Making Multi-Plane Crankshafts

by
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with
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*With significant contributions by
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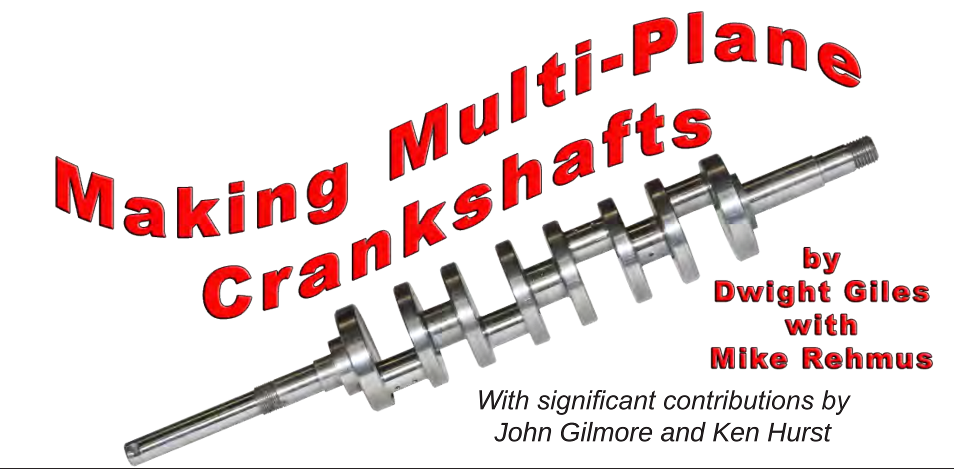
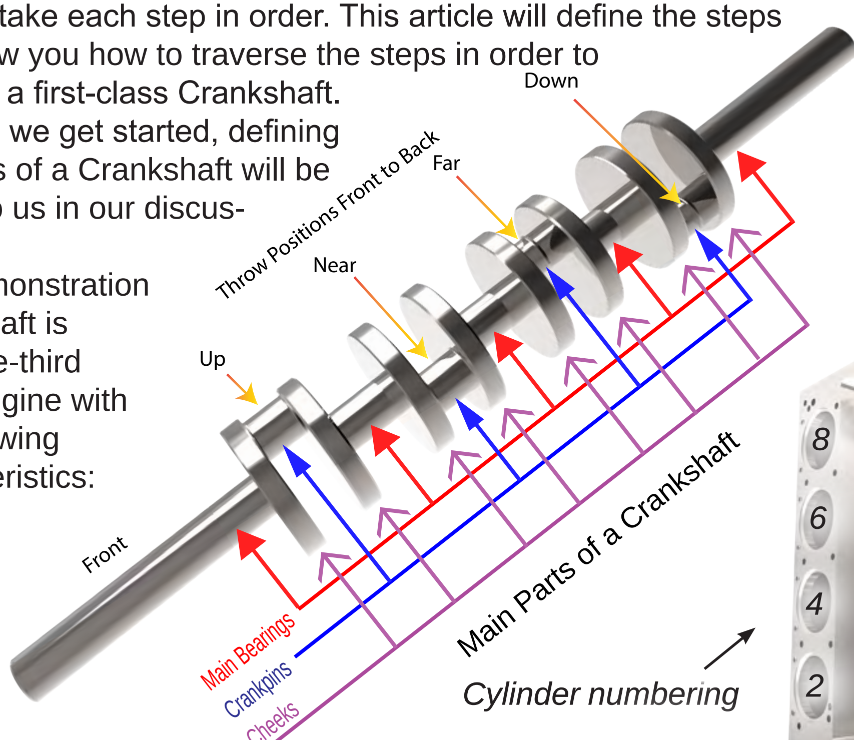


Making a Crankshaft has to rank right up there with the most fear-producing tasks to face a Model Engineer. When we contemplate a multi-plane Crankshaft, one where the connecting rod throws are not aligned in a single plane, the fear increases.

Fear not, they are not as difficult as they appear to be, you just need to take each step in order. This article will define the steps and show you how to traverse the steps in order to produce a first-class Crankshaft.

Before we get started, defining the parts of a Crankshaft will be useful to us in our discussions.



This demonstration Crankshaft is for a one-third scale engine with the following characteristics:

- Chevrolet cylinder numbering
- Chevrolet firing order, 1-8-4-3-6-5-7-2
- Clockwise rotation as seen from the front of the engine.

The annotations, Up, Far, Near and Down refer to the location every 90° of the Crankpins or Crank Journals in the Throws if you were observing the Crankshaft from the side with its front pointing to the left and the first Crankpin uppermost.

Clearances

Bearing clearances are important in these engines. You need to be aware of the location and design of certain elements. It is prudent to completely machine the engine's Crankcase before finalizing the dimensions on the Crankshaft. By making the Crankshaft after the Crankcase, you can adapt the Crankshaft dimensions to allow for minor mistakes in Cylinder and Main Bearing bore placement in the Crankcase.

I strongly recommended that you measure the Crankcase to detect if there is any deviation from plan and if so, decide how you are going to modify the Crankshaft and any other parts affected by the deviation(s) so they will work in the engine. Deviations from plan can be accommodated with very little or no performance degradation in the completed engine.

Make a sketch of the dimensions to which you must machine the Crankshaft before you start machining. On this particular Crankshaft, the Center Main Bearing also absorbs axial thrust and all measurements should be taken from that bearing and the two Cheeks that surround it. Main Bearings, Crankpins and Cheeks should be located relative to the Center Main Bearing and their location can be modified to fit the Crankcase.

If the small end of the Connecting Rod is allowed to significantly move side-to-side on the Wrist Pin, then the axial location and the side-to-side Crankpin clearances may be less critical compared to a Rod/Piston design where the little end of the Rod is not allowed to move more than a few thousandths of an inch. In that case, the Crankpins would have to be most carefully located.

Black Widow crankcase model courtesy John Gilmore

Strive for rod and main journal clearances of 0.001" - 0.002" (0.025mm - 0.05mm) and Crankshaft end play in its bearings in the Crankcase of 0.002" - 0.005" (0.05mm - ≈ 0.13mm). Side play for Rods is not too important but you should keep them between 0.001" - 0.005" (0.025mm - ≈ 0.013mm).

Metal Stock

You will spend somewhere around 20 hours not counting the time to make the fixtures, to complete an eight-cylinder, multi-plane Crankshaft. It makes no sense to use an inferior metal unless that is all you can obtain. These Crankshafts tend to be used in engines which run at high speeds. Mild steel may not withstand the stress and you might find yourself with a broken Crankshaft. The steel for this Crankshaft Blank is 1-⅝" (≈ 41.3mm) in diameter and 14-¼" (≈ 362mm) in length.

Dwight Giles and Ken Hurst use SAE Grade 4340 steel which has the following characteristics:

- Tensile Strength 108,000 psi (745 MPa)
- Yield Strength 68,000 psi (470 MPa)

Eighteen inches (≈ 257mm), of this in 1-¾" (≈ 45 mm) will cost about $60 in the U.S. from a company like Online Metals

By contrast, 1118 Carbon Steel has the following characteristics:

- Tensile Strength 76,000 psi (525 MPa)
- Yield Strength 45,700 psi (315 MPa)

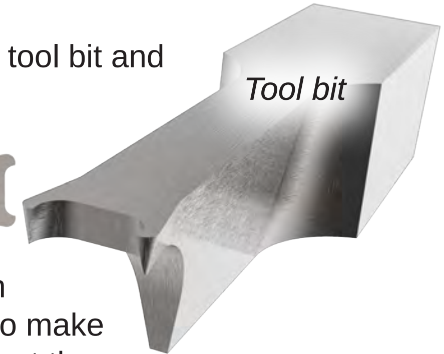
I would chose the stronger steel, wouldn't you?

Tools

In this process, you will need a lathe and it would be handy to have access to a milling machine but you will not need a toolpost grinder or any other exotic tools although you certainly can employ them if you wish. The only 'exotic' tool you will see used in this article is a Dividing Head which you do not need, it just makes the work easier. You could substitute a Rotary Table or you could improvise, depending on what tools you have available.

Without a mill, you can machine the five centers on each end of the Crankshaft Blank, perhaps on a drill press. You would make all of the cuts on the lathe, working slowly because of the interrupted cuts as you machined each Throw.

You will have to grind at least one special tool bit and possibly make four sets of fixtures.



The tool bit is ground from 5% Cobalt High Speed Steel and will require a bit of care to make it accurately. The payoff will be when you cut the bearing journals, a job at which this tool excels. The trick part of this tool design is in the horn-like cutting tips which are spaced side-to-side by ½ the width of the smallest bearing journal width you will be cutting. On this example Crankshaft, the smalles is the Main Bearing journals which are ½" (12.7mm) wide.

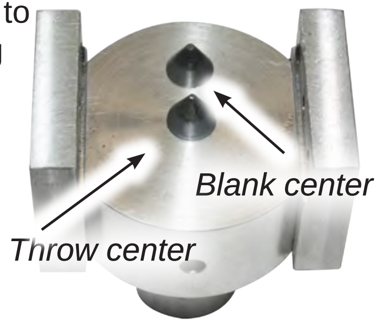
Cutting edge relief is 8° to 10° on the cutting edges which start at the inside tips and sweep around to the sides. The round geometry on the tip allows you to cut the straight journal surfaces from side-to-side, the inside corners where the journal meets the Cheek and the sides of the Cheeks. The final finishing of the cutting surfaces should be made with a diamond plate of around 600 grit so that it is very sharp. A drawing of this cutting tool is included in this issue.

Crankshaft Machining Support Fixture

1. A set of Crankshaft Machining Supports to rein-force the Crankshaft while turning the journals.

The Crankshaft Machining Support Fixtures are made from a single piece of 4130 tubing that is later split and then separated into two sections after the clamping screws are welded in place. The advantage of this tubing is that it is very strong, it comes with accurate inside and outside dimensions and no welded seam. 1-¾" (≈ 45mm) tubing with a 0.065" (≈ 1.65mm) wall thickness is available from Aircraft Spruce or any other aircraft materials supplier. The wall thickness of this tubing is convenient as it leaves the I.D. at 1.620" (≈41.3mm) which is the diameter of the Crankshaft Blank. A drawing of this fixture is included in this issue.

2. A Crankshaft Driver Fixture that is used to drive the Crankshaft Blank while turning the Connecting Rod Throws



Crankshaft Driver Fixture

The Crankshaft Driver provides a positive, non-slipping drive to the Crankshaft Blank in both the eccentric and concentric positioning in the mill and lathe. It consists of two Centers, one on the axial center and another positioned 1/2 stroke off-Axis. A pair of Clamp Plates complete the fixture and allow a pair of set screws to clamp onto the end of the Crankshaft Blank and prevent any free motion. In use, the fixture is mounted on a well-centered chuck on an Dividing Head or a collet in the lathe. A drawing of this fixture is included in this issue.

3. A Cross-Drilling Fixture.


Cross-Drilling Fixture

The Crankshaft must be drilled for Oil Galleries so oil can be supplied to the Rod Journals from the Main Journals. The easy way to do this is to make and use the fixture shown on the right to firmly hold the Crankshaft and protecting it from damage during the drilling operations. The fixture drawings are included in this issue. Once the fixture is made, you can clamp it in a suitable vise at the appropriate angle in the milling machine.

4. Possibly a Center Drilling Fixture.

The Center Drilling Fixture is shown on the right in the next column. It provides a stable and vertical position to the Crankshaft Blank when drilling the center holes in the ends of the blank.

Machining the Crankshaft

Face both ends of the Crankshaft Blank to finished length. Then, the next, and fairly critical operation is to accurately machine a center into the Z-Axis centerline and four more centers on each face that are on a circle diameter equal to the stroke of the engine and 90° from each other. The centers on the circle have to be as exactly opposite the matching center on the other end of the Blank as possible and ordered as shown for this Crankshaft. If you could see both ends of the Blank, you would see the centerholes as shown here.

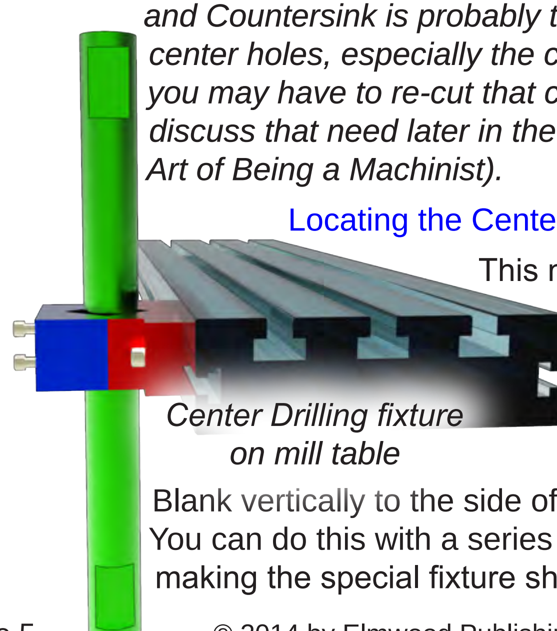
Both ends of the Crankshaft blank viewed with numbers on the center holes

There are several methods that we will discussed about how to accurately drill the centers.

