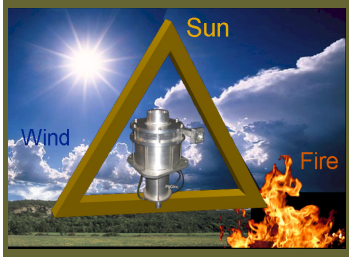
Volume 1, Issue 1

January 24, 2011



NEW TURBINE WORKSHOP

Lesson 1

Turbogenerator Construction

Shaft Assembly

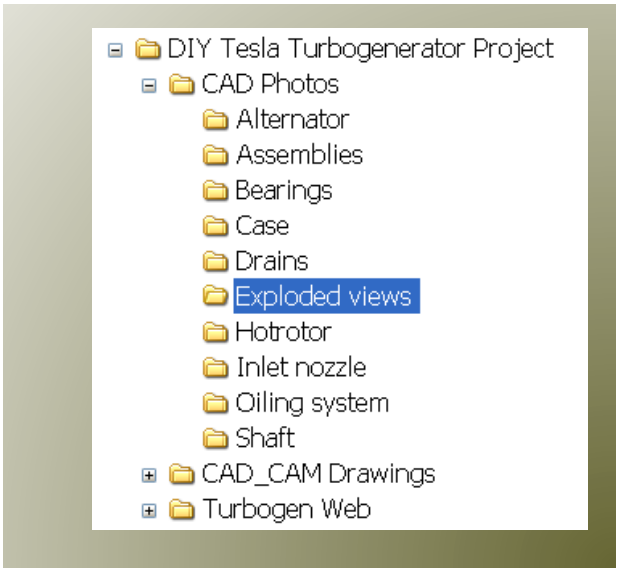
Ken Rieli, Instructor

We're going to begin our lessons on turbogenerator construction with the key component – the shaft assembly.

The shaft assembly is the only somewhat critical component as far as accuracy is concerned, but even there we don't have to be overly concerned. Any garden-variety lathe with an accuracy of .001" (one thousandth of an inch) is perfectly capable of turning out a good shaft. Also, after the shaft, hot rotor and magnet rotor are assembled as a unit, final balancing will yield a fairly true running assembly.

Let's start out by looking at our shaft assembly on the CD. If you haven't already done so, copy the entire CD to a temporary subdirectory on your hard drive.

Next, open the CAD Photos subdirectory, then Exploded views; click on *shaft rotor system-exp-photo2.bmp*.



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Materials you will need:

Flat sheet stock—stainless steel	.1875", .063", .188" thick
6061 aluminum round rod	4.75" diameter x 1.375" thick
Standard steel round rod	1.25" diameter x 12" long
Hot rotor cap screws	18
Round washers	36
Hot rotor star washers	3
Shaft end washers & nuts	2 each

Step-by-step:

- *Hot rotor assembly*
- *Permanent magnet rotor construction*
- *Shaft turning*
- *Rotor balancing*

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Here we see all of the components of the shaft system. The hot rotor is in the upper left corner, the magnet rotor is in the upper right, and the shaft group is in the lower part of the photo.

We'll show how to build this assembly in order, starting with the two rotors and finishing with the shaft and its sub components. You will see later on why we are taking it in this order, as we fit the two rotors to the shaft.

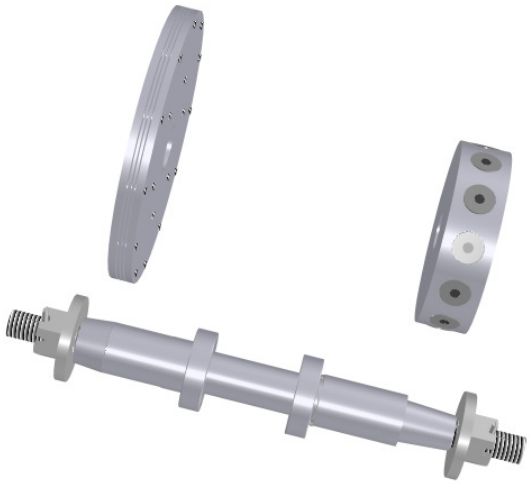

Figure 1 Shaft rotor system

Hot Rotor

Let's begin with the hot rotor.

