Tuning Your Lathe

Testing & correcting the accuracy of your lathe

To get the best performance from your lathe you need to check the accuracy of its working parts. Modern lathes have accuracy built into them, but there may be some parts that are not accurate or properly aligned. Some of these problems can be easily fixed, and some require more work, but as I describe each of these problems I will state how much deviation is acceptable (tolerance), and what operations would be ill affected by these errors. That way you can decide if you need to fix the problem. For example, if you never drill from the tailstock, or use the tailstock to steady work held in a chuck, then the alignment of the head and tail centers is not very important.

The tolerances I have stated in this article can surely be debated. I know many readers will say, *Jon, it's just a wood lathe!*—feeling that these standards are too high, and more in keeping with a machinist's lathe. I have been fortunate in my career to have worked extensively on both wood and metalworking lathes, and I know the tolerances I have given are much larger than most metal turning lathes.

Testing Lathe Alignment—For the photos, I am using a $90 test indicator because it is convenient and very sensitive, but all of these tests, except for the deep taper test, can be accomplished with a $25 dial indicator on a magnetic base. With this article I have included information about the evolution of precision indicators, because these are the tools used to do the tests and are closely associated with precision lathe work.

Most people know that the head and tail centers should meet together in perfect alignment, but this fact alone does not mean your lathe is aligned. Figure 1 shows how the axes of the head and tail intersect at the point of inspection allowing the centers to meet perfectly while the lathe is completely out of alignment.

The tests for lathe alignment are shown in Photos 1–7. The procedure involves determining whether the head and tailstock axes are parallel to the bed, and therefore parallel to each other. This is a big step, but it is only the first one, because parallelism by itself is insufficient—the axes must be coincident.

The first test (Photo 1) is done with the tailstock about 10″ out because this is the average position for drilling chucked work or using the tailstock for auxiliary support of chucked work. The dial should be observed as the spindle is rotated. Once the "high point" is located and the dial read, the low point reading will be opposite (180° rotation). The difference between these two readings should be less than 0.010″—Total Indicator Run-out.

Since the measurement is taken off the tail center, it assumes

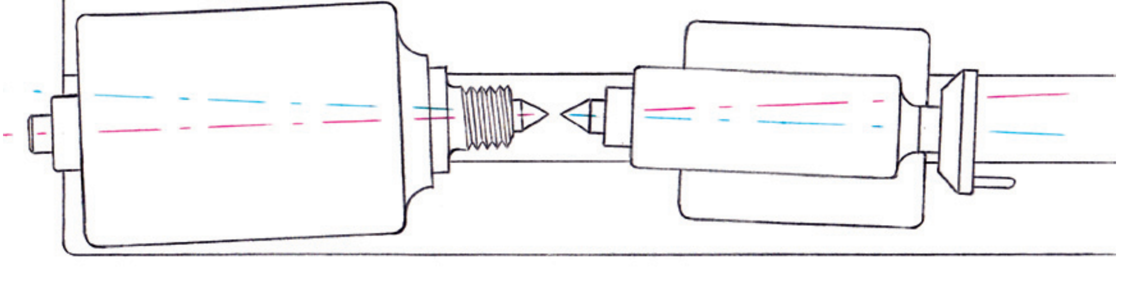
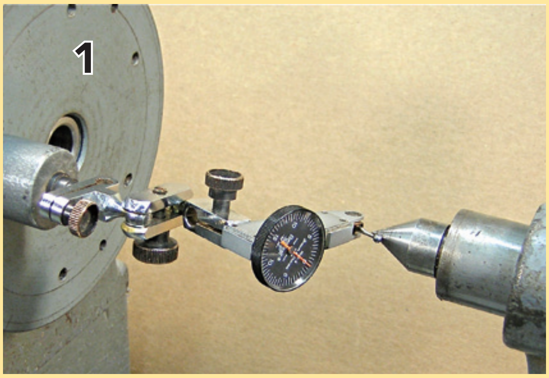
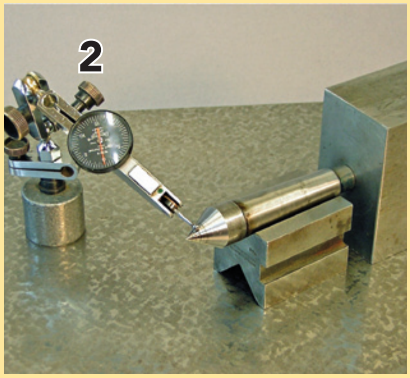
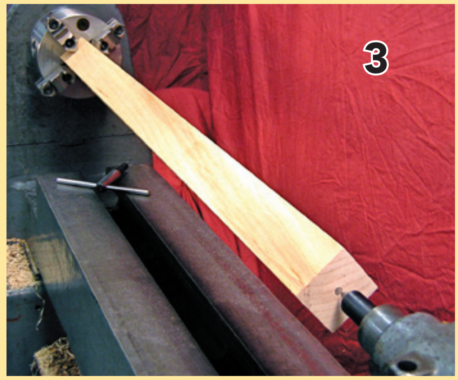
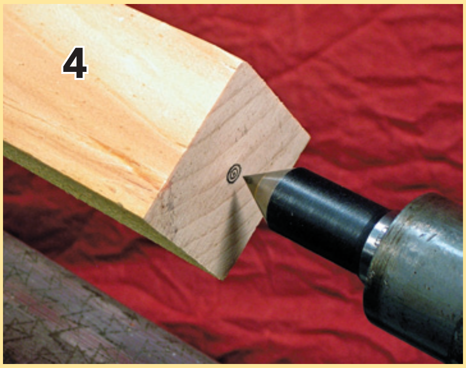