You might ask how important it is to place the center holes in exactly the correct location. The answer is "somewhat important." Being off by a thousandth or so will not be detectable in the finished Crankshaft by any measurement tools we are likely to have available. The almost unnoticeable effect will the subtle timing changes on a per-cylinder basis. Still, being accurate is always better.

Note: Just to get this out of the way, use a # 2 Combined Drill and Countersink with a 60° angle and, assuming you have a new, not re-sharpened drill, you should drill into the metal until you have drilled 0.196" (4.98mm) deep. This will create a center that is 3/16" (4.76mm) in diameter at the face surface. The closest metric Combined Drill and Countersink is probably the 1.6 X 4. Do not create large center holes, especially the center on the Z-Axis because you may have to re-cut that center at a later date (we will discuss that need later in the article, (it all has to do with the Art of Being a Machinist).

Locating the Centers

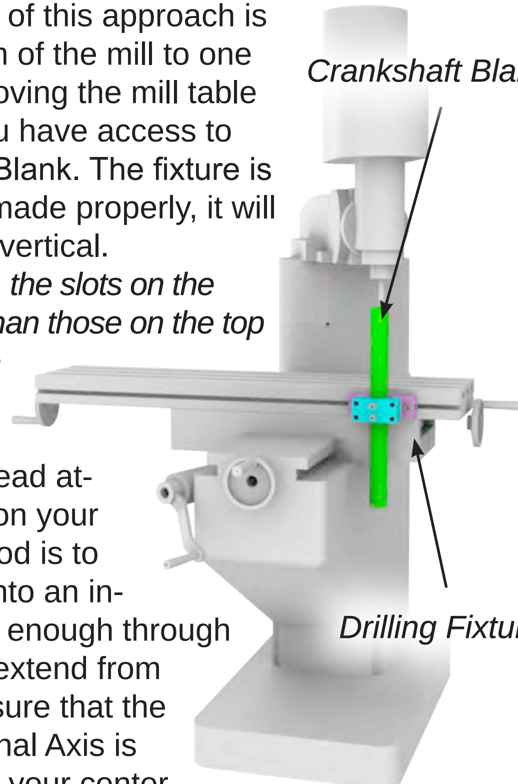

Center Drilling fixture on mill table

This might seem a difficult task but there are at multiple methods to solve the problem. We will talk about 3 methods but there are other ways too.

1. Clamp the Crankshaft Blank vertically to the side of your milling machine table. You can do this with a series of clamps in the T-slots or by making the special fixture shown here to hold the Crank-

shaft Blank. The downside of this approach is you have to swing the Ram of the mill to one side and extend it while moving the mill table forward or back so that you have access to the end of the Crankshaft Blank. The fixture is keyed into the table so, if made properly, it will hold the Crankshaft Blank vertical.

Note: On Bridgeport style mills, the slots on the sides of the table are smaller than those on the top of the table, so you will need to build or acquire a smaller than normal clamping arrangement.

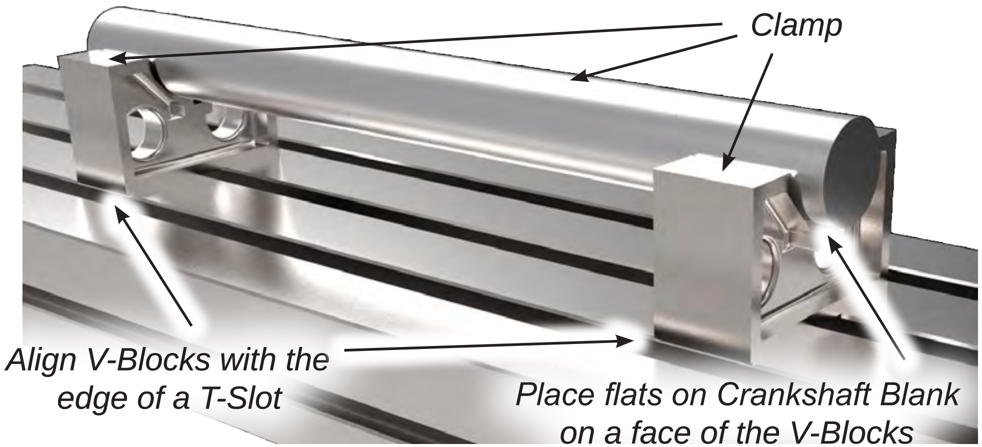


2. If you have a right-angle head attachment or a tilting head on your milling machine, one method is to put the Crankshaft Blank into an indexing head that has a big enough through bore to allow the Blank to extend from one side to another. Do insure that the Crankshaft Blank longitudinal Axis is lined up with the X-Axis so your centerholes will be in their correct locations. Locate the axial centerline using your normal method and drill the centerhole.
3. Or use a large set of V-Blocks to hold the Crankshaft Blank in

3 views of the Indexing Head with Crankshaft blank

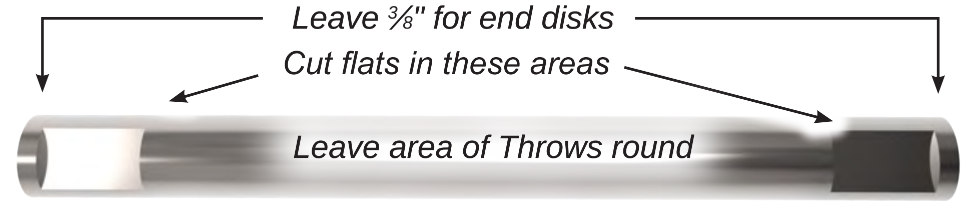
line with the X-Axis of the milling table. Then, with a right-angle attachment installed on your milling machine and properly aligned on the Y-Axis and centered on the Blank, you can drill the on-Axis center hole.

NOTE: To save time, clamp the V-Blocks, aligned with the edge of



a T-Slot, to the table separately from the Crankshaft Blank so when you flip the Crankshaft Blank over to drill the second set of holes, you don't have to axially realign the Blank. Also, by milling flats on the Blank, you can set them against the face of the V's in the Block so when flipping the Blank end-for-end to drill the second set of holes, a realignment of the Blank is not necessary.

Next, using any one of the workholding methods and knowing the



Milled flats for alignment of Crankshaft Blank held in V-Blocks while drilling centerholes

stroke of the engine, we can just move one-half the stroke distance on the Y-Axis from the centerline of the Blank and drill the second center hole and then a full stroke distance the other direction on the Y-Axis to drill the third center hole.

Note: If you are using the drilling fixture mounted to the edge of the mill table, substitute X-Axis movement for Z-Axis (Knee) movements.

Now move back to the center of the Blank and using the mill's Knee, move up and down the Z-Axis movement as you did the Y-Axis movement, completing the fourth and fifth center holes.

If you are using Method # 1, flip the entire assembly of Blank and fixture upside down and remount it to the mill table and realign. For methods 2 & 3, reverse the Indexing Head/Blank combination or the Blank in the V-Blocks on the table and repeat the movements to drill the five center holes on the opposite end of the Crankshaft Blank.

You can check vertical positioning by machining a set of flats about ¼" (≈ 6.35mm) deep on the ends of the Blank as shown to the left or using a dial indicator on the surface of the Blank. Machine the flats between where the Throws of the Crankshaft and the end disks will be located. See the illustration on the left and on the following page. Locate the center of the Blank using your normal method and drill the centerhole on the axial centerline of the Blank.

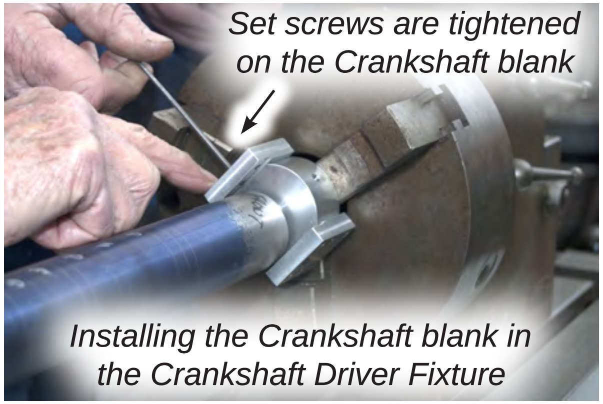
Roughing the Crankshaft on the Mill

With the Center holes drilled, next mount the Crankshaft Blank in the Dividing head using the Crankshaft Driver Fixture to engage the Blank by allowing the centers in the fixture to engage the appropriate centers in the Blank end.

The Crankshaft Driver Fixture is held in a chuck or collet in the tool, Indexer or Rotary Table you are going to use to turn the Blank when you mill out the Crankshaft Throws. Milling out the throws is is much faster than making a lot of interrupted cuts on the lathe. Cut the throws on a lathe if you do not have a mill. Make certain you are cutting each throw in its correct radial position. As shown in the illustration on the previous page, stamp the throw number beside each throw center hole make certain you put it in the mill and lathe correctly. It does not take much of a mistake here to make a scrap part out of an expensive piece of metal.

Use a Dividing Head or Rotary Table to rotate the Crankshaft Blank while milling the Throws. A suitable tailstock will be necessary to hold the other end of the Blank. Insure that the Blank will be both parallel to the mill table X-Axis and to the surface of the table when it is mounted in the tools.

Insert the Crankshaft Blank between the Crankshaft Driver Fixture and the Tailstock. Before you tighten the set screws in the Clamp Plates, try to wiggle the Blank in the driver fixture (rotate it around the centers). If it will wiggle, then the centers in the Crankshaft Driver Fixture are not fully engaged in the centerholes in the end of the Blank. Adjust the centers so that they both fit snugly into the centerholes in the Crankshaft Blank. Then tighten the setscrews in the Clamp Plates of the Crankshaft Driver Fixture. Once this is completed, you are ready to cut metal.


Set screws are tightened on the Crankshaft blank

Installing the Crankshaft blank in the Crankshaft Driver Fixture

Select a suitably sized roughing milling cutter (preferred as it keeps the cutting forces down a bit) which will leave enough stock (try for 0.0625" (≈ 1.6mm) on the Crankshaft Cheeks to allow finishing cuts to be performed in the lathe. With a Crankshaft Blank of this size, you can reasonably expect to cut about 0.050" (≈ 1.25mm) per cut with a roughing cutter.

Remember to measure every cut on the Crankshaft from the middle bearing.

At this point, if you have not done so already, coat the Blank with Dykem®. You will note in some of the pictures that scribe marks have been made in the Dykem and notes scratched in it to identify where parts of the Crankshaft are located. This can prevent an expensive and nasty mistake.

Rotate the Blank so that in its eccentric motion, the Blank is as


Ready to start milling

high as it can rotate up off the milling table. The next steps vary depending on whether you have a Knee on your mill or prefer to operate the Quill.

1. Lower the quill until the cutter just touches the Blank and then lock the quill. Zero the dial on the knee of your mill. Rotate the Blank about 90° clockwise as viewed from the tailstock.
2. Raise the Knee or lower the quill by 0.050" (≈1.25mm). Turn on the mill at an appropriate speed for the Crankshaft's steel and the milling cutter and start rotating the Blank into the cutter with the Dividing Head. Make a complete revolution then stop.
3. Repeat step 2 until you have just left the last bit of Dykem on the Blank at this Throw. This is called leaving a Witness Mark and insures that you have left enough stock to allow finishing in the lathe.

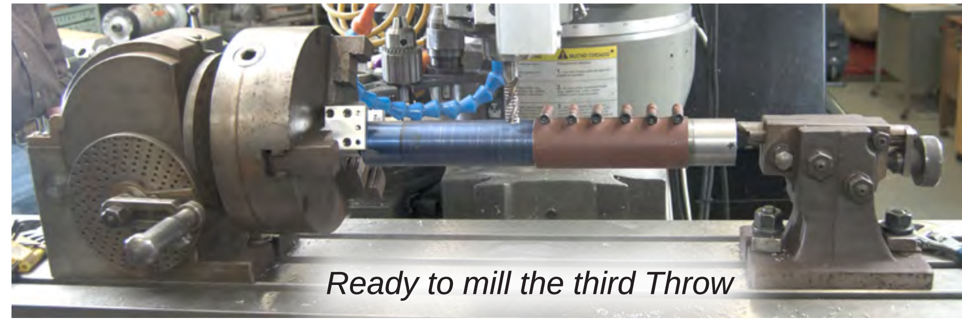
When the first throw is milled, remove the Crankshaft Blank from between the centers and install the smaller Crankshaft Machining Support Fixture over the milled Throw and clamp it firmly. Then install the Crankshaft Blank so that the second set of Throw centers are properly located between the Crankshaft Driver fixture and the indexer tailstock.

Witness mark

Repeat the appropriate set of Throw milling steps until a witness mark is just left on the second Throw of the Crankshaft Blank.

Ready to mill Throw number two

Then remove the Crankshaft Blank from between the centers and replace the smaller Tubular Support fixture with the larger Tubular Support fixture so that it covers both milled Throws. Reverse the Crankshaft Blank and support it on the third Throw centers between the Crankshaft Driver fixture and the tailstock.



Ready to mill the third Throw

Repeat the appropriate set of Throw milling steps until a witness mark is just left on the third Throw of the Crankshaft Blank.

