Refurbishing a 1952 South Bend 13”x40” Lathe

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December 28, 2015

Abstract

This document was created from a website on the same subject that was removed from the internet after its host server was discontinued. I have reproduced the original website as a .pdf file, with many updates and corrections and enhancements.

This work took many hours, not only in terms of performing the work of refurbishing the lathe, but particularly in the time spent creating this document. I provide it free of charge, in the hopes it may help the community. I ask that you obey international copyright law by not attempting to make a profit from it.

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1 Introduction

This document chronicles what I did when refurbishing (not rebuilding) my 1952 South Bend Lathe. It's all here, including mistakes I made. It is not meant to be an authoritative source on how to rebuild a machine like this - just one person's experiences in the hopes others might learn from what I did. Please don't take any of the content of this document as being "the correct way" of doing anything.

In June 2008 I made the mistake of having a look around Ebay and Craigslist at lathes. I was always worried that by the time I was ready to buy a lathe there either wouldn't be any in my price range, or all the old timey models would be gone.

One evening I found a 13" South Bend on Ebay located in Lima, OH that was ending in just a few hours with no bids. I emailed the seller and let him know I was interested, but would need to inspect the lathe before bidding. When the lathe didn't sell, he contacted me and we set up a time for me to look at it.

It was located at a company called High Tech Metal Products, and the proprietor took time out of his Saturday morning to show me the lathe. He made numerous cuts on a steel round bar, demonstrating that the machine cut no taper at least 3 inches out from the chuck. The lathe was utterly silent when running, except for the gentle "tick-tick-tick" of the metal links in the leather flat belt contacting the pulley cones. It was clear to me the moment he turned it on that I'd be buying it.

1.1 Moving

So I took some measurements and headed home to fabricate a rolling platform for the lathe. I simply used 3"x1/4" angle iron (A36) for the front and rear, linked together by pieces of 1.5"x1/4" square A36 tube. I bolted casters to the angle iron at each corner - two fixed, two swivel), and used 2x12 pine boards for the lathe to rest on. Figure 1 is a photo of the platform strapped into the trailer I rented.

There are 4 500-lb ratcheting straps, one at each corner, and the casters are locked with wheel brakes.

The trailer is a Bil-Jax Escalate, rated to 5000 lb and equipped with a hydraulic deck elevating system. You simply pull a lever and push a button to raise or lower the deck to the ground.

When I got to High-Tech, the owner loaded the lathe atop the platform with a forklift, placing the forks under the bed way. At one point, while maneuvering the lathe into position, he picked it up by the chip pan, so I can say with absolute

Figure 1: Rolling platform secured to the trailer with straps and ready to depart.

confidence that a South Bend 13" chip pan will support the entire weight of the lathe (between 1300 and 1500 lb).

In figure 2 we have the lathe as it was towed back the 90 miles to my house. There are a total of 10 ratcheting straps holding it to the trailer. 4 straps on the rolling platform rated at 500 lb each (as seen in figure 1), 4 1500 lb straps wrapped around the bed, and 2 1500 lb straps wrapped around the underdrive cabinet and secured to the front and rear of the trailer.

I stopped at two rest areas on the highway to check and adjust the strap tension. At the first stop, about 10 miles from High Tech, I found one strap had loosened. At the second stop no straps were found loose.

This thing survived a trip through some of the worst sections of highway in the country (I think). I drove as slow as I could without causing an accident, and everything went fine. Nothing broke.

You can see in figure 1 a piece of angle iron clamped to the platform transversely. 2 of these were clamped to the underside of the platform for the drive home as added insurance against tipover (the lathe is apparently very top heavy).

There are lots of smart, experienced machinery movers who would castigate me for moving in this manner. Technically, the safest way to move this machine would be to weld it directly to the trailer deck and weld strong steel support beams between the lathe and the trailer, effectively making the machine and the trailer a single piece of metal. Then fasten it securely using either chain binders or rachet straps with minimum 5000 lb capacity. At the destination, the welds are torch cut.