Again in the CAD photos | Exploded Views section, pull up the *hotrotor asm exp-photo2.bmp*. We see all of the parts needed to assemble the hot rotor.

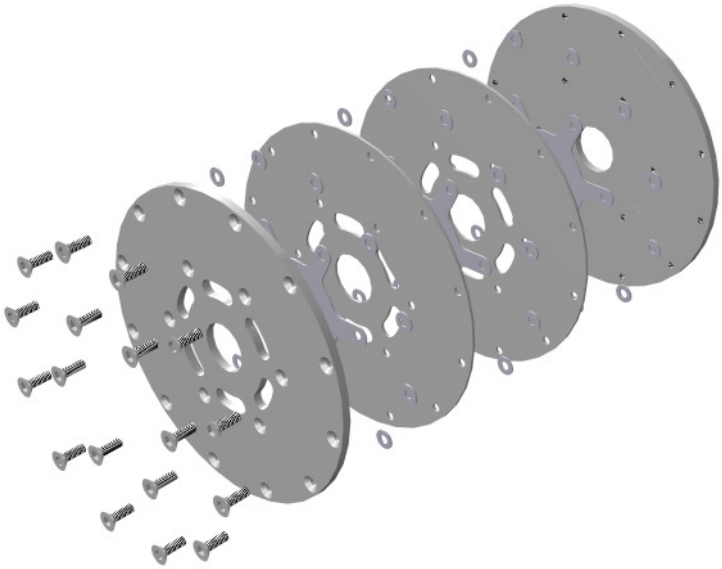

Figure 2 Hot rotor exploded view

TIP:
We always use 304 stainless for the hot rotor, but you could use ceramic-coated steel alloy.

From left to right, we have the cap screws, top plate, star and round washer set, followed by mid plates and washer set, and finally the threaded bottom plate.

The easiest way to start on this component is to have your local machine shop laser-cut the parts, or CNC mill them. The shop we use laser-cuts them for us, and their prices are very reasonable.

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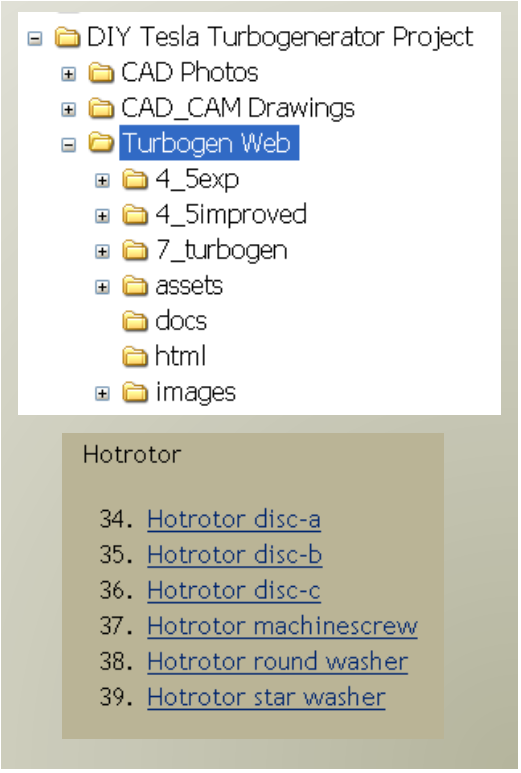
You can also check out machine shop resources on our club site.

If you contract your local shop to fabricate these parts for you, simply send them the DWG drawings with a notation for material type and thickness. After getting your parts in from the laser cutter, you will have to post-finish each disc to dimensions on the specs pages.