Again remove the Crankshaft Blank from between the centers and add the smaller Tubular Support Fixture over the third Throw and support it on the fourth Throw centers between the Crankshaft Driver fixture and the tailstock.

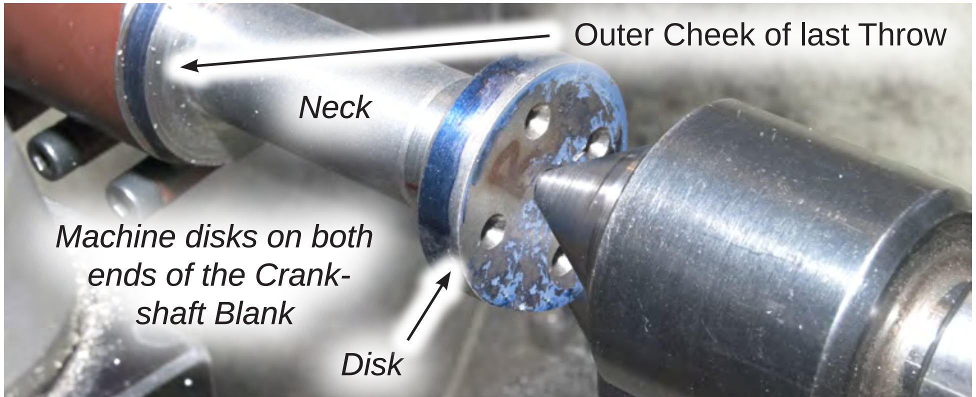
Repeat the appropriate set of Throw milling steps until a witness mark is just left on the fourth Throw of the Crankshaft Blank.

Mount the Crankshaft Blank on the axial centerholes and machine the Main Bearing Journals to their rough dimensions in the same manner as the Rod Journals.

Onto the lathe

The milling process is now complete and the Crankshaft Blank can be mounted in the lathe. Use the Crankshaft Driver Fixture, held in a collet or well-centered chuck, to hold the Crankshaft Blank between it and the lathe tailstock on the centerline of the lathe spindle.

Reduce sections of the Crankshaft Blank to make a Neck as shown on the next page to 1" (25.4mm) leaving a disk of approximately 0.5" (≈ 12.7mm) thick on each end and additional material on the outer Cheek of the outer Throws of 0.0625" (≈ 1.5mm). Your dimensions may be different depending on your engine design.



Machine disks on both ends of the Crank-shaft Blank

Journal cutting tool

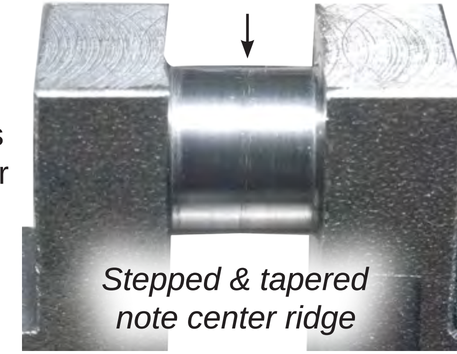
Cutting tool

The High Speed Cutting tool used in this project is ground to very specific dimensions with a narrow neck and because of this, it will flex side-to-side if you take too big a cut. This is an advantage because you will be machining large cross-sections of steel that are connected by relatively small diameter shafts, the Rod and Main Bearing Journals. A large cut with this tool would be around 0.01" (≈ 0.25mm).

Setting up the tool requires care. The tips of the tool must be absolutely square to the centerline of the lathe spindle to avoid creating a journal with two diameters. To square the tool, lightly clamp the tool in the toolholder and use your fingers to push the tool into contact with the Neck and rock it back and forth until the cutting tips make simultaneous contact with the Cheek.

Make 0.005" (≈ 0.13mm) deep trial cuts on the Neck, moving the cutting tool about 0.1" (≈ 2.5mm) side to side. Measure the diameter of the Neck in the cuts made by each side of the cutting tool. If they are not the same, adjust the toolholder until they do cut at the same depth. To not make this check could result in a Journal that looks like this to the left that is ≈ 0.002" (0.05mm) greater in diameter on the left side of the journal. You may need a Blade Micrometer to make this measurement. The problem on the left is the result of using a Micrometer with anvils that were too wide to properly measure the 0.312" (≈ 7.9mm) width journal. Don't ask me how I know about and have a picture of this. Please.

Planning the cuts



Stepped & tapered note center ridge

It is time to start machining each Throw and Main Bearing to its final dimensions in both diameter and width. Planning the process is always a good idea when there are a number of somewhat complex steps.

Note: The Crankshaft Machining Support Fixtures are used to support the Crankshaft Blank at all times.

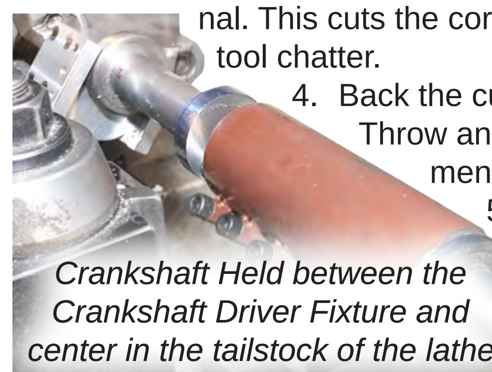
When using the *cutting tool*, the goals are to finish the Cheeks and the Journals to within 0.001" - 0.0015" (≈ 0.025mm - ≈ 0.04mm) and the corners where the Journal meets the Cheeks to whatever radius is desired which in this case is equal to the tip radius of the cutting tool, 0.0625" (≈ 1.6mm).

The sequence of cuts, as you get near the final dimension is important as is the use of cutting tool position. The proper use of handwheel dials or a DRO become important.

The machining steps for Throws and Main Bearings are as follows:

Note: A large cut with the special cutting tool is 0.01" (0.254mm)

1. Bring the Cheeks and Journals to within 0.002" (≈ 0.05mm) of final dimension.
2. Adjust the cutter position to remove the last 0.002" on one Cheek. Run the lathe under power to cut the Cheek until you are within 0.001" of the Journal's current dimension, then stop the lathe.
3. Now, turning the lathe by hand (do not grab the workpiece for this), move the tool down to the *finished* dimension of the Journal. This cuts the corner without causing any cutting tool chatter.

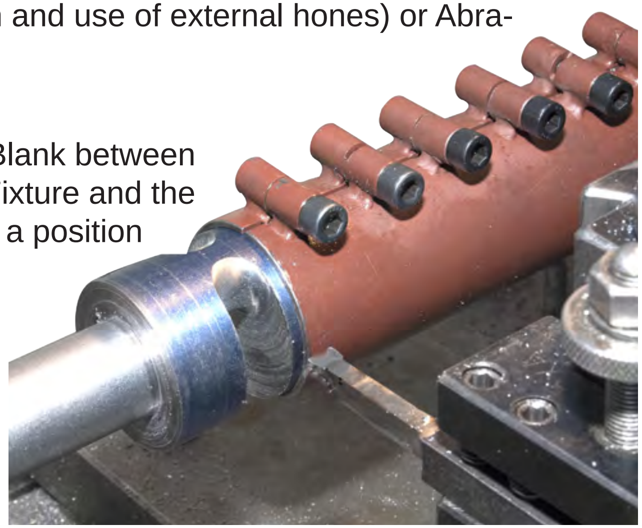


Crankshaft Held between the Crankshaft Driver Fixture and center in the tailstock of the lathe

4. Back the cutting tool diagonally out of the Throw and then cut the other Cheek to dimension in the same manner.
5. At this point, the Journal is ready for final finishing and that can be accomplished with a Toolpost Grinder, an External Hone (see *Model Engine Builder*

issue # 25 for design and use of external hones) or Abrasive Paper.

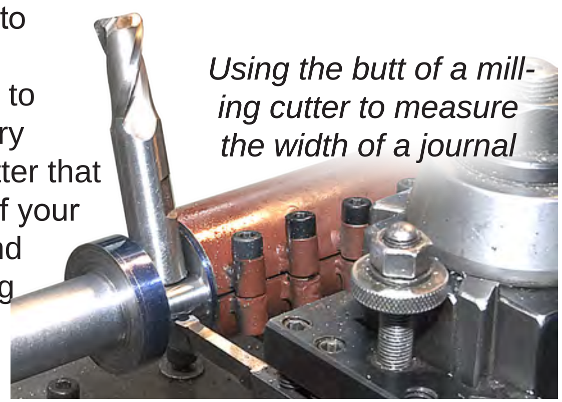
Cutting Throw Journals



Mount the Crankshaft Blank between the Crankshaft Driver Fixture and the lathe tailstock center in a position to machine the Journal of the first Throw. The longer Crankshaft Machining Support Fixture should be well-tightened and will protect the Crankshaft from bending during machining operations.

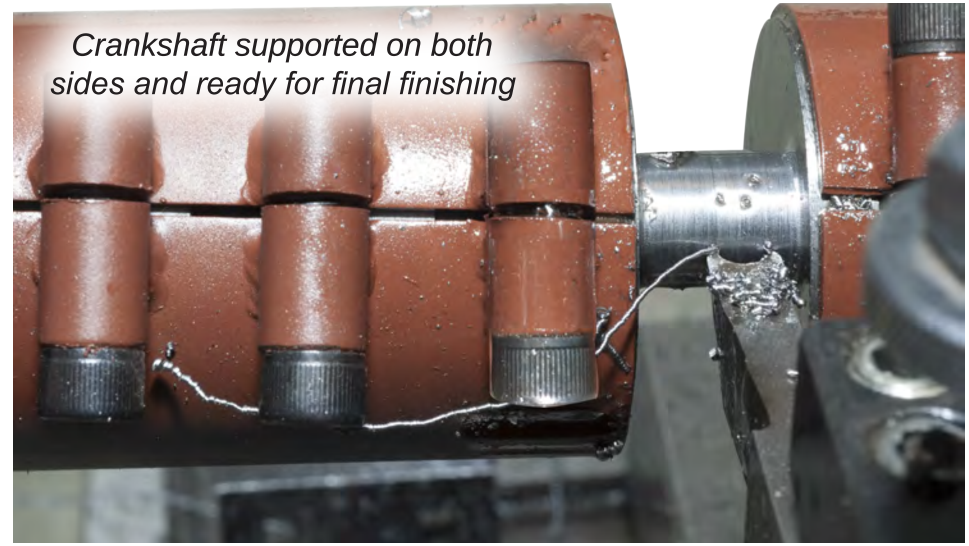
Having adjusted the cutting tool in the proper position, start the lathe at a reasonable speed for the unbalanced load and start cutting the first Throw, following the previously mentioned procedures. At this stage, given the slow cutting speeds and small cuts, lubricant is not really needed although a small amount will keep the cutting tool sharper for a longer period of time. Use a good cutting oil for the last 0.02" (0.5mm) of the Journal to obtain a better surface finish.

Instead of using an Caliper to measure the Journal width, try using the butt of a milling cutter that matches the finished width of your Journal. This is very quick and accurate (measure the milling cutter before using it). The cutter should be a firm push fit between the Cheeks.



Using the butt of a milling cutter to measure the width of a journal

Each time a Journal is machined to near-finished diameter, finish the Journal using whatever methods you wish. As you completely finish each section, insure all except the Journal you will work on next is supported by a tightly clamped Crankshaft Machining Support Fixture.



Crankshaft supported on both sides and ready for final finishing

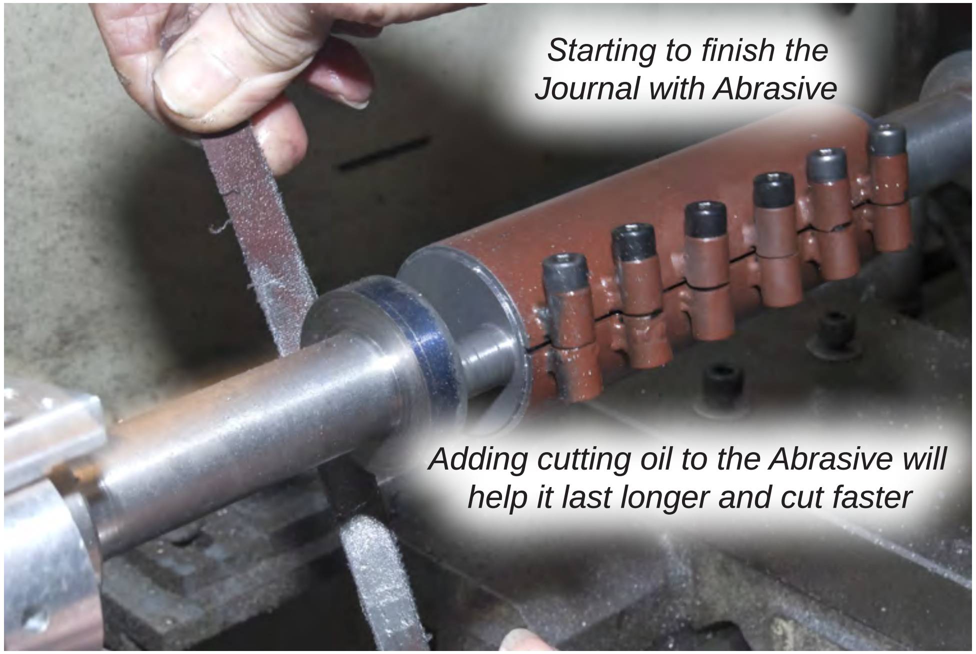
Final finishing a Journal

For this article, we used Abrasive Paper to bring the Journals to final dimension and finish. Crankshafts finished in this fashion have been functioning in supercharged ⅓-scale V-8's for more than 10 years and are still running well.