Although the way I secured it worked, I make no claims it was the "correct"

Figure 2: The lathe strapped to the trailer after moving it home.

way of transporting a machine. When in doubt, consult a professional machinery mover, and always secure your load properly. If something like this falls off the trailer on a busy highway you are likely to cause a fatality.

1.2 Dealer Shenanigans

I bought the lathe for $1300. It came with no tooling or accessories, except for an old Cushman 6" chuck and a very shoddy toolpost.

The day before buying this lathe I visited 2 machinery dealers in Cincinnati - C.W. Wood and Mohawk. My problem with machinery dealers around here is that, at least in the class of small machines in which I have an interest, they think everything they have is made of unicorn carcasses. I will give two examples.

First, at C.W. Wood, I looked at several small lathes. Two stand out as good examples of the "this-equipment-is-made-of-gold-and-you-should-feel-blessed-to-lay-eyes-on-it" attitude. They had 4 Clausing-Colchester 13x40" lathes available. Brand new, these machines are somewhere between $20k and $30k. Wood was asking $7k for these used units. They had been stored outside (abandoned, really) by the previous owner. The salesman at C.W. Wood, referring to the heavily rusted ways, said "oh, we'll clean those up". Re-grinding ways on a machine like that would cost almost as much as a new machine. How were they planning to "clean those up?"

C.W. Wood also had a small South Bend 9" lathe on a cabinet. It had "badly worn ways" - their words, not mine. They wanted $900 for it. A friend recently bought a near-mint South Bend 9" for $475. The salesman went on at length about how they constantly get ridiculously low offers on this stuff. Well, DUH!

The second example of ridiculous dealer pricing was at Mohawk. They had an 11" Logan on a cabinet stand that was worthy of the scrap heap. It had obviously been out in the rain for some time, and although the ways had little rust, almost everything on the machine was frozen. They wanted $1275 for it.

I don't know what happens to these machines that end up at dealers who try to sell them for substantially more than they're worth, but I suspect that after sitting in the warehouse for awhile unsold they end up being scrapped. That's a shame, because there's a buyer for almost everything out there if the price is right.

My point in relaying these stories is caveat emptor (buyer beware) when shopping machinery dealers. I'm not saying they are all crooked, but the buyer needs to be well educated to avoid being ripped off.

2 Underdrive

We begin this project at the bottom. Specifically, the underdrive assembly, shown in figure 3. The housing here contains the motor and countershaft, which drives the headstock spindle. Figure 3 depicts the as-purchased state of the underdrive.

Figure 3: Underdrive before cleaning.

This really isn't bad. Most of what's in here is bits of rubber from the vee-belts that link the motor to the large drive wheel. There's a slight oil film as well, which gets worse as you move toward the top of the housing. I suspect this is leakage of oil from the headstock down, because there are no oil-lubricated parts in the underdrive assembly.

There are 2 bearings on the countershaft, both of which were initially smooth and silent. They are double shielded bearings (not sealed). It's remarkable that they're still in excellent shape after all these years, but I suppose that has to do