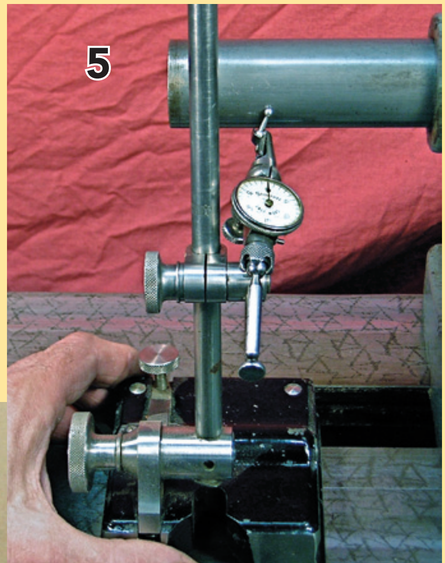
Figure 1—The axes of the head and tail intersect at the point of inspection allowing the centers to meet perfectly while the lathe is completely out of alignment

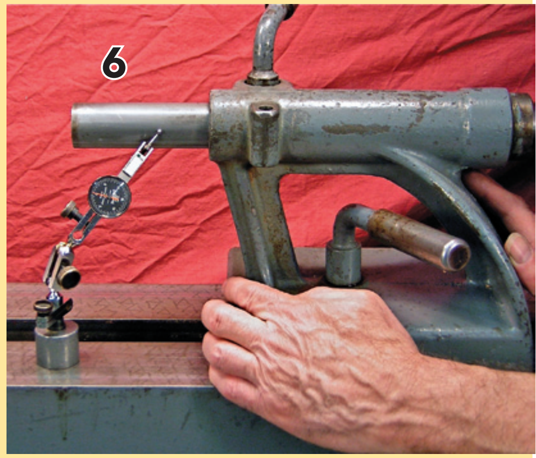


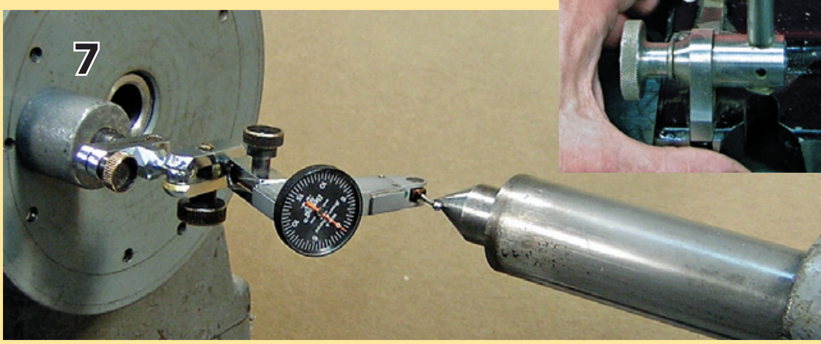












1 Near Test—It is difficult to put a tolerance on this test, because it depends on the demands of your work, but in general your lathe should test within 0.010″ TIR (Total Indicator Runout). Anything over 0.015″ TIR will cause noticeable problems when drilling from the tailstock, or when using the tailstock center to support chucked work.