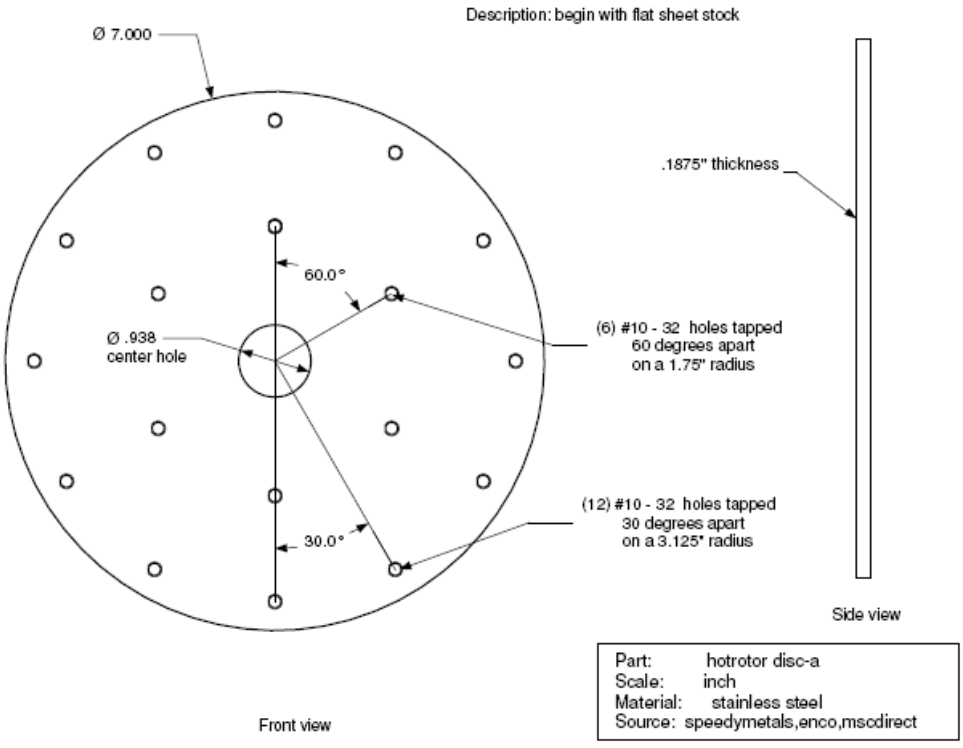
To pull up the specs pages, open the Turbogen Web subdirectory. Click on startup.html to open the web. (You must have a web browser and PDF reader installed on your computer.)

Next, click on the DIY 7-inch Tesla Turbogenerator photo.

Then select any of the hot rotor parts (34-39) on the Drawings page.

Looking at *hotrotor disc-a*, we see all of the finished dimensions of the disc. **Do not post-finish the center bore of any of the 4 discs or start washers – the center bore will be dealt with in the final shaft assembly process.**

Along with post finished the holes and outer diameter, the discs must be polished to a near-mirror like surface. – NOTE: *The exception is the outer faces of the two end plates – these should be left relatively rough to break up adhesion.*



When I begin building a new hot rotor, I start with the bottom (back) plate (disc-a). The .125" holes are opened up with a #25 drill bit to .1495". A #10-24 or #10-32 tap is used (depending on the TPI threads of your #10 cap screws) to thread all 18 holes.

Set the back plate aside for now.

Next, enlarge all of the holes on the remaining 3 plates (disc-b and disc-c) to slightly over .1875" (.19"-.2").

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Next, use a ½" - 60° metal cutting countersink bit to cut beveled holes into the outer face of disc-c. The bevels should be cut just deep enough to allow the #10 flat cap screws to sit just below the surface of disc-c.

Next, enlarge the 6 holes on each star washer to .19"-.20".

Finally, debur all of the drilled and tapped holes, sand all internal surfaces of the discs with #150-#220 grit sandpaper, and finish polish the discs on a motorized polishing wheel – with generous amounts of polishing compound.