The first step is to insure that the Journal is of a single diameter across its width. You want no more than 0.0002" (0.0051mm) deviation across the Journal before you start to finish the Journal and less would be better.

Depending on the roughness of the Journal at this stage, start with 1" wide number 240 or 320 abrasive roll, tearing it lengthwise into an appropriate width. In the picture on the top of the next page, the starting grade of the abrasive was 220.

The width decision for the abrasive should be controlled by the state of the rough Journal. If its diameter is completely uniform, then tear it into a width equal to slightly less of the Journal width. If the Journal has a slight diameter difference between the left and right sides of the Journal, then a strip equal to ½ the Journal width can be applied on the greater diameter to bring it to the same diameter as the other half. Then proceed with a wider strip of abrasive roll to complete the smoothing of the Journal with that abrasive grit.



The length of the strip should be approximately double the distance from the Journal to a comfortable distance to hold your hands while you grasp each end of the abrasive roll. Keep your hands clear of the eccentrically rotating Crankshaft and support clamps.

Note: 3M describes the fabric-backed abrasive roll as "3M Utility Cloth Roll." They also have a more expensive version of this abrasive with a guarantee that there are no over-sized abrasive particles in the product. We've never had problems with the 3M Utility Cloth Roll in this regard.

Abrasives (nearly) Equivalent Table

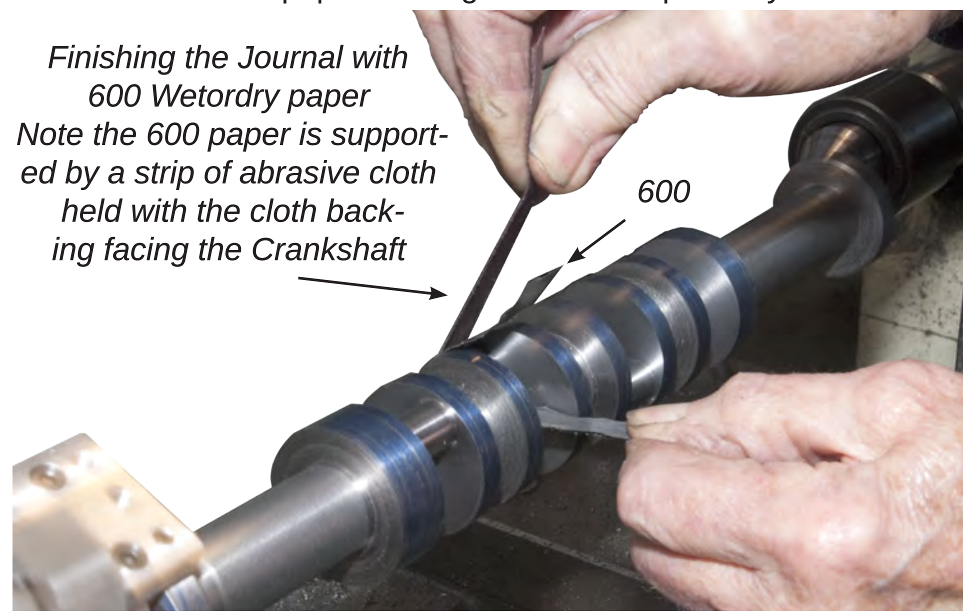
Micron size	*JIS*	*ANSI*	*FEPA (P)*
72	*220*	*220*	*P220*
38	*360*	*320*	*P360*
16	*1000*	*600*	*P1200*
12	*1500*	*1000*	*P1500*

In practice, cutting oil is used to lubricate the abrasive and help it to cut faster. Hold an opposing end of the abrasive fabric in each hand and exert a pull on the fabric to cause the abrasive to wear the Journal surface. Alternately pull on one end of the fabric, allowing your other hand to be forced towards the Crankshaft. Reverse the pull and continue until you observe a change in appearance of the Journal. By the time you have applied this strip to the Journal and there are no further changes in the Journal's surface; the surface should be uniform with no deep scratches.

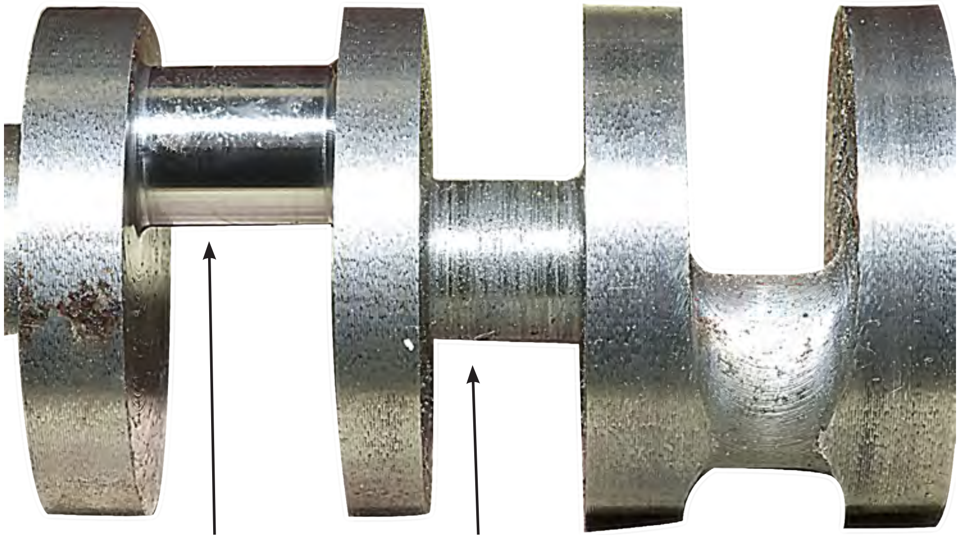
When there is no more change in appearance and the surface is uniform, clean the Journal and measure its diameter in several places. The 220 abrasive has probably removed 0.00075" to 0.001" (≈ 0.02mm - 0.0254mm) of metal.

Switch to the 320 grit abrasive, oil a nearly full-width strip and apply it to the Journal as before. When you can no longer see a change in the surface appearance of the Journal, you can switch to a strip of 600 grit 3M Wetordry Polishing Paper or its equivalent.

This abrasive has a paper backing and it would probably tear before



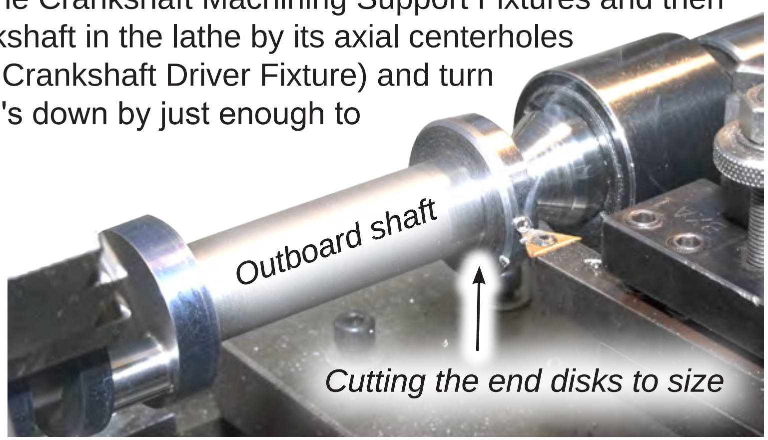
you exerted enough pressure on it to polish the Journal. Cut a strip from the Wetordry paper slightly wider than the 320 abrasive you just used. Then, oiling the Wetordry abrasive with cutting oil and hold it to the surface of the Journal with the *back* of the 320 abrasive strip and polish the Journal's surface until you can slide your fingernail across the surface in the axial direction and feel no more roughness than you would on a piece of polished steel.



One finished Rod Journal, one roughed Main Journal and a milled Rod Journal. Visible distortions are caused by the camera and lighting. Note the excellent finish on the left Journal (the white dots on top are contamination, not defects. Look at the underside of the Journal)

Cutting and finishing the Main Bearings

First remove the Crankshaft Machining Support Fixtures and then hold the Crankshaft in the lathe by its axial centerholes (still using the Crankshaft Driver Fixture) and turn the Cheek OD's down by just enough to smooth and true them. A cut of no more than 0.003"-0.005" (≈ 0.08mm - 0.13mm*)* should work.



Cutting the end disks to size

Next Hold the Crankshaft by the Cheeks in an Adjust-Tru style or 4-jaw chuck so they run true and hold the outboard shaft in a tailstock center. Then turn the end disks down to the diameter of the Neck and then reduce the diameter of the outboard shafts to about 0.0625 (≈ 1.6mm) oversize, insuring that they will exactly fit into a standard C5 collet.

Cut and finish the Main Bearing Journals to specification in the same manner as you did the Rod Throw Journals.

Reducing the Crankshaft Outboard Shafts to size

Finishing the Crankshaft's outboard shafts

Hold the Crankshaft by the Cheeks in an Adjust-tru style chuck so they run true and check the runout of both outboard shafts.

Note: Reducing the diameter of the shafts may relax residual stress in the relatively thin and long shafts and they may bend out of true. This happened to this Crankshaft even though it was made of 'Stressproof Steel,' not the usual 4340 alloy.

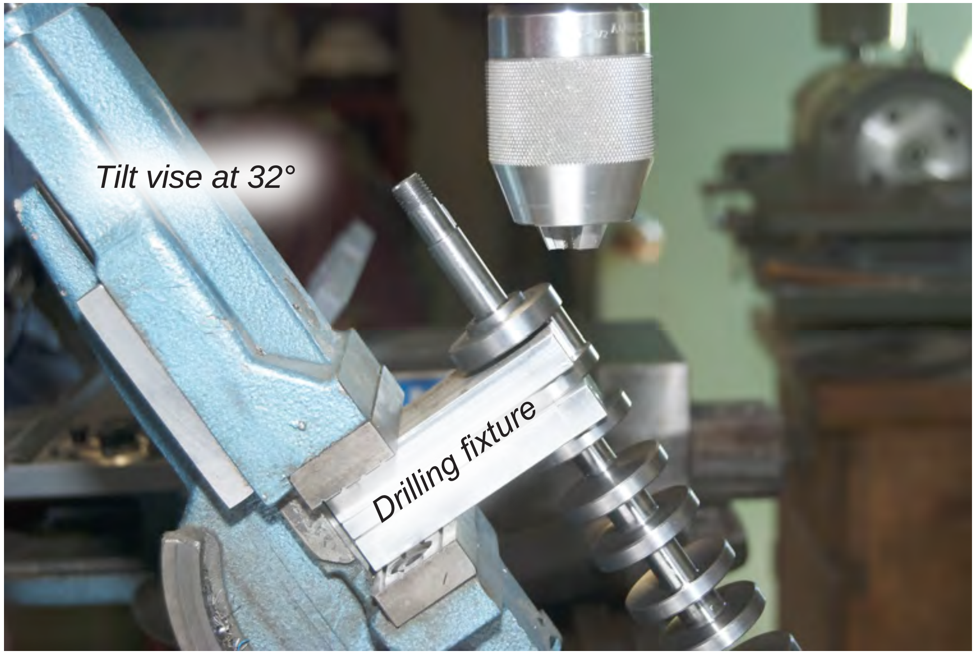
If the Outboard Shaft runout is less than 0.001" - 0.002" (≈ 0.025mm - 0.05mm) the shaft is OK. If the runout is more, then the best 'fix' is to recut the axial centerholes with a lathe tool. Use a thin, sharp blade and take very small cuts until you have cut the 60° center hole completely true.

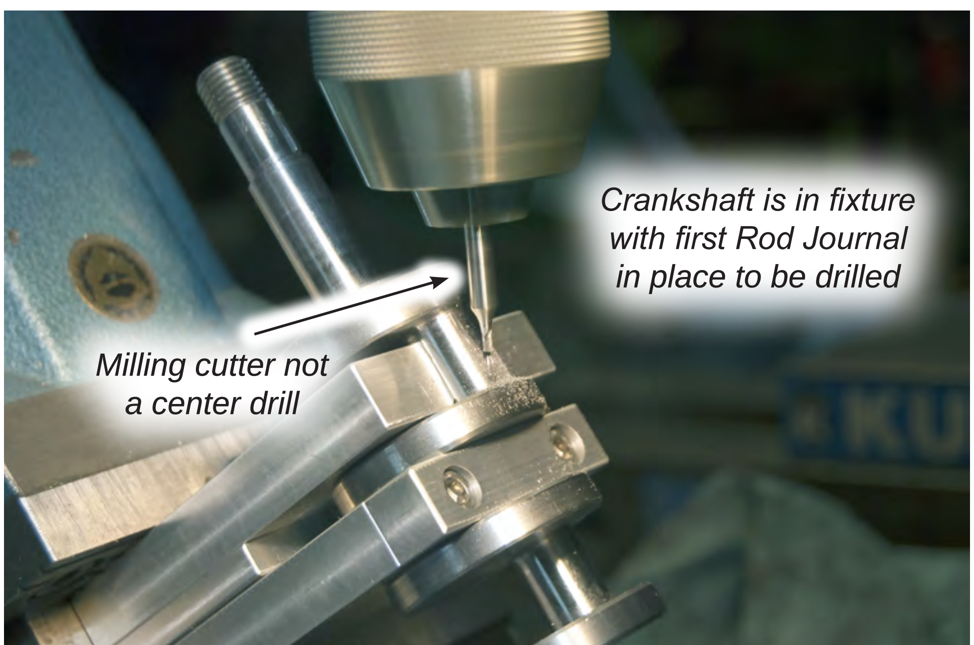
At this stage, the shafts centerholes are true enough and you should place the Crankshaft in the properly sized C5 collet and a tailstock center. Now reduce the shafts to their finish dimensions, cut threads, finish ends and insure that (on this Crankshaft) the areas that fit in the ball-bearings are of proper dimension.