2 Test Center—If the headstock center does not run true in your lathe, you must determine if the fault is with the lathe, or the center, or both. This test will tell you if the center is concentric with its own shank. Because the shank is tapered, it must be backed-up by a stationary object to prevent axial movement on the vee-block. Run-out should be less than 0.002″ TIR.

3 Test at Distance—If you get good results from the near test, but not on the distance test shown here, then the headstock is not parallel to the bed. Error should be less than 0.010″ per foot of distance from headstock.

4 Test at Distance 2—This photo gives a good look at the "bulls-eye" penciled on the end of the wood with the lathe running at its slowest speed.

5 Test Ram 2—This is the best way to test parallelism of the ram to the bed because the tailstock is locked. The guide pins of the surface gage are extended below, and ride against the edge of the slot. Error should be less than 0.001″ per inch of travel.

6 Test Ram—With the ram fully extended, slide the tailstock along the bed. Error should be less than 0.001″ per inch of travel.

7 Near Test, Ram Extended—If you get different results when the ram is extended vs. retracted, then the tailstock axis is skew or intersecting the axis of the spindle.

that the center is accurate. If you have any doubts about the concentricity of the tail center, test the center on vee-blocks (Photo 2), or simply take it out, turn it 180° and do the test again to see if you get the same result. Another way to eliminate error caused by an eccentric center is to remove the center and take the measurement on the inside of the taper. Remember that this test by itself doesn't prove anything. The next test is done at a distance from the headstock (Photo 3) using a stout piece of pine in a chuck. With the lathe running at its slowest speed, inscribe the center location as shown and bring the tail center up to the wood (Photo 4). If you want to be more accurate, you can clamp the indicator onto the end of the wood square, but the *bulls eye* test is good because the angular error is magnified by the long distance. This is a test that anyone can do even if they do not own an indicator. If this checks out, then you know your headstock axis is parallel to the lathe bed. If not, the mounting of the headstock needs adjustment. On lathes with swivel heads, this is trivial. On some others you can just loosen the bolts that hold the headstock to the bed and tweak the position—but on some lathes this adjustment requires a significant amount of work involving removal of the headstock. This may seem daunting, but the rewards are great if you want to do precise work that involves drilling from the tailstock. Remember that if the headstock spindle axis is not parallel to the bed, then the tailstock will never be in line with it, except possibly at one point on the bed.

The test for parallelism of the tailstock axis to the bed is shown in Photo 5. With the tailstock locked and the ram fully extended and locked, the indicator is slid along the bed ways. In this case a surface gage is used as a base with the pins extended below the bed surface to ride against the slot in the bed. Alternately the indicator can be stationary while the tailstock is moved on the bed (Photo 6). This is not as accurate because the tailstock is not locked. Admittedly, this is a short baseline (3″ or 4″), but the test is accurate enough if done carefully. Yet another way to test the parallelism of the tailstock spindle to the bed is to repeat test #1 with the ram fully extended (Photo 7) and compare the results. An error of less than 0.001″ per inch of travel is acceptable.

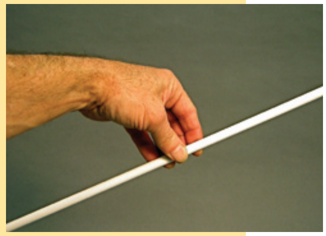
It is rare to find a tailstock on a wood lathe that has lateral adjustment unless the lathe has a carriage, like a patternmaker's lathe. In that case the tailstock *set-over* is used to control taper of the workpiece. For the vast majority of wood lathes, errors in tailstock alignment can only be corrected by hand filing or scraping the contact surfaces.

In these photographs, the test is being done in the horizontal plane, which is where most inaccuracy seems to occur. But all the tests should be performed in the vertical plane as well, because that is just as important.

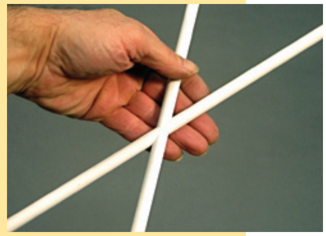
The lathe is aligned when both the spindle axis and the tailstock axis are coincident on a line that is parallel to the bed.