After cleaning the polished discs, assemble the disc pack (using the #10-24 screws) **without the star washers and round washers.**

Next, mount the disc pack in a lathe and cut the outer diameter to 7 inches (or therabouts).

Disassemble the disc pack, clean up the disc edges with a file, and reassemble the disc pack **with the washers in place**, torqueing the screws down as tightly as possible.

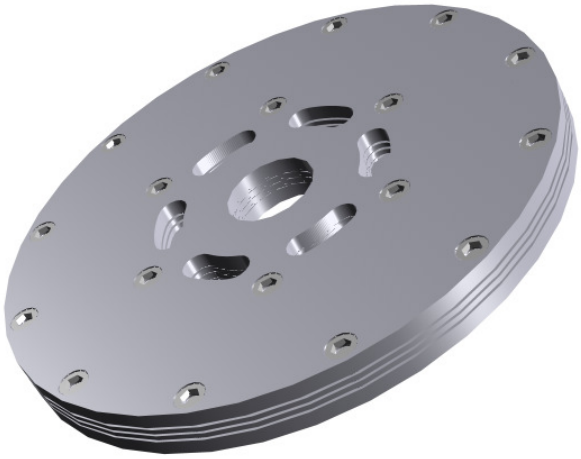

Figure 3 Hot rotor assembled

Grind off the protruding screw shanks, mount the disc pack back in the lathe, and true-up the back plate with a carbide lathe bit.—Flip the disc pack around and true-up the front plate.

Remove the disc pack from the lathe and use a sharp prick punch to lock the threads of the cap screws into the back plate.

Set the hot rotor aside for now.

Magnet Rotor

The next part we are going to make is the permanent magnet rotor.

Alternator

1. Magnet retaining nut
2. Magnet retaining screw
3. Magnet rotor sheet-a
    - Magnet rotor sheet-b

Open the Turbogen Web and select the DIY 7" Tesla Turbogenerator section, Drawings, *Magnet_rotor-sheet-a and b*. As you can see, the magnet rotor is a section of round aluminum rod that is 4.75" in diameter by about 1.375" thick in its raw state.

We begin by chucking the blank in a 6-inch or larger lathe chuck, and running a bit across the face of the blank at about 500-700 rpm to obtain a perfectly flat face.

We then flip the blank around and again run a lathe bit across the face, taking off sufficient material to end up with a 1.25" thick blank.

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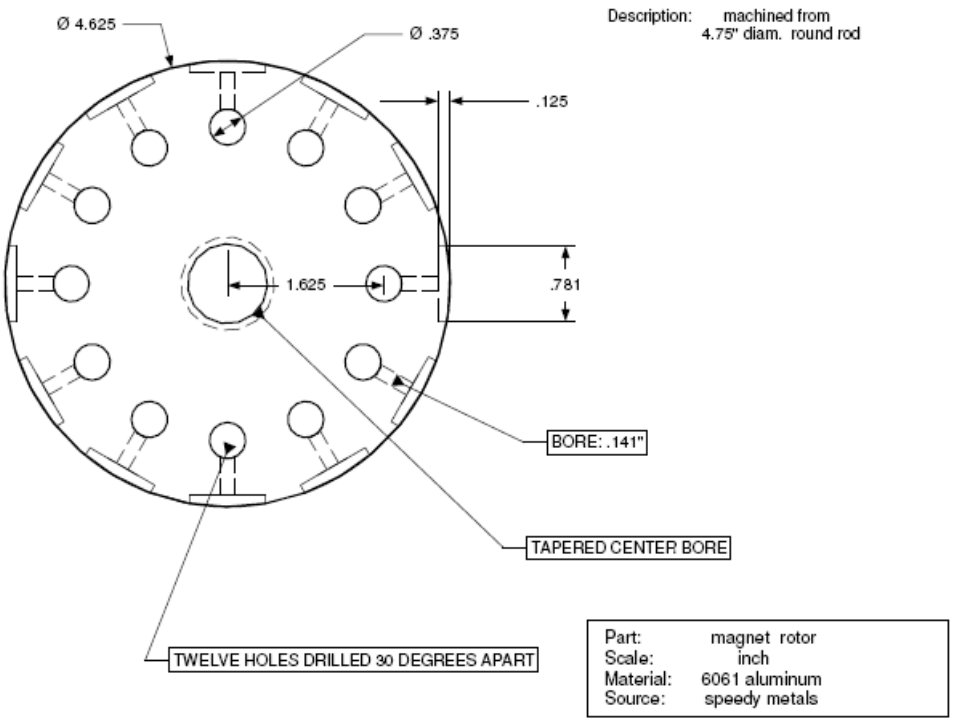
Next, use a combo drill-counterbore to spot the center of the blank. Then use a ½" – ¾" drill bit to bore a hole down the center of the blank. This will give us a means of mounting the blank to cut the outer diameter.

