful, the material being clamped must be a multiple of 1/64" exactly, or within 0.003" undersized for the collet to secure the workpiece. If the material to be clamped is always a multiple of 1/64" in diameter, then 5C would make sense. But looked at another way, if you want to clamp any arbitrary diameter between 1/8" and 1" using 5C collets, you would need a set of 290 collets at 0.003" increments - this doesn't exist.

Most of my work on the lathe with smaller diameter (1" or less) bar stock will result in a final diameter that is not necessarily a multiple of 1/64" +0.000/-0.003". If the follow-on operation requires flipping the part around in the chuck (common occurrence) then I might or might not have a 5C collet that can hold the work piece for the 2nd operation.

Now, let's take the case with ER40. The stated clamping range of the ER40 is 0.40", but if TIR is important, it's better not to count on that full clamping range. So, let's assume that the conservative clamping range is 0.020" to guarantee a good TIR. To cover the same range of 1/8" to 1" in 0.020" increments, you'd need 44 collets. Indeed, a metric set in 1/2mm increments will cover the entire range with ZERO gaps and meet the 0.020" maximum clamping restriction. So, it is at least possible (with the right collet set) to cover any workholding situation with ER40 and 44 collets. The only way to have this same flexibility with 5C is to use emergency collets and machine them to exact diameter for the off-nominal dimensions.

If your workholding needs are consistently some multiple of 1/64" then either 5C or ER40 will serve the need. But if the requirement is to hold material of any arbitrary diameter, then ER40 is a better alternative unless you want to swap out for a 3-jaw or 4-jaw conventional chuck, or make your own 5C emergency collets. A set of 23 imperial ER40 collets will cover the 1/8-1" range with a clamping range of 0.038 per increment. This is a slightly lower clamping range than using metric 1mm increment sets where the clamping range is 0.040" per increment. In my situation I decided to buy the metric set and fill in with half-millimeter collets for a few frequently used sizes.

As such, I have the following set of components:

- 1-26mm set of metric high precision ER40 collets
- ER40 collet chuck for the spindle on the lathe
- ER40 collet chuck with MT3 taper that fits the lathe tail stock and the MT3 taper in my rotary table
- ER40 collet chuck with R8 taper for the mill
- Square and hex ER40 collet blocks
- Rego-Fix collet nuts which improve TIR significantly

With this setup, I can hold any diameter tool or material up to 1" in the lathe spindle, the lathe tail stock, the rotary table, the mill spindle, or the mill vise.

If I were doing production of hundreds of small diameter parts on the lathe, I would prefer to have a 5C collet chuck on the lathe with the quick release closer mechanism on the left side of the spindle. But I don't do that kind of work. And if I need to hold oddball-shaped parts in the lathe spindle, I can do that with a 3- or 4-jaw chuck or make my own chuck jaws that conform to the profile of the part.