The Four Conditions of Two Lines in Space—After taking the measurements described above you begin to get a mental picture of the way the headstock and tailstock are misaligned. Think of the line of the headstock axis as a single line in space. Think of the axis of the tailstock as a second line. These two lines should be coincident, that is, they should exist in the same location, and thus

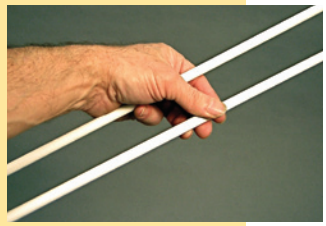
A The lines are coincident. When two lines are coincident, they become one line, because they have ALL points in common and both exist in the same location. As with all straight lines, there are an infinite number of planes that contain it.



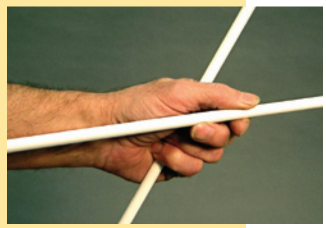
B The lines intersect. Intersecting lines lie in a plane—like an "X" drawn on a sheet of paper—and they have ONE point in common. (This is the unfortunate condition of the lathe shown in Figure 1.)

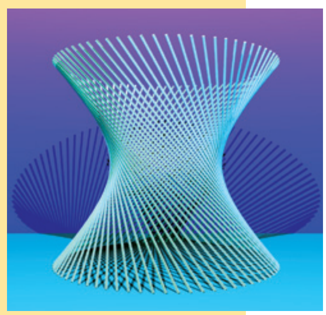


C The lines are parallel. Parallel lines lie in a plane, but they have NO points in common. A very important and useful property of parallel lines is that parallel lines appear parallel in every view.



D The lines are skew. Skew lines do not intersect, nor are they parallel or coincident. Skew lines do not lie in a plane and have NO points in common. Having defined skew lines by what they are not, we should examine some interesting properties they possess: On each line there is a point that is closest to the other line, and a third line connecting these two points is perpendicular to both skew lines. When viewed normal (perpendicular) to this third connecting line, skew lines appear to be parallel even though they are not. When one skew line is rotated around the axis of the other, the resulting solid of generation is a hyperboloid (illustration, photo of model made from straight dowels posted by Rainerwonisch). All this may seem esoteric, but the next time you are jointing a twisted board, remember that the problem you are facing exists because the edges of that board are skew lines instead of the parallel lines you wish them to be.





merge into a single line. That is the goal, but the measurements might show that the two lines are not coincident but exist in some other relationship. There are three other possibilities described below. Once you understand the four possible conditions of two lines in space, you can use these concepts to access your particular misalignment problem and it will be clear what you have to do to correct it.

- A The lines are coincident (this is the goal)
- B The lines intersect
- C The lines are parallel
- D The lines are skew (the general condition)

Running Truth—When a cylindrical form, or any generated solid of revolution, rotates on its axis, the position of its surface appears stationary within the limits of the smoothness and circularity of the surface. This is because the axis is in the center by definition. But if the axis is off center (eccentric), then there is *movement* of the surface as it rotates, and this movement follows a regular sinusoidal pattern of one cycle per revolution. *This is known as run-out.*

The important thing to know about measuring radial run-out is that the error measured at the surface is two times the eccentricity. This is because one side is below the true surface location, and the other side is above the true surface location by the same amount. For example, if a bowl is re-chucked and the center is ⅛″ off, then the error at the surface will be ¼″. To avoid confusion, machinists refer to this measurement as total run-out, and it does not refer to eccentricity (which is ½ of the run-out). Usually measured with a dial indicator, it is abbreviated TIR for Total Indicator Run-out.

Spindle Nose—For chucks and faceplates to center accurately, both the shoulder (Photo 8) and the threads must run true. Checking the run-out of the thread by the "split nut" method is shown in Photo 9. The vice-grips are closed with just enough pressure to snug the split nut, but still be able to rotate the spindle. The indicator is applied to a flat on the nut, and the reading is observed over several revolutions. It often happens that the sides of the nut are not exactly parallel to the axis, so you might observe an increase or decrease of the indicator reading as the nut moves. This can be ignored because you are looking for the sinusoidal movement of the indicator dial that cycles with each revolution—that would demonstrate run-out.

The Fine Points of Lathe Centers—In previous articles I have covered methods of duplication and the importance of working in steps, instead of trying to turn the entire piece in a single operation. Many turners do not use this method because of the difficulty of removing the workpiece and replacing it and having it return exactly on center again. This error of procedure occurs when the turner is trying to compensate for faulty lathe centers. You should be able to remove your workpiece, replace it, or turn it end-for-end an infinite number of times—and have it return to exact center without fuss and without fail every time. If you do not have this, you are operating at great disadvantage, and you should fix your centers.