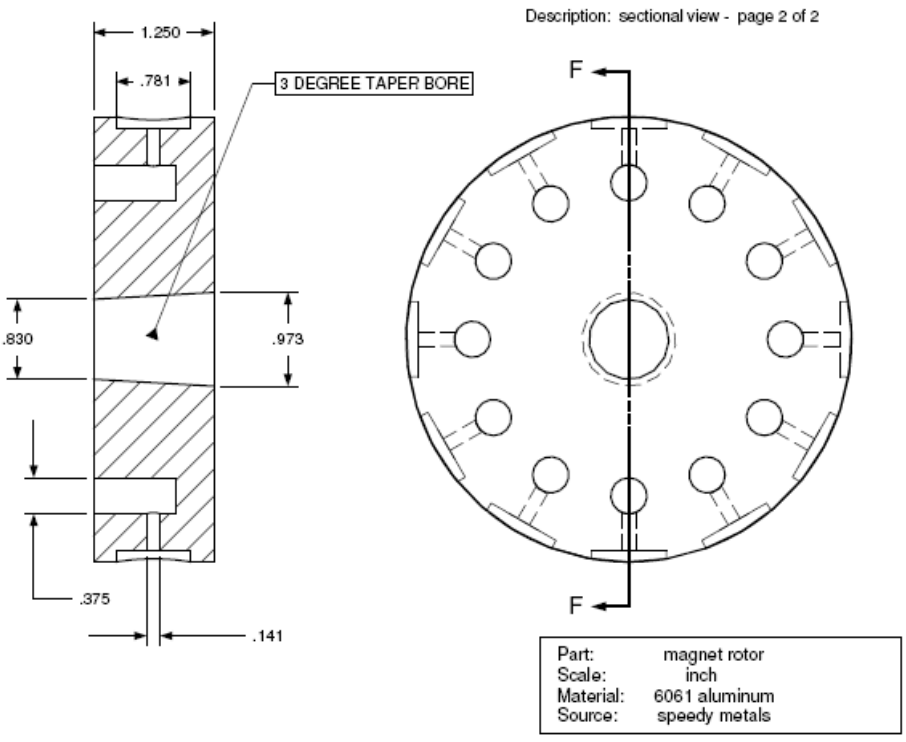
Use a straight length of rod – threaded at one end – to mount the round blank in the lathe with the outer edge free to cut.

Now cut the outer diameter down from 4.75" to 4.625". This establishes the rotor clearance for the stator's 4.75" iron core.



For the next few steps we will use a rotary table and mill setup.

First, mount the rotary table to the mill table in the horizontal plane. Center the blank on the rotary table, flat face up.



Next insert a .375" drill bit into the mill head, and offset the table 1.625". Drill 12 holes 30 degrees apart and approximately one inch deep – using the rotary table to accurately clock the workpiece every 30 degrees.

With the workpiece still clamped to the rotary table, rotate and mount the rotary table in its vertical plane and center the mill head exactly over the center of the workpiece circumference.