## About Runout or TIR

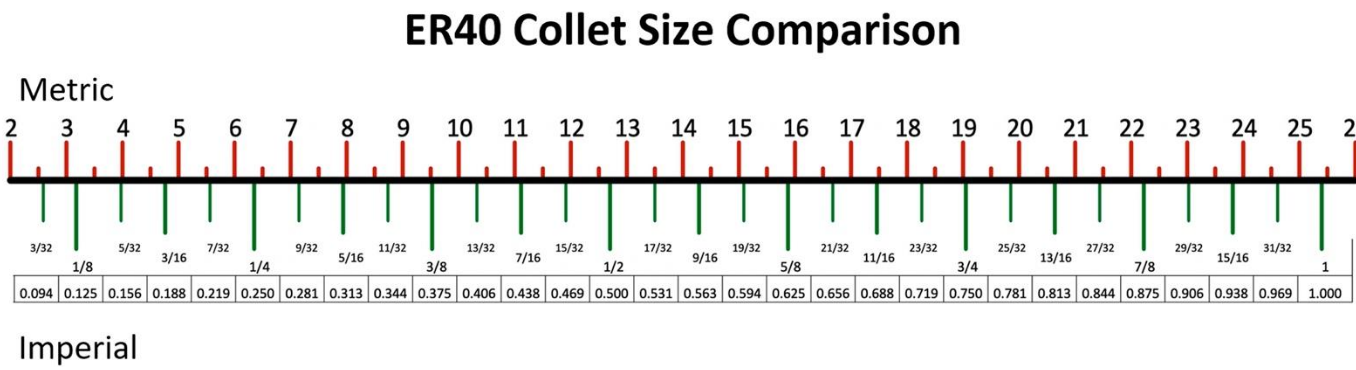
As far as TIR is concerned, I went down this rabbit hole in 2019, performing extensive testing and talking with some sophisticated tooling engineers and CNC production managers in my quest to improve tolerances. Rego-Fix (the Swiss company that invented the ER system) will guarantee their TIR specs across the full clamping range if you employ all Rego-Fix components in the ER system (collet chuck, collet, and collet nut) using a torque wrench for tightening. Their stated clamping range for ER40 is 0.040" whether it's an imperial or metric collet. But you really must look at it at a SYSTEM, and all three of the components contribute to TIR at nominal and fully compressed limits.

Obviously, a collet chuck that has a poorly machined taper or is off-axis to the spindle rotation is going to have runout. Same with a poorly made collet. And if the material being clamped does not extend the full length into the collet, this can also contribute to poor TIR results. But this is equally true of the collet nut which has its own 30° taper that aligns the nose of the collet as it's driven into the collet chuck taper.

If the 30° taper inside the collet nut is not machined precisely, the nut will drive the collet slightly askew axially as it's tightened down - and the harder you tighten the nut, the more it's driven off-axis. The same holds true of the 30° taper on the nose of the collet - it must be precisely on-axis to the longer taper at the opposite end to achieve a precise alignment as the nut is tightened. Adding a bearing to the collet nut to make it easier to twist on/off can also contribute to off-axis alignment. Matching the collet size to closely the diameter of the material being held will reduce the required clamping range, which can improve TIR.

Every element here contributes to the resulting TIR. Having a Set-True style collet chuck in the spindle provides the flexibility to adjust the collet taper on-axis to the spindle. Investing in precision collets will also improve TIR. But if you put an $80 Rego-Fix precision collet in a $800 Bison collet chuck and use a $20 ER collet nut to tighten the setup, I can speak with authority that your TIR will be disappointing and get worse the more you tighten down on the nut. The single best thing I have done to improve ER40 TIR is to employ a Rego-Fix collet nut. And with consistent torque applied, I see no difference in TIR across the full 0.040" clamping range with either metric or imperial ultra-precision collets. With any of the other ER40 collet nuts I've tried (Maritool, Parlec, HHIP, Shars, Technicks, Accupro) the results vary considerably and are not proportional to price of the nut.

Does any of this TIR-related analysis matter in practice? Well, that has a lot to do with the kind of precision you are after, and whether you can complete all the required machining operation in one setup. If your parts are brought to final size, then parted off and flipped around in the collet chuck for a second operation (which is what I do often), it can be frustrating to have to re-align the Set-True chuck individually for each of the 20 parts you just made in order to hit tolerance. Limiting the required clamping range is one strategy that helps - I have two half-millimeter ER40 collets (18.5 and 16.5) specifically for this reason. But investing in a decent collet nut can also really improve TIR.