Finished except for cross-drilled oil feed holes

Cross-drilling the Crankshaft for oil galleries

Note: A 32° angle is correct for the dimensions of this Crankshaft, your Crankshaft may require a different angle.





Once the Ctrankshaft's axial centerline is aligned with the mill's spindle, you can lock the X-Axis of the mill table. The next movement will be to align the mill's Z-Axis with the entry point on the first Rod Journal. Lock the Y-Axis when this is done because the only motion, until we have completed the angle drilling, will be with the mill's knee and spindle. Mount a 1⁄16" (≈ 1.6mm) end mill in the drill chuck and spot mill the entry point for the 1⁄16" twist drill. Insure that the milling cutter penetrates the journal and creates a small cylindrical pocket that will capture the drill bit and prevent tip wander.

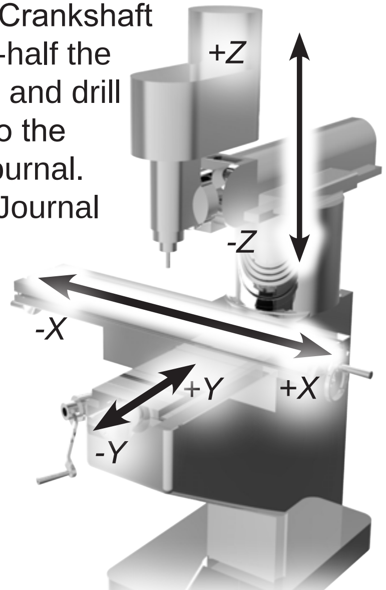
Switch to a new and sharp (inspect it for proper sharpening and symmetry before you use it) M35 or M42 Cobalt drill bit of sufficient length to drill through the adjacent Main Journal. A 'Jobbers' drill should be of sufficient length (1-7⁄8") to drill the approximately 1-1⁄4" distance to breakthrough. Be sensitive to the feel in the mill quill to the breakthrough and be careful not to touch the Rod Journal with the jaws of the drill chuck. Frequently withdraw the drill to clear chips and avoid breaking the drill in the hole. After breaking through to the adjacent Main Journal, retract the drill and remove it from the drill chuck.

Move the Crankshaft up and rotate it so the next Rod Journal is under the Z-Axis and repeat the spotting and drilling from the Rod Journal through the center Main Bearing Journal. Once you have finished this hole, reverse the Crankshaft in the fixture and drill the other two diagonal holes from the remaining Rod Journals. You should now have four diagonal 1⁄16" holes leading to the Rod Journals from the Main Journals. One from the front Journal and one from the rear Journal and two from the center Journal. *Note: These are actually the second, third and fourth Main Journals as the front and rear main Journals are outside the Crankcase and are ball bearings.*

Now mount the Crankshaft and fixture on

Centering the crankshaft

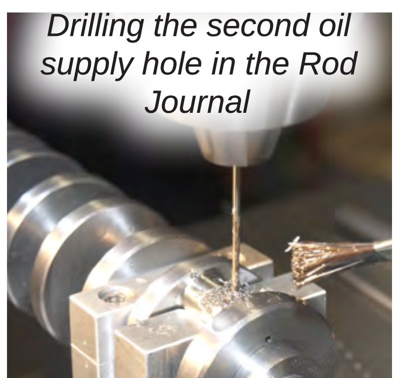
the milling table as shown in the last picture previous page. Once it is mounted, the fixture aligned and the Crankshaft centered, you move the milling table one-half the stroke in the + Y direction. Then spot drill and drill with a 1/16" drill until you break through into the diagonal gallery coming from the Main Journal. This makes an oil gallery in the end Rod Journal from the outside of the Cheek. Move the mill table in the + X direction by one-half the stroke and then one-half the stroke



Axis designations

Finishing the second Rod Journal

in the - X direction. Then spot drill and drill with a 1/16" drill until you break through into the diagonal gallery coming from the Main Journal on the second Rod Journal. You will probably need to make a drill extension and use a longer-than-normal drill in order to drill into the second Rod Journal. The drill extension is a piece of 3/8" (≈ 9.5mm) aluminum with a 1/16" on-Axis hole and two set screws at 90° to each other to hold the drill in the drill extension.


Drilling the second oil supply hole in the Rod Journal

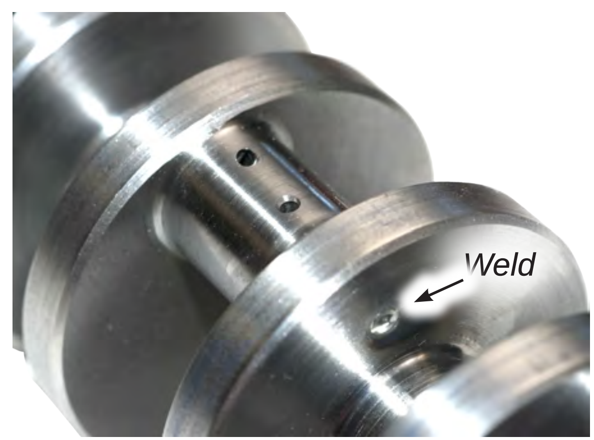
After drilling the first two holes, reverse the Crankshaft in the fixture and drill the second set of holes into the remaining Rod Throws.

Using a center drill and a 1/16" drill, drill the second oil supply hole into the oil galley on each Rod Journal.

Smooth the lips of all holes on the Journals with a small abrasive stone held in a rotary tool. Use caution to avoid damaging the Journal surfaces.

Weld the four holes in the outer surfaces of the Rod Journal Cheeks. We had a professional welder, Tim Mogul, use a TIG with 4130 filler wire to plug the holes. A MIG with 0.035" (≈ .9mm) wire should be able to do the job as well. Except for threading and cutting keyways, the Crankshaft is finished.

Notes: There is an alternate drilling option and that is to drill angled holes from the two inner Rod Journals to both adjacent Main Journals. In doing so, you could avoid drilling the long hole into the second Rod Journals and the welding of those holes. Either way, the Crankshaft will work OK.



Notes:

1. If you would like more of a shriek from your V-8, use a flat Crankshaft, not a multi-plane Crankshaft. IndyCars and NASCAR engines are V-8's but the IndyCar engines shriek and the NASCAR engines bellow. Flat Crankshaft machining is covered in Model Engine Builder magazine Issue # 6, Page 9.

2. Please understand that all of the dimensions shown in the drawings apply to this particular instance of a Crankshaft for a Black Widow V-8. This engine, being built by John Gilmore, is build like a billet-block drag racing engine. It was cut from a solid block of aluminum and has no coolant passages, etc. It may eventually find its way into a scale model race car.

Thanks to Dwight Giles, John Gilmore and Ken Hurst for their help in writing this article.

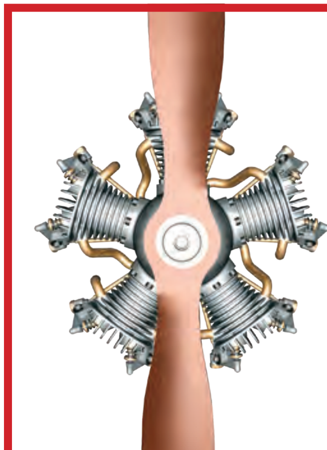
Drawings start on page 54

A 3D PDF of all tools is available

Finished Crankshaft

THE END

Advertiser Index



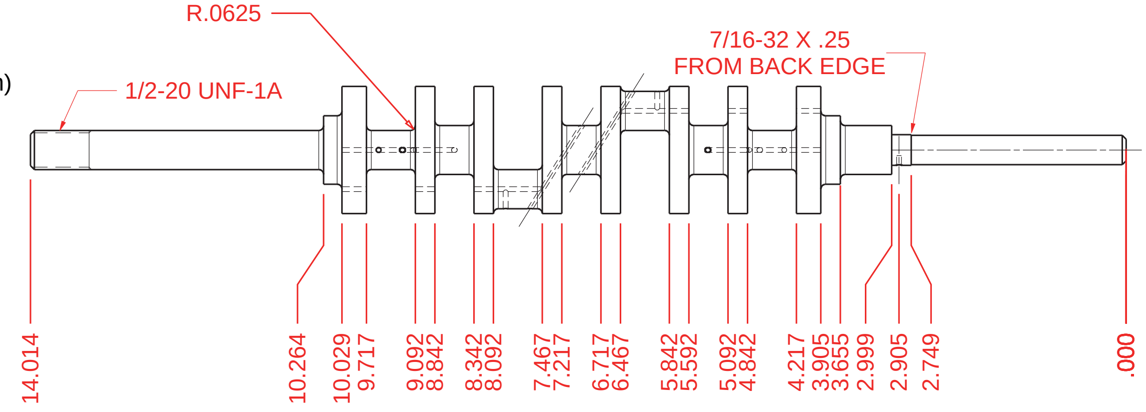
Want to build your own radial engine?

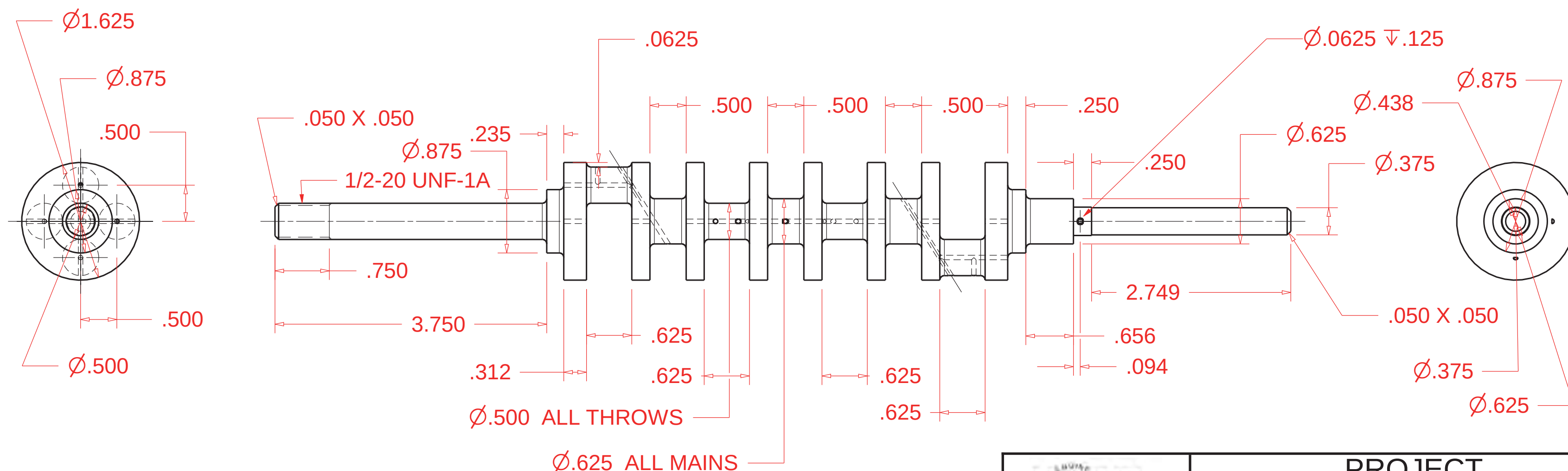
Take a look at the Morton M5 or M1 featured in Model Engine Builder magazine, issues # 2 & 3

Click here to read the Table of Contents:
Issue #2, Issue #3

BLACK WIDOW CRANKSHAFT
4340 STEEL, 1 REQ'D
1/2 X SCALE

NOTES:
ALL INTERNAL OIL
BORES ARE 1/16" (1.6m)