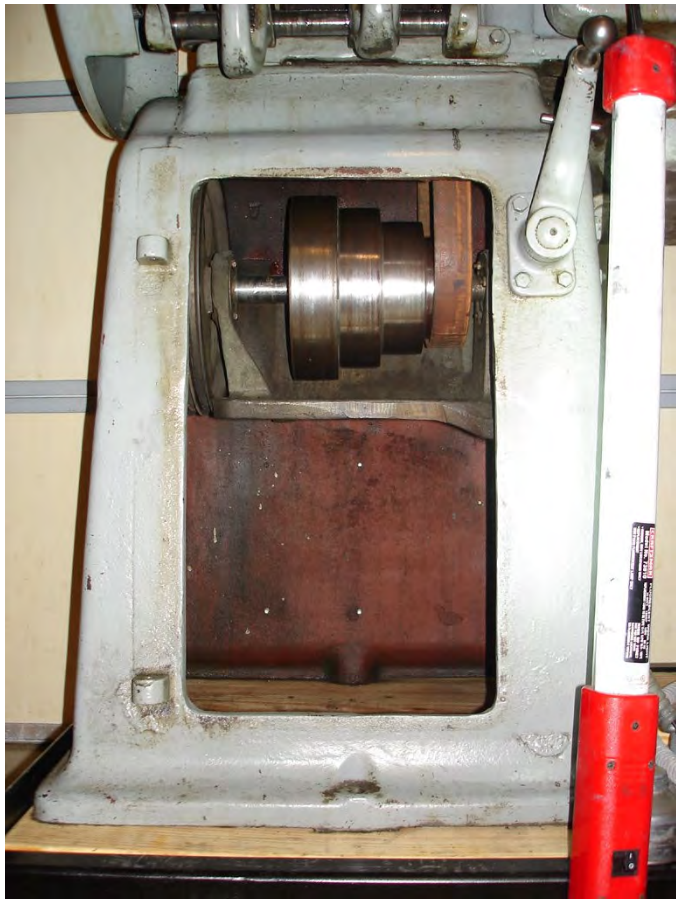


Figure 4: Underdrive after cleaning

with the belt tension being relatively low.

Initially I cleaned the assembly in-place (except for the motor and its mounting plate, which I did remove and clean separately) and placed it into service. To clean it I used a combination of simple green and Brillo pads. These took care of most of the oily film on the housing walls, and a vacuum sucked up most of the tiny rubber bits. I did my best to keep contaminants away from the bearings.

Figure 4 is after cleaning, with the motor and its mounting plate removed. It might not look much better than the dirty photo in figure 3, but it was "better enough".

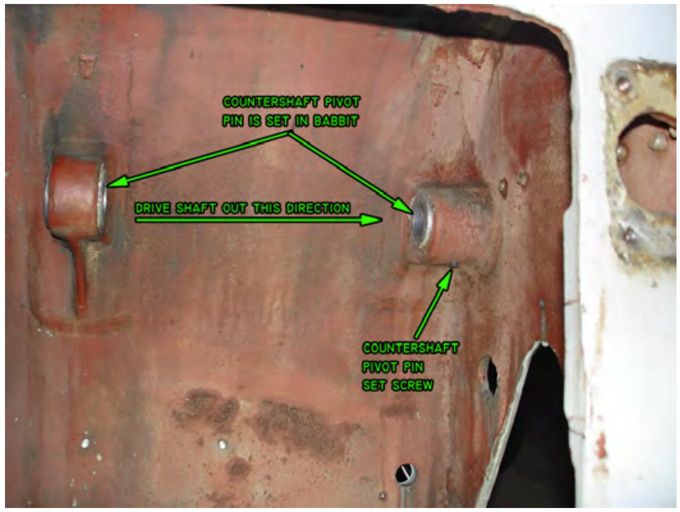


Figure 5: Showing location of countershaft pivot set screw.

2.1 Disassembly

After running the lathe for a couple hours, I became aware of a squeak-squeak-squeak-squeak somewhere in the underdrive assembly. Near as I could tell, it was coming from one of the two bearings in the countershaft pulley. You know, the two bearings that I referred to as "smooth and silent" earlier. I decided to tackle the problem immediately, even though I was in the middle of my first "real" job in the lathe.

2.1.1 Removal

To remove the assembly, begin by removing the motor and its mounting plate as described in section 3. Remember to remove the flat belt before proceeding.