Using the rotary table's dial, rotate the workpiece until one of the .375" holes is directly under the mill head.

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Mount a .75” center cutting mill bit in the head and proceed to cut (12) blind holes in the circumference of the rotor - .125+” deep (magnet slots).

Finally, replace the mill bit with a .141” diameter drill bit and proceed to drill (12) holes – one in each .75” slot center – clear through to the .375” holes. These are the screw through-ways.

Set this rotor aside for now – we will deal with the tapered bore later.

Shaft Turning

Now that we have the hot rotor and magnet rotor somewhat completed, we’ll turn our attention to the shaft.

The shaft does a couple of things for us. It not only turns on bearings for electro-mechanical power, but also sets the quasi-critical spacing between the two rotors, and the bearings.

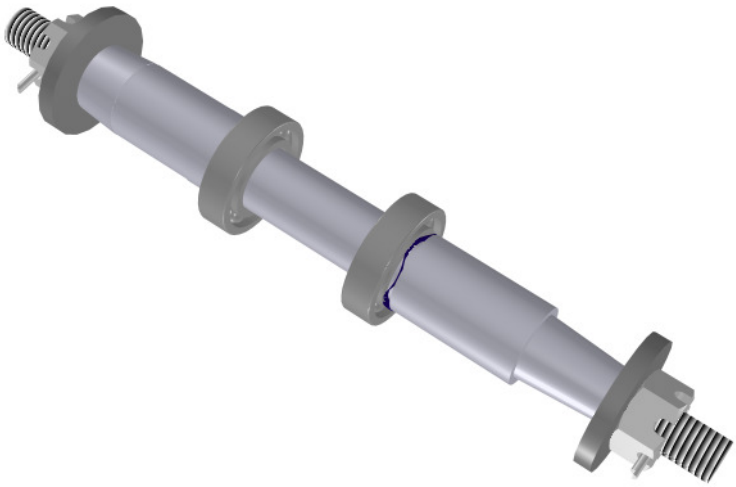

Figure 6 Shaft & bearing assembly

Figure 6 shows the relationship between the two rotors and two bearings. Spacing dimensions are given in drawing 68 -Main Shaft.

As we mentioned earlier, these dimensions are somewhat critical, but only in that they should be close to what is displayed. *If there is some variation, the shaft spacers may be modified to adjust final alignments of rotors, inlet and stator.*

So let’s go back to the turbogenerator web and open the Drawings section. Find and open the Main Shaft drawing.

This is the only part that needs to come out within .001” or less. The more accurate your lathe, the better running your turbine will be.

Since the largest diameter feature on the shaft is 1.1875”, we can start with a 1.25” steel rod, cut to 12 inches long.

The first thing we want to do is run a lathe bit across each end of the rod to give us a perfectly perpendicular end.

Next, use a .5” combo drill-countersink to spot both shaft ends with a 60° tapered hole – this will center the shaft on the lathe end stock for accurate turning.

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Next, turn both ends down to .625” diameter, 1.625” long. - Later we’ll cut the threads into these sections.

Next locate the shaft between the turning centers and cut down the shaft to .984” diameter, 6.66” long. Check the bearing fit at this point. If the shaft is just slightly too large to slip the bearings on, use a piece of fine sandpaper to grind off a minimal amount of material for a slip fit.

The next operation will fit the two rotors to the shaft with a taper fit. Tapers are easily cut by setting the tool post slide to a 3° offset.