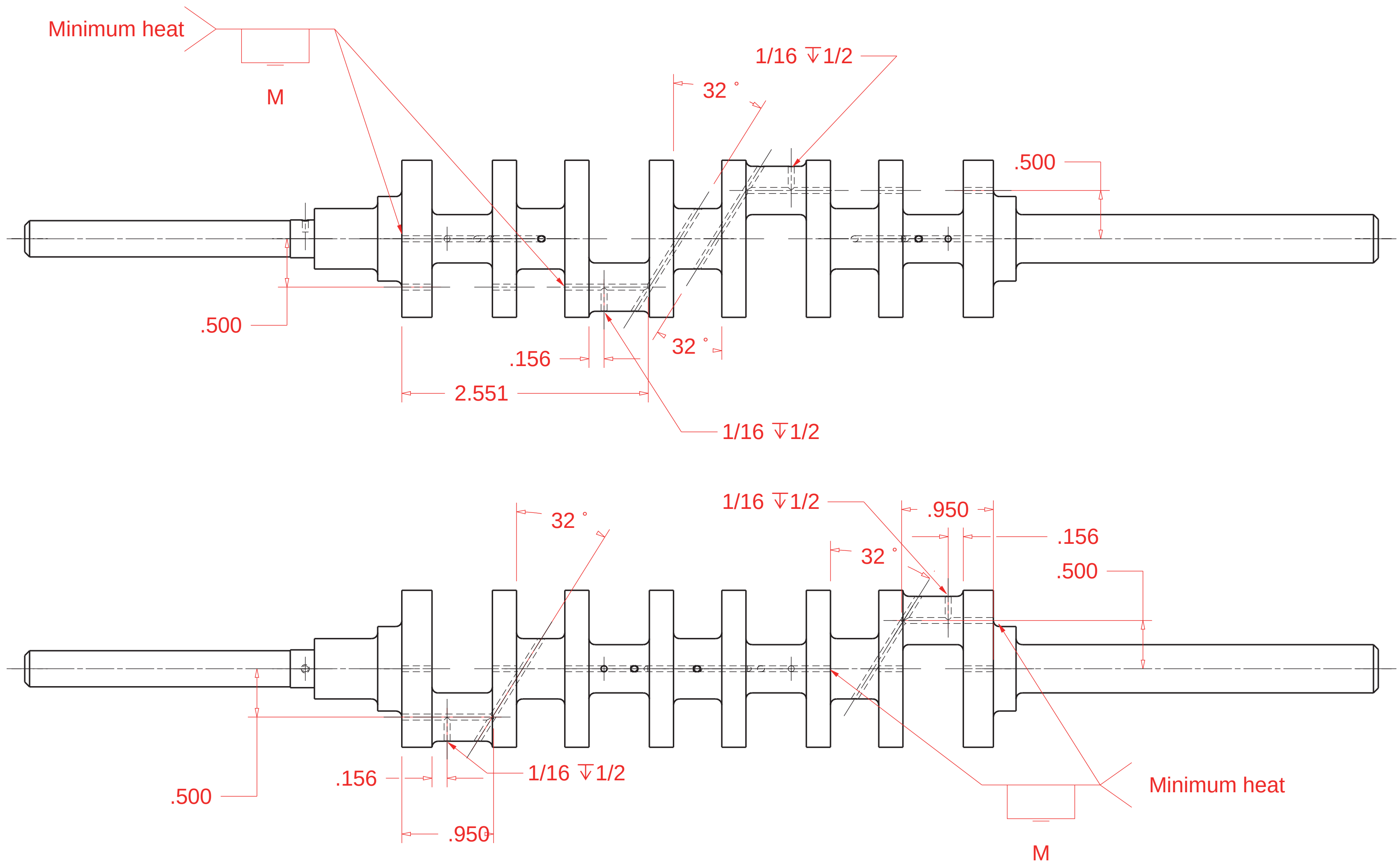


DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED

MODEL ENGINE BUILDER	PROJECT BLACK WIDOW V-8 CRANKSHAFT	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Ken Hurst
EDITED BY MIKE REHMUS	Project drawing # 1 of 9	3RD ANGLE PROJ.



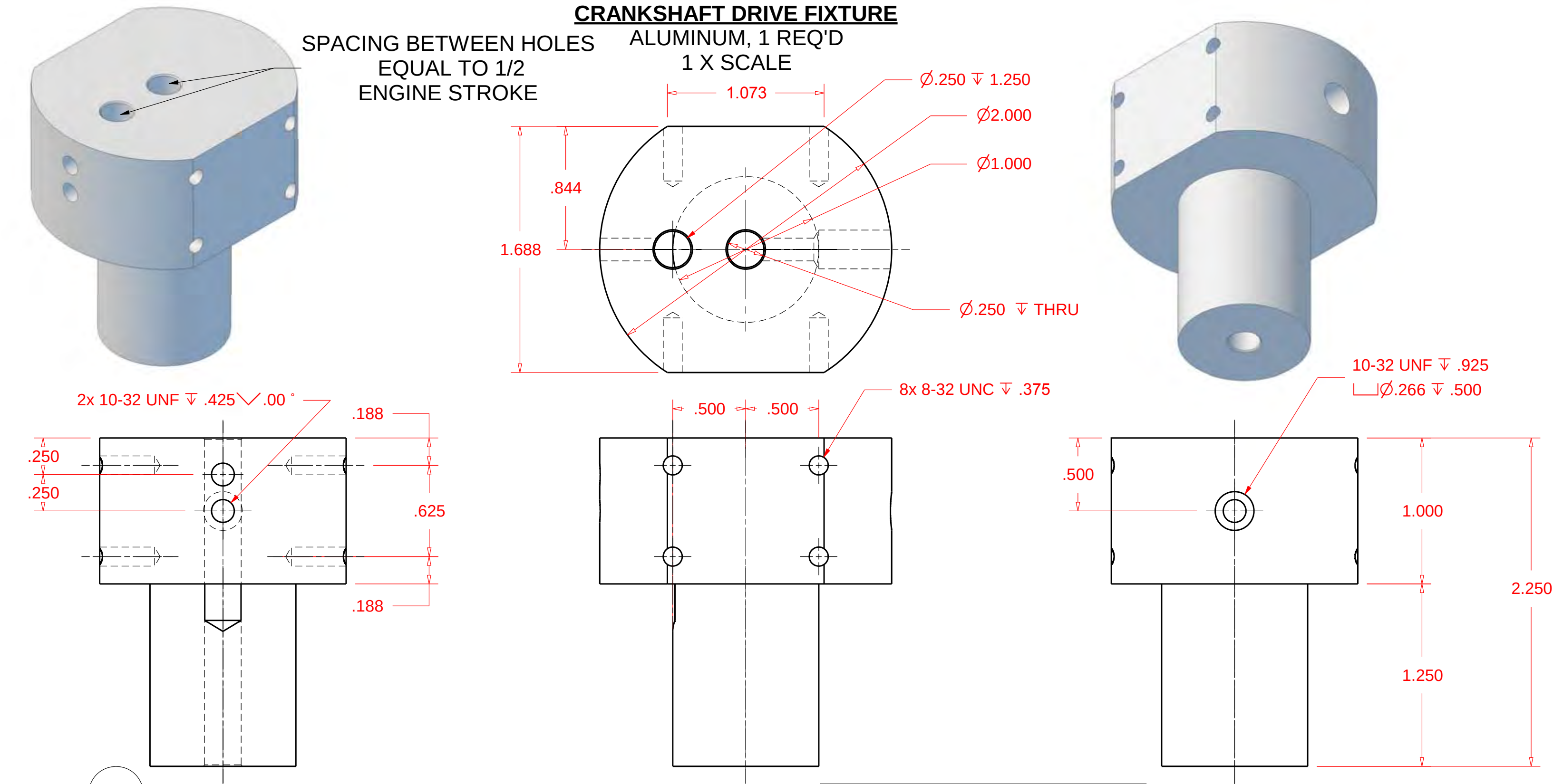
DRILLING ORDER
1-DRILL ANGLED HOLES
2-DRILL LONGITUDINAL HOLES
3-DRILL HOLES FROM JOURNAL SURFACE TO OIL GALLERY
IN ALL CASES STOP WHEN THE DRILL BREAKS THROUGH

BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED

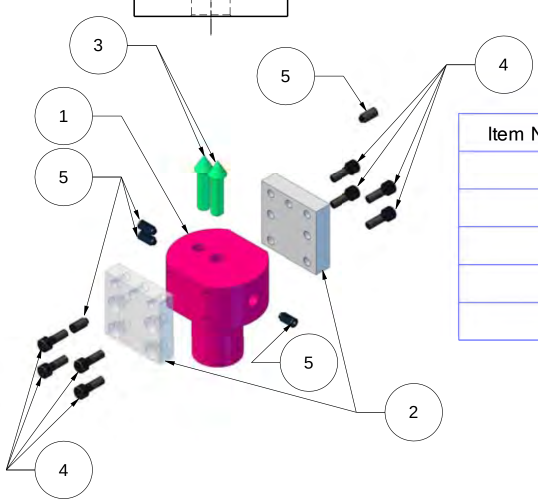
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

MODEL ENGINE BUILDER	PROJECT BLACK WIDOW V-8 CRANKSHAFT	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Ken Hurst
EDITED BY MIKE REHMUS	Project drawing # 2 of 9	3RD ANGLE PROJ.



CRANKSHAFT DRIVE FIXTURE
MODIFY DIMENSIONS TO SUIT



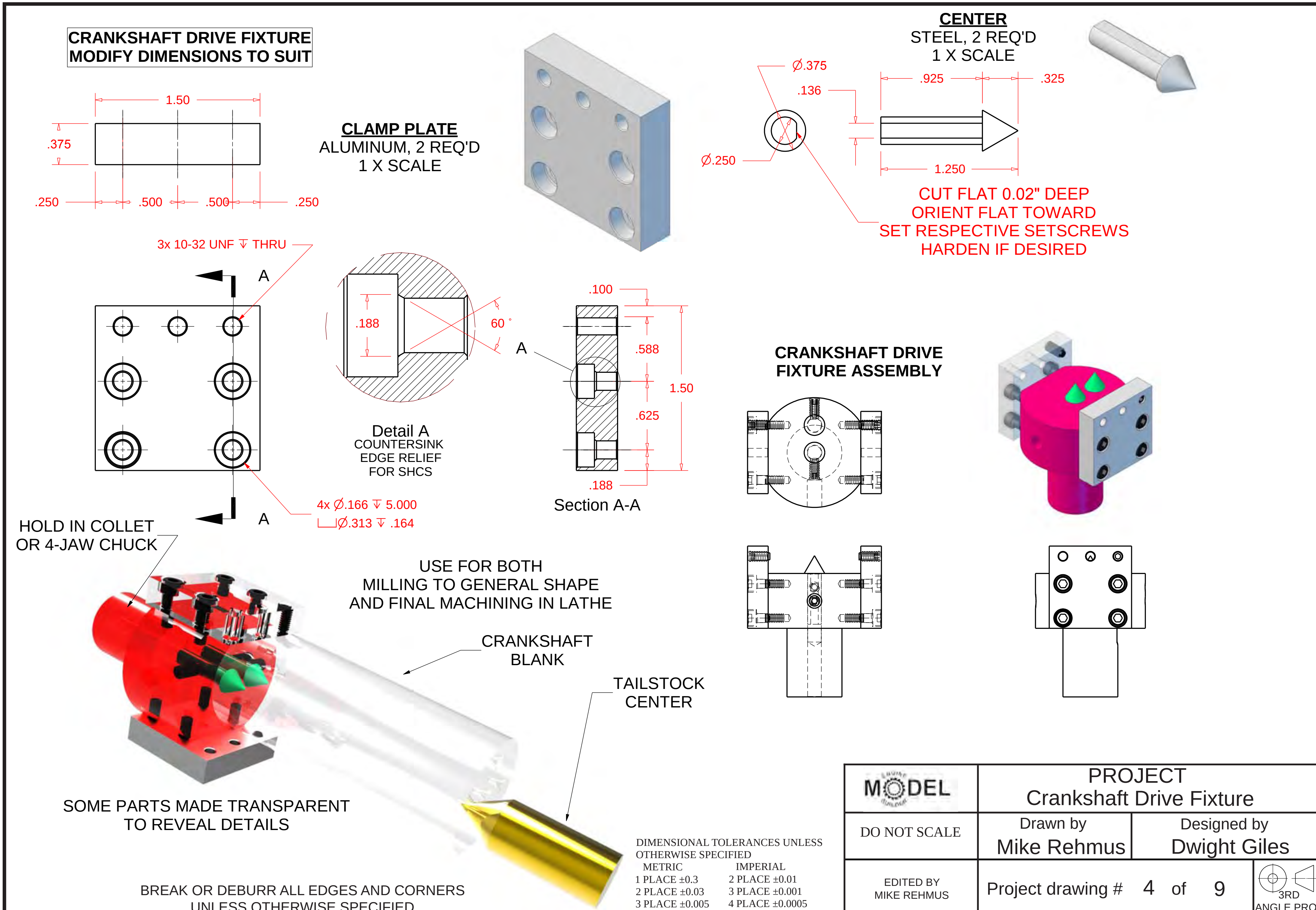
Item Number	Quantity	Part Name	Material	Stock Size
1	1	CRANKSHAFT DRIVE FIXTURE	2024 ALUMINUM	2 RND. X 2.25
2	2	CLAMP PLATE	2024 ALUMINUM	3/8 X 1.5 X 1.5
3	2	CENTER	CARBON STEEL	3/8 RND. X 1.25
4	8	SOCKET HEAD CAP SCREWS	STEEL	8-32 X 3/8
5	5	SET SCREWS	STEEL	10-32 X 3/8