To extract the counterdrive assembly, you must remove the pivot shaft at the rear of the cabinet. This shaft is secured on the right side (the side closest to the chuck) by a single socket head set screw. Figure 5 illustrates the location of the set screw. It is not possible to see the screw without shrinking down to the size of a house cat or being a contortionist and using several mirrors. Rest assured it's a socket-head screw (six point), and just feel around until you find it.

You'll need to drive the shaft out to the right. *It's set in babbit!* This may or may not make it difficult to remove. I was able to drive the shaft out with no particular trouble using a good quality 3/8" diameter punch and a 3-lb hammer. Several hard its were required to dislodge the shaft initially, then things got easier.

You're pressing this shaft a long distance. The shaft itself is more than a foot long, and it must be driven completely out of the cabinet. So you'll need

Figure 6: Method for removing the underdrive with a hydraulic floor jack.

a long punch. I started with the aforementioned 3/8" x 6" long punch, then moved up to a 1-foot piece of 4340 steel rod (1/2" diameter) that I use as a punch. I finished up using a 3-foot piece of 4340 1/2" rod to drive the shaft the last few inches.

The assembly must be supported while the shaft is removed, not only to prevent it dropping to the floor when the shaft comes out, but (more importantly), to keep the weight of the countershaft assembly from binding the shaft. One method of doing this is shown in figure 6. This floor jack is convenient, although a smaller model would be even better. Try to place the jack near the center of gravity for the assembly (it's toward the back).

With the countershaft safely supported, disengage the tensioner by removing the return spring and unscrewing the tension adjustment bolt from the countershaft casting, as shown in figure 7. The bolt will rotate inside the tensioner, because it attaches using a ball-and-socket joint at the top. Use pliers on the unthreaded portion as necessary. This is a somewhat slow process.

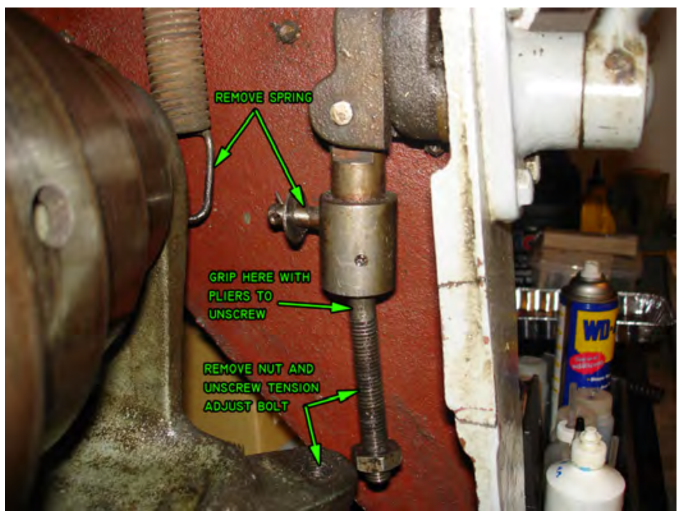


Figure 7: Details of the underdrive tensioner assembly.

Figure 8: Long punch being used to drive out the underdrive pivot pin.

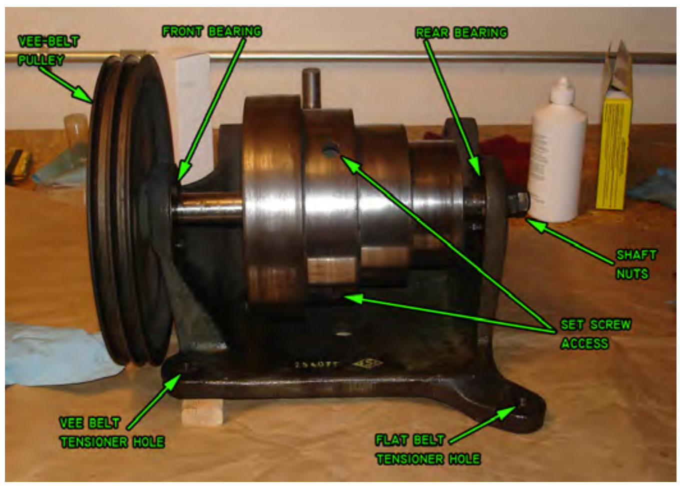


Figure 9: Overview of the underdrive assembly.