The Perfect World vs Reality—If the taper bore in your spindle runs out, there is not much you can do about it short of replacing expensive parts. Does this mean that your centers will always run-out? No—there is something you can do to eliminate the error. The center points of lathe centers are often eccentric to the shank anyway. In final analysis it is the combination of these two errors that determines whether your center runs true, and the errors may reinforce each other, or possibly cancel out, depending on the placement of the center in the taper bore. The solution is to make a *witness mark* on both the center and on the lathe spindle nose that allows you to always place the center in the same position. In a perfect world, you would not have to do this, but in the real world, it solves a multitude of problems. Once you have inserted the center and made the witness marks, you can proceed to *true up* the center point by scraping with a HSS chisel, or in tough cases a carbide tipped tool. There are some rare center points that are made from hardened steel that can't be scraped, and must be worked with abrasives. With these "one-time" procedures, you are customizing your centers to your lathe to achieve a higher degree of accuracy than was originally built into the machine.

Photos 10, 11 & 12 show how to test the true running of the taper bore. A simple dial indicator will give a basic measurement

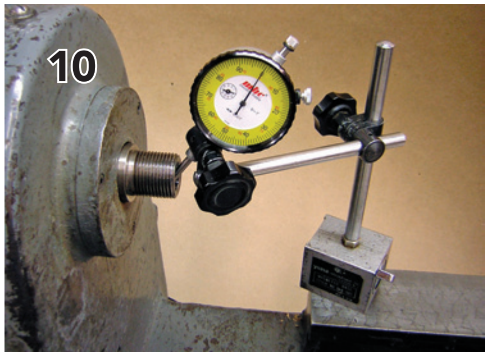
8 Test shoulder—This simple test is often overlooked, but very important. Run-out should be less than 0.001″TIR.

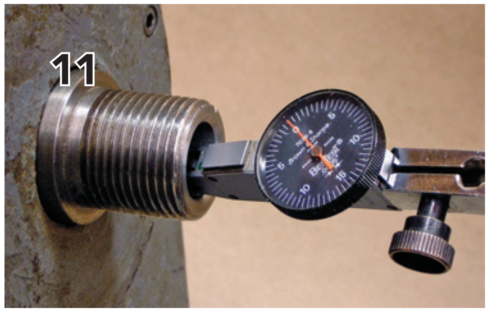
9 Test threads—The nut is split, and thus is flexible enough to be compressed by the Vice-Grips until the clearance is near zero. The handle of the Vice-Grip rides on the tool rest (placed in rear position for this photo). Run-out should be less than 0.002″TIR.

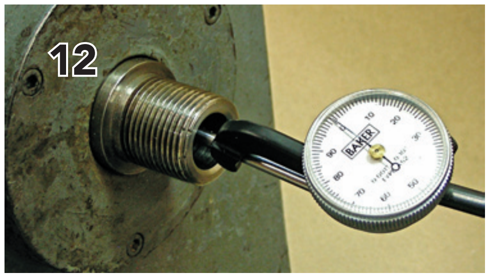
(Photo 10). A test indicator is better because it will reach somewhat deeper (Photo 11). After testing near the opening, an indicator with a lever extension will reach 2″ deep or more, and confirm that the bore runs true over its length. A TIR of less than 0.001" is very good. The Blount lathe in Photo 12 was made in Milford, NH 50 years ago. It exhibits less than 0.0005″ TIR.

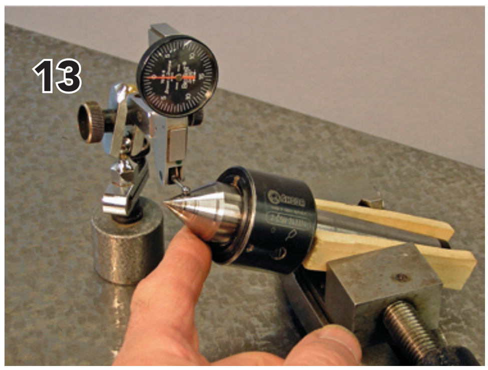
Many spur centers utilize a point that is held in place by a set-screw, and this method, while allowing adjustability of length, is not conducive to true running. The best centers have 60° points, and by using 60° points at both ends, the workpiece will center perfectly when turned end-for-end.