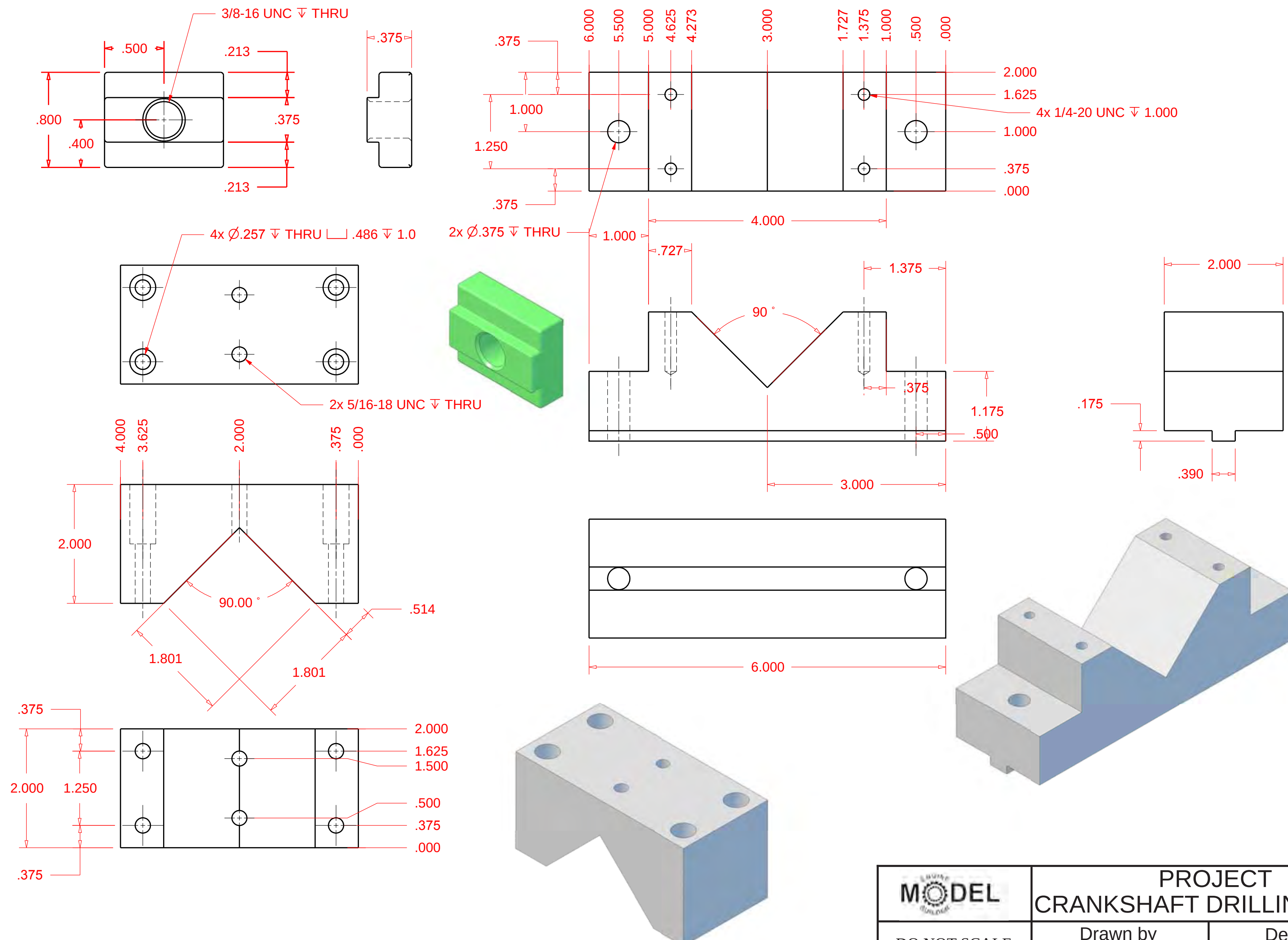
BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

MODEL ENGINE BUILDER	PROJECT Crankshaft drive fixture	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Dwight Giles
EDITED BY MIKE REHMUS	Project drawing # 3 of 9	3RD ANGLE PROJ.


CRANKSHAFT DRIVE FIXTURE
MODIFY DIMENSIONS TO SUIT
1.50
.375
.250
.500
.500
.250
CLAMP PLATE
ALUMINUM, 2 REQ'D
1 X SCALE
CENTER
STEEL, 2 REQ'D
1 X SCALE
Ø.375
.136
Ø.250
.925
.325
1.250
CUT FLAT 0.02" DEEP
ORIENT FLAT TOWARD
SET RESPECTIVE SETSCREWS
HARDEN IF DESIRED
3x 10-32 UNF ↧ THRU
A
.188
60 °
A
Detail A
COUNTERSINK
EDGE RELIEF
FOR SHCS
.100
.588
1.50
.625
.188
Section A-A
CRANKSHAFT DRIVE
FIXTURE ASSEMBLY
4x Ø.166 ↧ 5.000
⌴Ø.313 ↧ .164
A
HOLD IN COLLET
OR 4-JAW CHUCK
USE FOR BOTH
MILLING TO GENERAL SHAPE
AND FINAL MACHINING IN LATHE
CRANKSHAFT
BLANK
TAILSTOCK
CENTER
SOME PARTS MADE TRANSPARENT
TO REVEAL DETAILS
BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED
DIMENSIONAL TOLERANCES UNLESS
OTHERWISE SPECIFIED
METRIC
1 PLACE ±0.3
2 PLACE ±0.03
3 PLACE ±0.005
IMPERIAL
2 PLACE ±0.01
3 PLACE ±0.001
4 PLACE ±0.0005
MODEL
DO NOT SCALE
EDITED BY
MIKE REHMUS
PROJECT
Crankshaft Drive Fixture
Drawn by
Mike Rehmus
Designed by
Dwight Giles
Project drawing # 4 of 9
3RD
ANGLE PROJ.

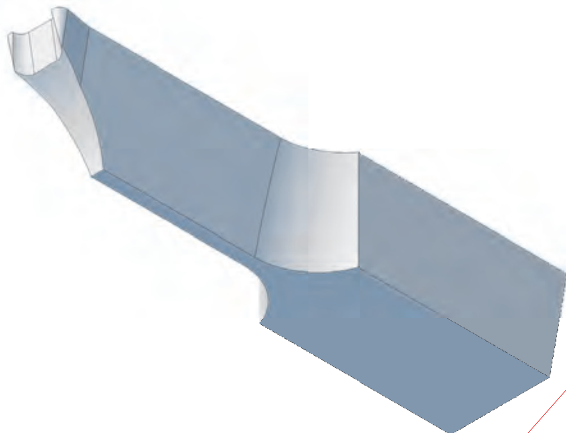


BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

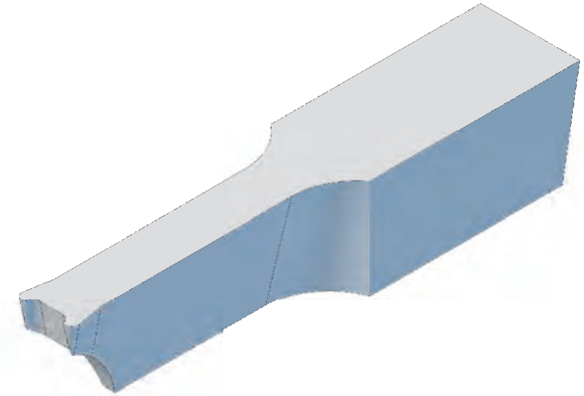
MODEL	PROJECT CRANKSHAFT DRILLING FIXTURE	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Mike Rehmus
EDITED BY MIKE REHMUS	Project drawing # 5 of 9	3RD ANGLE PROJ.

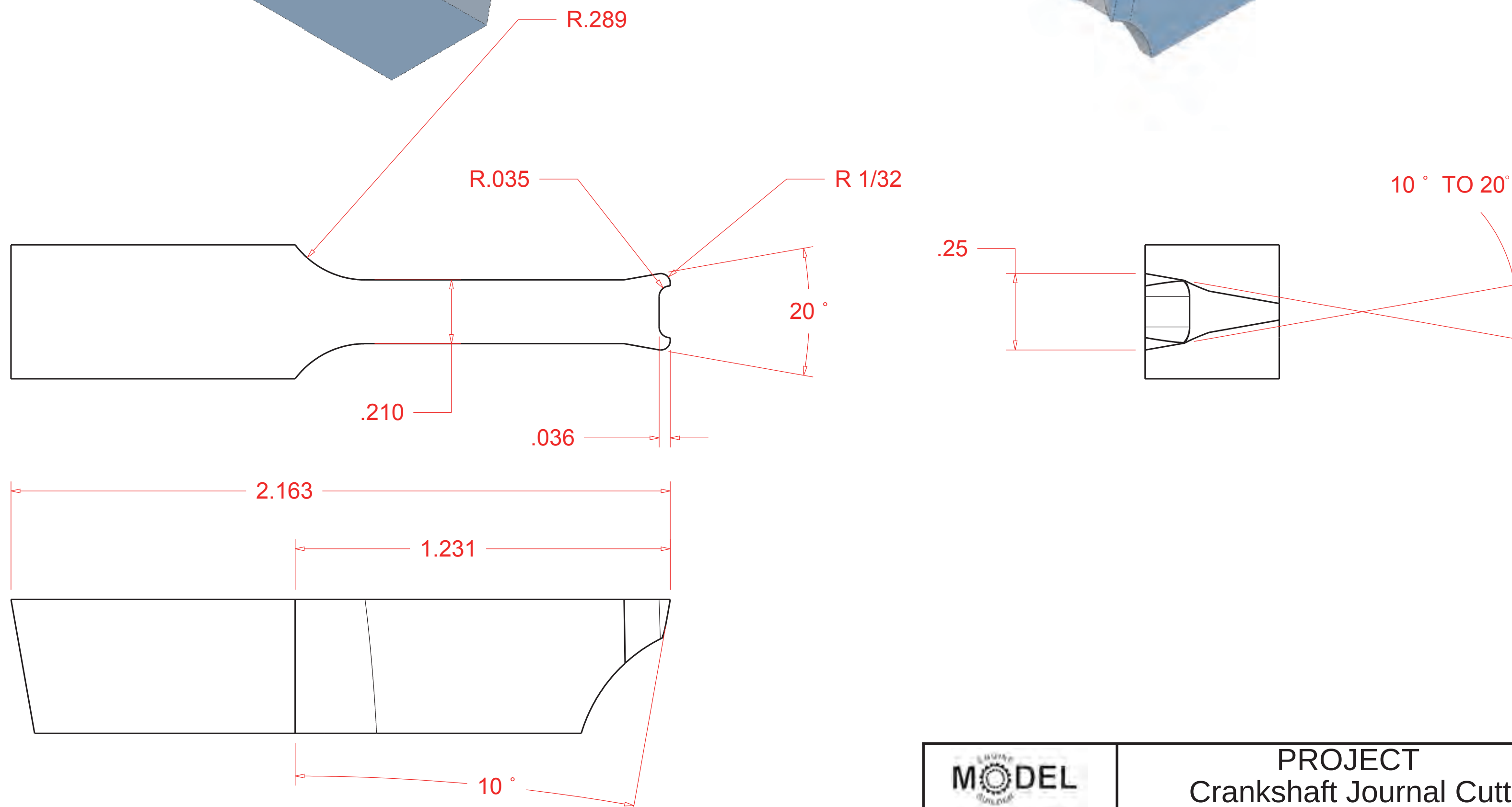


CRANKSHAFT JOURNAL CUTTING TOOL

5% COBALT HSS, 1 REQ'D

2 X SCALE





BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED

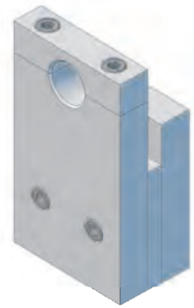
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

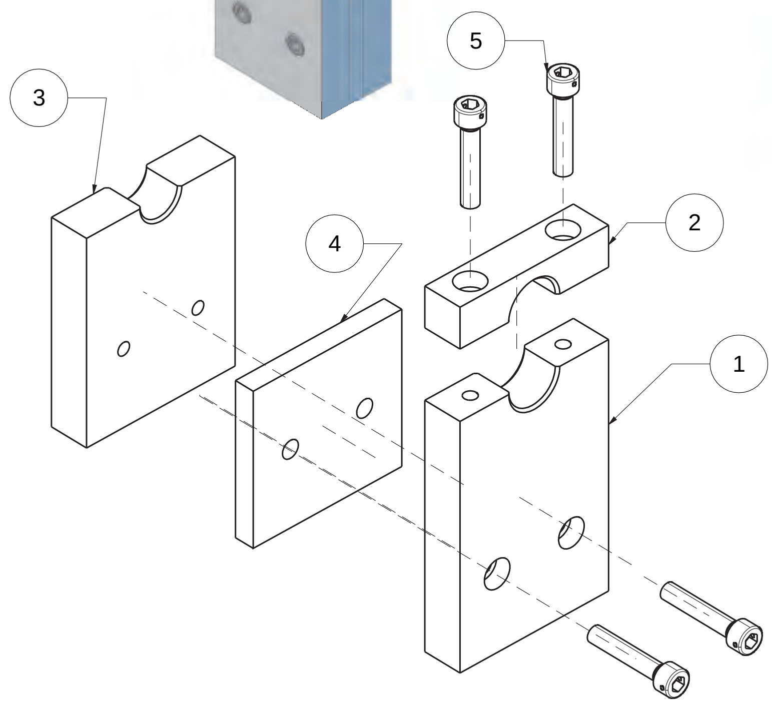
METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

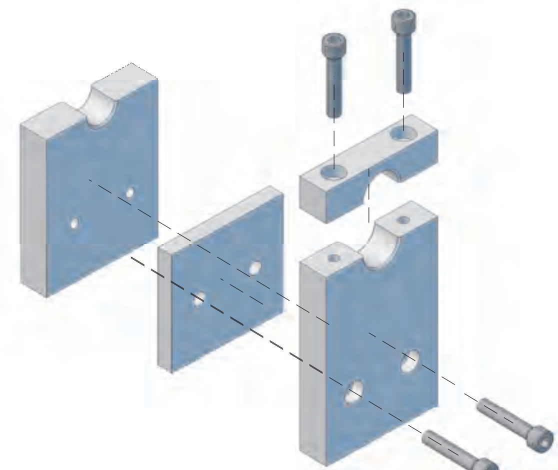
MODEL	PROJECT Crankshaft Journal Cutter	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Dwight Giles
EDITED BY MIKE REHMUS	Project drawing # 6 of 9	3RD ANGLE PROJ.