| ER40 Imperial Collets - Min/Max Clamping Range | | | | | | |
|---|---|---|---|---|---|---|
| Nominal Size | Rego-Fix Equivalent Part Number | Clamping Range Millimeters | | Clamping Range Inches | | Best Fit for Imperial Size |
| | | Maximum Ø | Minimum Ø | Maximum Ø | Minimum Ø | |
| 1/8 | 1140.03182 | 3.18 | 2.16 | 0.1250 | 0.0850 | 1/8 |
| 3/16 | 1140.04762 | 4.76 | 3.75 | 0.1875 | 0.1475 | 3/16 |
| 1/4 | 1140.06352 | 6.35 | 5.33 | 0.2500 | 0.2100 | 1/4 |
| 5/16 | 1140.07942 | 7.94 | 6.92 | 0.3125 | 0.2725 | 5/16 |
| 3/8 | 1140.09532 | 9.53 | 8.51 | 0.3750 | 0.3350 | 3/8 |
| 7/16 | 1140.11112 | 11.11 | 10.1 | 0.4375 | 0.3975 | 7/16 |
| 1/2 | 1140.12702 | 12.7 | 11.68 | 0.5000 | 0.4600 | 1/2 |
| 9/16 | 1140.14292 | 14.29 | 13.27 | 0.5625 | 0.5225 | 9/16 |
| 5/8 | 1140.15882 | 15.88 | 14.86 | 0.6250 | 0.5850 | 5/8 |
| 11/16 | 1140.17462 | 17.46 | 16.45 | 0.6875 | 0.6475 | 11/16 |
| 3/4 | 1140.19052 | 19.05 | 18.03 | 0.7500 | 0.7100 | 3/4 |
| 13/16 | 1140.20642 | 20.64 | 19.62 | 0.8125 | 0.7725 | 13/16 |
| 7/8 | 1140.22232 | 22.23 | 21.21 | 0.8750 | 0.8350 | 7/8 |
| 1 | 1140.25402 | 25.4 | 24.38 | 1.0000 | 0.9600 | 1 |