Ball bearing tailstock centers are a modern convenience that we appreciate, but they eventually wear out and become wobbly, contributing to workpiece vibration. How long this takes depends on how much you spend on engineering refinements. Meanwhile, the center should run true in its own bearings to less than 0.002″ TIR as shown in Photo 13. ■









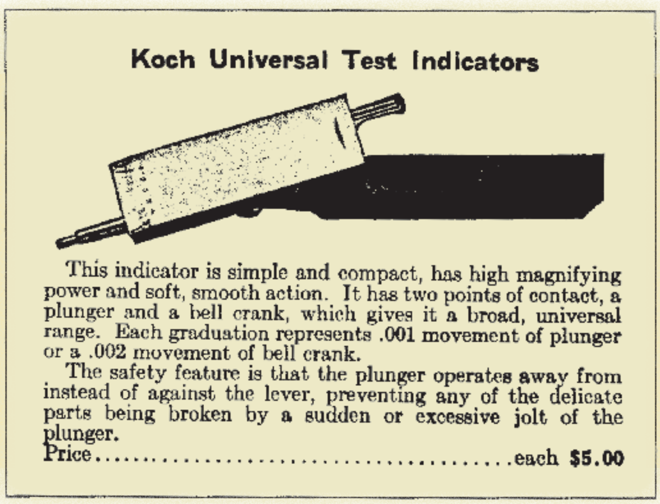
10 OK test—The simplest test of the spindle bore is with a dial indicator. This is good, but for a better test it is necessary to probe deeper into the bore. Run-out should be less than 0.001″TIR.

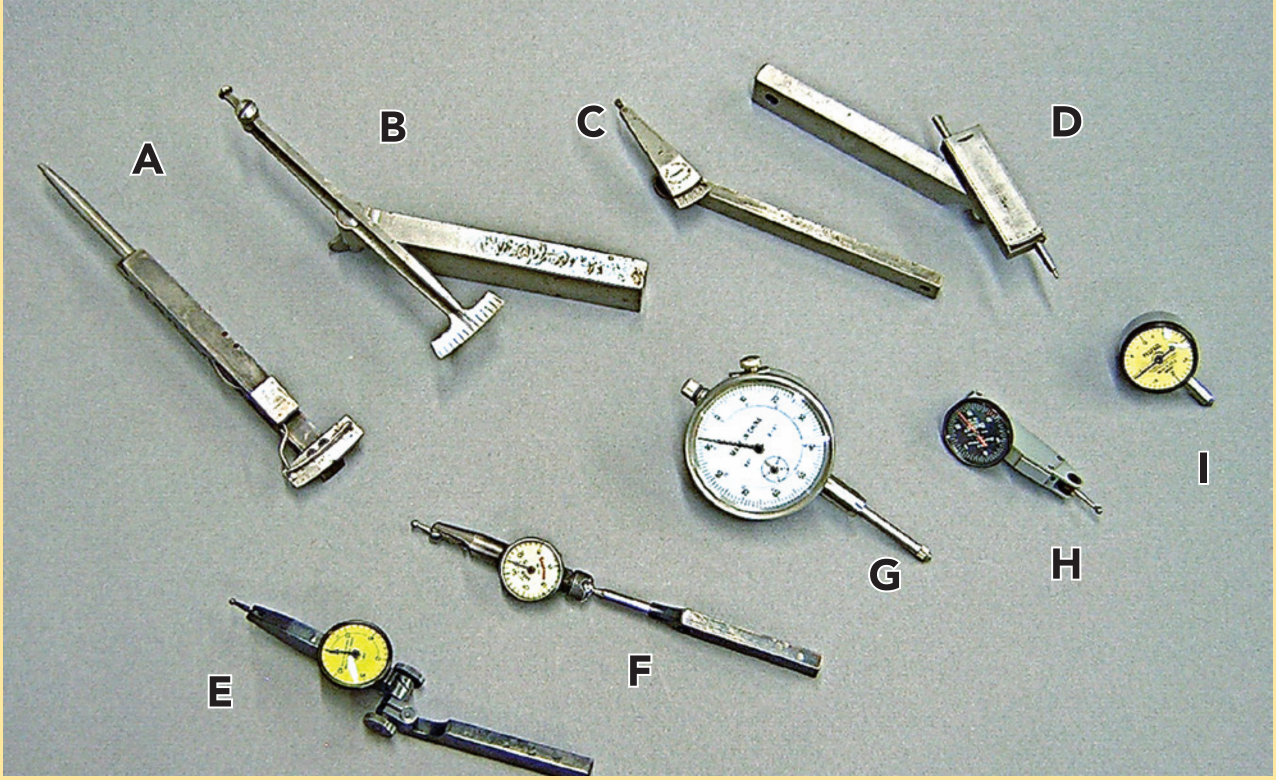
11 Much better—The extended contact point of the test indicator will reach deeper into the bore, and the graduations are 0.0005″. Run-out should be less than 0.001″TIR.