CRANKSHAFT OIL DRILLING FIXTURE

1 REQ'D
1-1/2 X SCALE







Item Number	Quantity	Part Name	Material	Stock Size
1	1	CRANKSHAFT OIL HOLE DRILLING FIXTURE CLAMP BASE	ALUMINUM	0.5" X 2" X 3"
2	1	CRANKSHAFT OIL HOLE DRILLING FIXTURE CLAMP CAP	ALUMINUM	3 X 2 X .5"
3	1	CRANKSHAFT OIL HOLE DRILLING FIXTURE THROW CRADLE	ALUMINUM	0.5" X 2" X 2.5"
4	1	CRANKSHAFT OIL HOLE DRILLING FIXTURE SPACER	ALUMINUM	0.5" X 2" X 2"
5	4	10-32 X 1 INCH SHCS	STEEL	10-32 X 1"

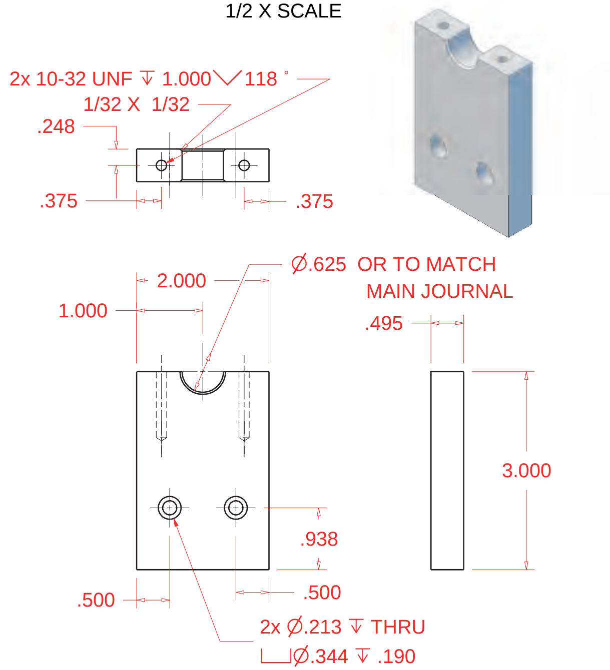
BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

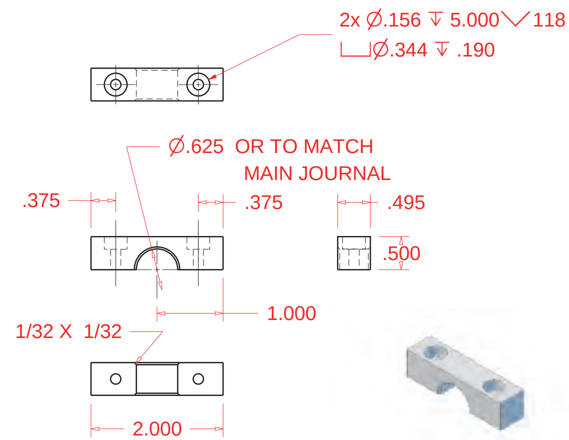
METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

MODEL	PROJECT Crankshaft Drilling Fixture	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Ken Hurst
EDITED BY MIKE REHMUS	Project drawing # 7 of 9	3RD ANGLE PROJ.

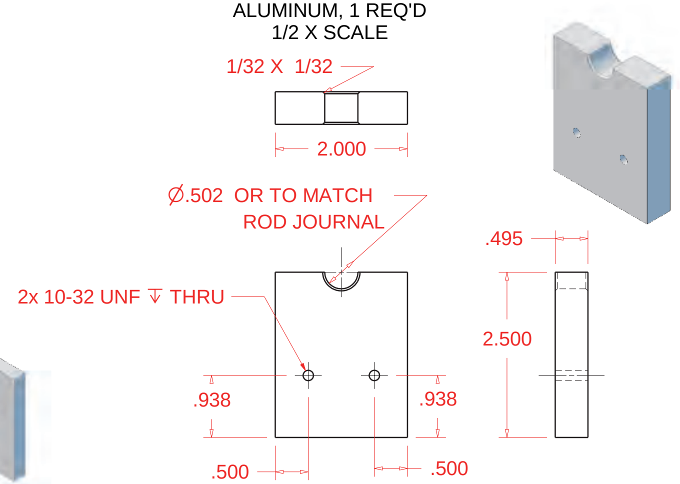
CRANKSHAFT OIL DRILLING FIXTURE BASE
ALUMINUM, 1 REQ'D
1/2 X SCALE



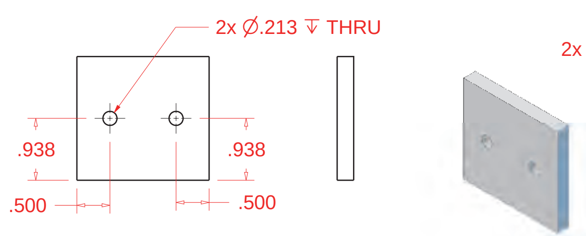
CRANKSHAFT OIL DRILLING FIXTURE CLAMP
ALUMINUM, 1 REQ'D
1/2 X SCALE



CRANKSHAFT OIL DRILLING ROD THROW CRADLE
ALUMINUM, 1 REQ'D
1/2 X SCALE



CRANKSHAFT OIL DRILLING ROD SPACER
ALUMINUM, 1 REQ'D
1/2 X SCALE



BREAK OR DEBURR ALL EDGES AND CORNERS
UNLESS OTHERWISE SPECIFIED

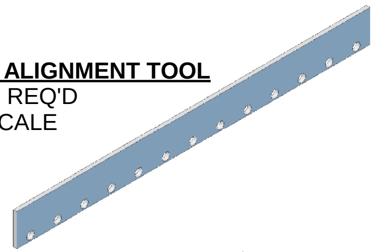
DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

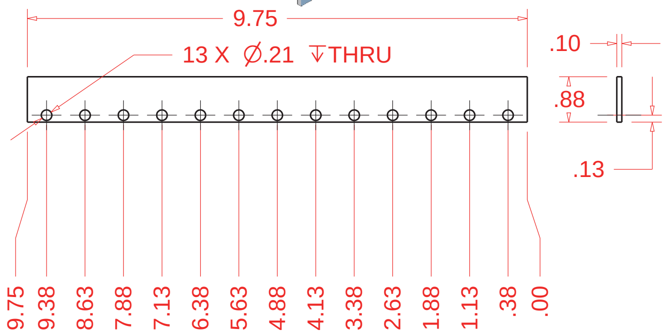
METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

MODEL ENGINE BUILDER	PROJECT Crankshaft Drilling Fixture	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Ken Hurst
EDITED BY MIKE REHMUS	Project drawing # 8 of 9	3RD ANGLE PROJ.

CRANKSHAFT BOSS ALIGNMENT TOOL

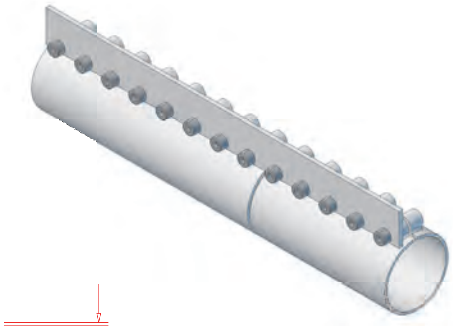
STEEL, 1 REQ'D
1/3 X SCALE

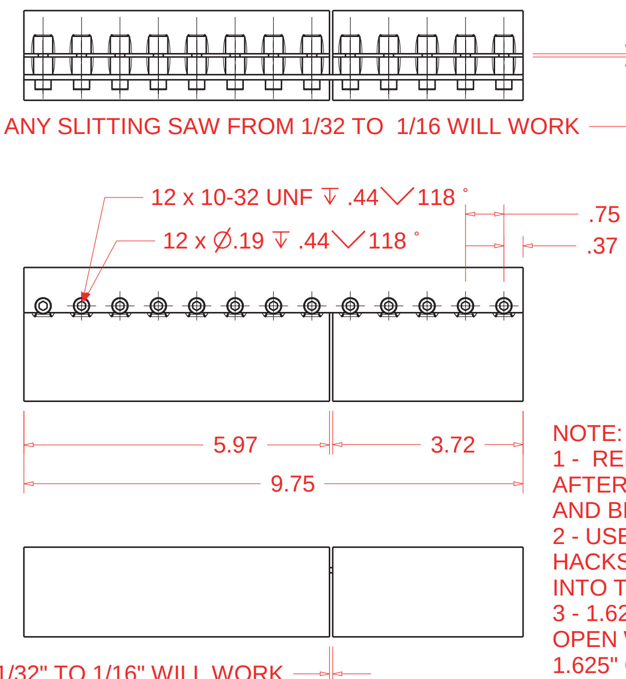


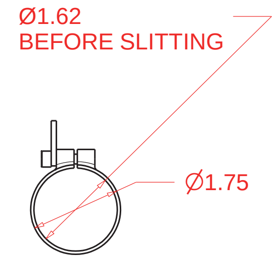


CRANKSHAFT MACHINING SUPPORT FIXTURE ASSEMBLY

4130 TUBING, 1 REQ'D CUT IN TWO
1/3 X SCALE

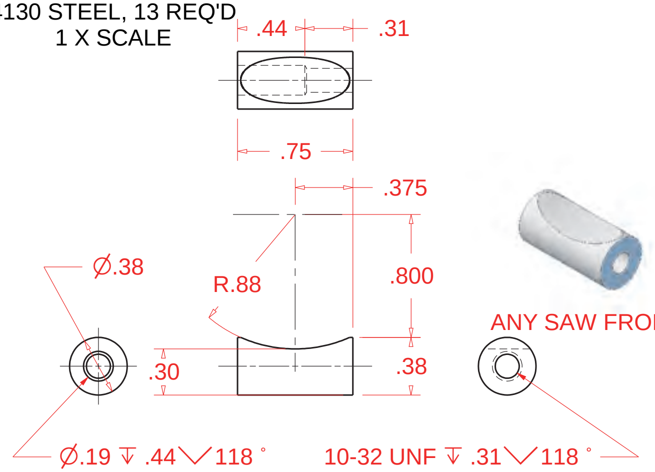






CRANKSHAFT BOSS

4130 STEEL, 13 REQ'D
1 X SCALE



ASSEMBLE BOSSES ON ALIGNMENT TOOL AND CLAMP TO TUBING. WELD BOSSES TO TUBING, REMOVE ALIGNMENT TOOL AND SLIT TUBING AS SHOWN

NOTE:
1 - REMOVE BOSS ALIGNMENT TOOL AFTER BOSSES ARE WELDED AND BEFORE SLITTING TUBING
2 - USE SLITTING SAW OR 32 TOOTH HACKSAW TO SPLIT TUBING AND CUT INTO TWO SECTIONS
3 - 1.62" I.D. TUBING WILL SPRING OPEN WHEN SLIT TO ACCOMMODATE 1.625" CRANKSHAFT
4 - ADJUST DIMENSIONS TO SUIT YOUR CRANKSHAFT

MODEL ENGINE BUILDER	PROJECT Crankshaft Machining Support Fixture	
DO NOT SCALE	Drawn by Mike Rehmus	Designed by Dwight Giiles
EDITED BY MIKE REHMUS	Project drawing # 9 of 9	3RD ANGLE PROJ.

DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED

METRIC	IMPERIAL
1 PLACE ±0.3	2 PLACE ±0.01
2 PLACE ±0.03	3 PLACE ±0.001
3 PLACE ±0.005	4 PLACE ±0.0005

BREAK OR DEBURR ALL EDGES AND CORNERS UNLESS OTHERWISE SPECIFIED