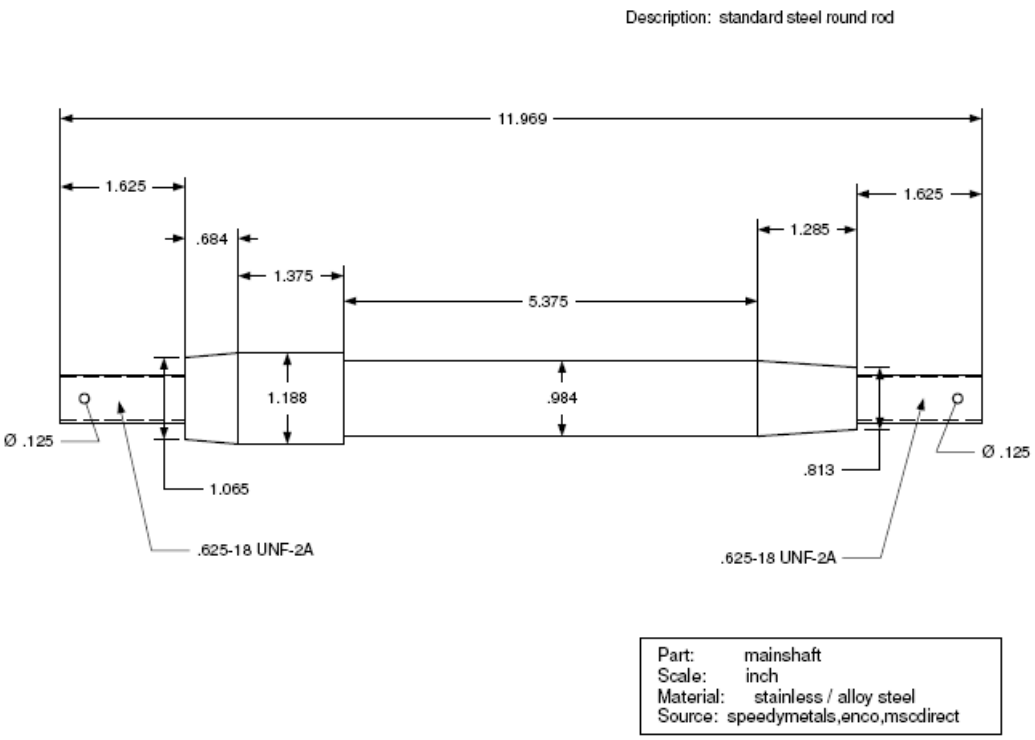

Figure 7 Main Shaft drawing

First, cut the two shaft tapers as indicated in the shaft drawing.

After cutting the tapers, cut the .625”-18 threads into the rod ends of the shaft with the lathe’s screw-cutting capability.

The next operation involves fitting the rotors to the shaft. After removing the shaft from the lathe, mount the hot rotor, bottom side out, in the chuck. With the tool post slide still set to 3°, use a boring bar and the offset slide to slowly cut a taper on the inside bore of the hot rotor.

Stop the machine regularly and insert the shaft taper into the hot rotor taper to check the fit.

When the bottom of the shaft taper (largest taper diameter) meets the bottom edge of the hot rotor, that part is done. Remove the hot rotor and mount the magnet rotor, topside out.

Again, use the 3° offset tool post slide to slowly cut an inside taper into the aluminum magnet rotor. Regularly check the fit and stop cutting when the distance between the two rotors is 7 inches.

We are now ready for the final operation – balancing the rotors.

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Rotor Balancing

In balancing the rotors, two things are important:

a) Take off as little material as possible

b) Mark the rotors and shaft with a punch to make sure they are assembled the same way every time.

Begin by fitting the two rotors to the shaft with shaft end washers and nuts.

Use a sharp prick punch to mark both the rotors and where they meet the shaft.

Next, mount the assembly in the lathe between two turning centers, supporting the shaft on the two counter-bore tapers.

Use a lathe dog or similar connecting tool to spin the assembly (60 rpm for stainless, 500 rpm for aluminum).

Taking care to remove as little material as possible, run a lathe bit across the spinning outer diameters of both the hot rotor and magnet rotor.

Another option is to use a tool post grinder to remove the material. Grinding is preferred on the hot rotor stainless, since it does not leave burrs on the edges of the discs.

Now that the shaft assembly is completed, it's time to build the rest of the turbogenerator around it.

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