12 Deep test—A back-plunger type dial indicator, fitted with a lever extension will reach 2 inches or more into the bore. This test gives confirmation that the taper bore is true throughout its length, not just at the opening. Run-out should be less than 0.001″TIR.

13 Test BB center—Ball bearing tailstock centers must run true in their own bearings. Secure the shank in a vice or clamp (or in the lathe), and rotate the center with your fingers. Run out should be less than 0.002″TIR.

My favorite non-dial indicator is the Koch





Indicators—A thorough documentation of the historic evolution of machinist's indicators is covered in Kenneth L. Cope's book, Makers of American Machinist's Tools (ISBN 1-879335-55-7), but here are a few from my collection. Those in the top row are non-dial type, and in the bottom row are dial indicators. All the older types have rectangular stems designed for clamping into a lathe tool post, while modern indicators are usually attached to a magnet.

A A rare Boulet indicator, 1900 patent, range 0.030", graduations 0.001". This indicator was made by Fallon in Salem, MA, before Boulet started his own factory in Beverly in 1908. Front plunger type with attachments.

B Although this resembles ancient indicators made by Starrett, there is no company name on it. This is possibly an apprentice project, but the spring is very sophisticated. Action is side only—has no noticeable backlash, so it operates in both directions from center zero.

C. Ideal (1925 patent), Rochester, NY, is one of the first auto-reversing types, and probably the first to have a friction adjustable contact point—both features set the standard for future indicators. Range 0.010", graduations 0.001".

D My favorite non-dial indicator is the Koch. It has a swivel head with front plunger on one end and side contact (bell crank) on the other. I use the term "non-dial" instead of "pre-dial", knowing that it would be easy to make the argument that the dial made these early types obsolete, but in spite of its narrow range (0.010″) and the fact that the side contact is right hand only, this 100 year-old tool is a joy to use.

E Federal test indicator, 0.030" range, manual reversing.

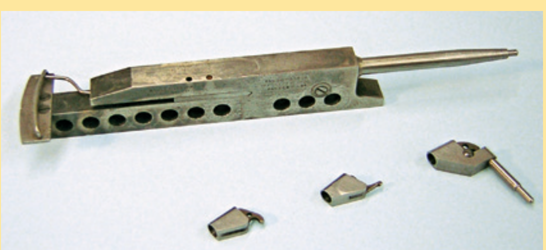
F Starrett, Athol, MA, "Last Word" test indicator, 0.030" range, 0.0005" graduations, auto-reversing.

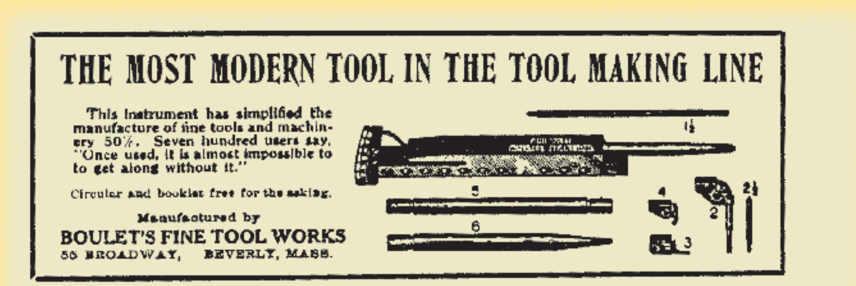
G A cheap Chinese dial indicator, one inch travel, 0.100" per revolution, with revolution counter, 0.001" graduations, great price: $10. Get one. ($24 with magnetic base).

H My favorite test indicator: Brown & Sharpe BestTest, 0.030" range, 0.0005" graduations, auto reversing. Middle price test indicator: $90.

I Ultra sensitive Starrett dial indicator, range 0.004" (two revolutions, no revolution counter), 0.0001" graduations!

A rare Boulet indicator, 1900 patent

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