| ER40 Metric Collets - Min/Max Clamping Range | | | | | | |
|---|---|---|---|---|---|---|
| Nominal Size | Rego-Fix Equivalent Part Number | Clamping Range Millimeters | | Clamping Range Inches | | Best Fit for Imperial Size |
| | | Maximum Ø | Minimum Ø | Maximum Ø | Minimum Ø | |
| 3 mm | 1140.03000 | 3 | 2 | 0.1181 | 0.0787 | 3/32 |
| 3.5 mm | 1140.03500 | 3.5 | 2.5 | 0.1378 | 0.0984 | 1/8 |
| 4 mm | 1140.04000 | 4 | 3 | 0.1575 | 0.1181 | 5/32 |
| 4.5 mm | 1140.04500 | 4.5 | 3.5 | 0.1772 | 0.1378 | |
| 5 mm | 1140.05000 | 5 | 4 | 0.1969 | 0.1575 | 3/16 |
| 5.5 mm | 1140.05500 | 5.5 | 4.5 | 0.2165 | 0.1772 | |
| 6 mm | 1140.06000 | 6 | 5 | 0.2362 | 0.1969 | 7/32 |
| 6.5 mm | 1140.06500 | 6.5 | 5.5 | 0.2559 | 0.2165 | 1/4 |
| 7 mm | 1140.07000 | 7 | 6 | 0.2756 | 0.2362 | |
| 7.5 mm | 1140.07500 | 7.5 | 6.5 | 0.2953 | 0.2559 | 9/32 |
| 8 mm | 1140.08000 | 8 | 7 | 0.3150 | 0.2756 | 5/16 |
| 8.5 mm | 1140.08500 | 8.5 | 7.5 | 0.3346 | 0.2953 | |
| 9 mm | 1140.09000 | 9 | 8 | 0.3543 | 0.3150 | |
| 9.5 mm | 1140.09500 | 9.5 | 8.5 | 0.3740 | 0.3346 | 11/32 |
| 10 mm | 1140.10000 | 10 | 9 | 0.3937 | 0.3543 | 3/8 |
| 10.5 mm | 1140.10500 | 10.5 | 9.5 | 0.4134 | 0.3740 | 13/32 |
| 11 mm | 1140.11000 | 11 | 10 | 0.4331 | 0.3937 | |
| 11.5 mm | 1140.11500 | 11.5 | 10.5 | 0.4528 | 0.4134 | 7/16 |
| 12 mm | 1140.12000 | 12 | 11 | 0.4724 | 0.4331 | 15/32 |
| 12.5 mm | 1140.12500 | 12.5 | 11.5 | 0.4921 | 0.4528 | |
| 13 mm | 1140.13000 | 13 | 12 | 0.5118 | 0.4724 | 1/2 |
| 13.5 mm | 1140.13500 | 13.5 | 12.5 | 0.5315 | 0.4921 | 17/32 |
| 14 mm | 1140.14000 | 14 | 13 | 0.5512 | 0.5118 | |
| 14.5 mm | 1140.14500 | 14.5 | 13.5 | 0.5709 | 0.5315 | 9/16 |
| 15 mm | 1140.15000 | 15 | 14 | 0.5906 | 0.5512 | |
| 15.5 mm | 1140.15500 | 15.5 | 14.5 | 0.6102 | 0.5709 | 19/32 |
| 16 mm | 1140.16000 | 16 | 15 | 0.6299 | 0.5906 | 5/8 |
| 16.5 mm | 1140.16500 | 16.5 | 15.5 | 0.6496 | 0.6102 | |
| 17 mm | 1140.17000 | 17 | 16 | 0.6693 | 0.6299 | 21/32 |
| 17.5 mm | 1140.17500 | 17.5 | 16.5 | 0.6890 | 0.6496 | 11/16 |
| 18 mm | 1140.18000 | 18 | 17 | 0.7078 | 0.6693 | |
| 18.5 mm | 1140.18500 | 18.5 | 17.5 | 0.7283 | 0.6890 | 23/32 |
| 19 mm | 1140.19000 | 19 | 18 | 0.7480 | 0.7078 | |
| 19.5 mm | 1140.19500 | 19.5 | 18.5 | 0.7677 | 0.7283 | 3/4 |
| 20 mm | 1140.20000 | 20 | 19 | 0.7874 | 0.7480 | 25/32 |
| 20.5 mm | 1140.20500 | 20.5 | 19.5 | 0.8071 | 0.7677 | |
| 21 mm | 1140.21000 | 21 | 20 | 0.8268 | 0.7874 | 13/16 |
| 21.5 mm | 1140.21500 | 21.5 | 20.5 | 0.8465 | 0.8071 | 27/32 |
| 22 mm | 1140.22000 | 22 | 21 | 0.8661 | 0.8268 | |
| 22.5 mm | 1140.22500 | 22.5 | 21.5 | 0.8858 | 0.8465 | 7/8 |
| 23 mm | 1140.23000 | 23 | 22 | 0.9055 | 0.8661 | |
| 23.5 mm | 1140.23500 | 23.5 | 22.5 | 0.9252 | 0.8858 | 29/32 |
| 24 mm | 1140.24000 | 24 | 23 | 0.9449 | 0.9055 | 15/16 |
| 24.5 mm | 1140.24500 | 24.5 | 23.5 | 0.9646 | 0.9252 | |
| 25 mm | 1140.25000 | 25 | 24 | 0.9843 | 0.9449 | 31/32 |
| 25.5 mm | 1140.25500 | 25.5 | 24.5 | 1.0039 | 0.9646 | 1 |
| 26 mm | 1140.26000 | 26 | 25 | 1.0236 | 0.9843 | |
| 27 mm | 1140.27000 | 27 | 26 | 1.0630 | 1.0236 | 1 1/16 |
| 28 mm | 1140.28000 | 28 | 27 | 1.1024 | 1.0630 | 1 3/32 |
| 29 mm | 1140.29000 | 29 | 28 | 1.1417 | 1.1024 | 1 1/8 |
| 30 mm | 1140.30000 | 30 | 29 | 1.1811 | 1.1417 | 1 5/32 |