In figure 8 we see the extra-long punch required to drive the counterdrive pin out. It's a three foot long piece of 4340 steel. I worked my way up from a 10" to a 12" to this 36" model.

When the pin is free, lower the jack. I pulled the assembly out through the opening on the left side of the cabinet. It weighs around 30 lb (I think), so it's not too bad to lift.

You're left with figure 9, which has some parts labeled for nomenclature.

2.1.2 Removing The Vee-Belt Pulley

The first task is to remove the vee belt pulley, which is secured using a taper pin as indicated in figure 10. According to people who work on these machines regularly, this pulley was installed in such a way as to ensure it can never be taken apart again. Fortunately, your experience may vary. In my case, the taper pin came free after about 10 solid hits with a 3-lb hammer.

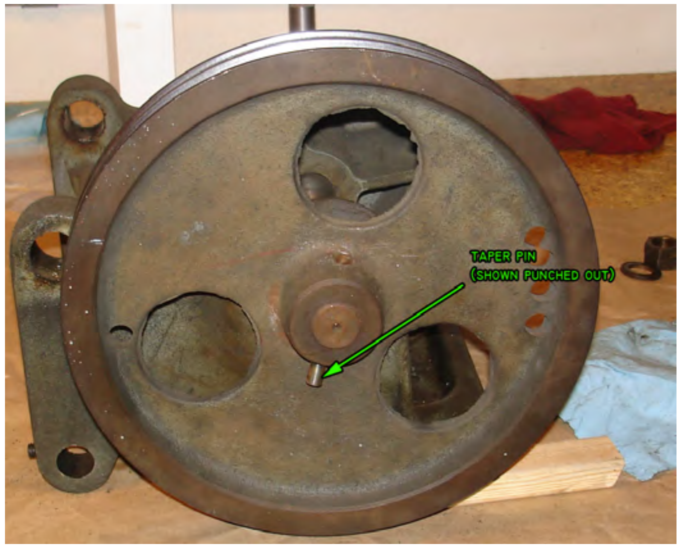


Figure 10: Vee-belt pulley being removed.

Figure 11: Pulling the vee-belt pulley using a 7-ton OTC brand 2/3-jaw puller.

Figure 11 illustrates the procedure to pull the pulley from the countershaft. That's an OTC model 1038 2/3 jaw puller, good to 7 tons. In the case of this lathe, it took no more than a couple hundred pounds of force to remove that pulley. It practically fell apart.

Figure 12: How to remove the underdrive pulley assembly.

2.1.3 Removing The Underdrive Cone Pulley From Its Casting

With the vee belt pulley removed, the next step is to remove the two bearing retention plates which are secured by 3 bolts (each). I didn't take a photo of these plates, but it's obvious once you're looking at the assembly. Also remove the the two shaft nuts in preparation for pulling the rear bearing.

Drive the countershaft in the direction shown in figure 12. The bearings are not tightly pressed into the casting, so it shouldn't take much force to get the shaft into the position shown in figure 12.

Once in this position, use a 3-jaw puller to remove the rear bearing. Unfortunately, I didn't take a photo of this step, but it's just a normal bearing pressing operation. The bearing comes off the shaft to the right in figure 12.

To pull the bearings I used a 3-jaw Posi-Lock model 104, which is far more suited to pulling small bearings than the big OTC model used in figure 11.

2.1.4 Removing The Underdrive Cone Pulley

With the rear bearing removed, the entire countershaft can be removed from the casting using the method shown in figure 13. However, I found I had to slide the cone pulley to the left in figure 13 in order to provide sufficient clearance to get the left end of the shaft to clear the bearing hole in the casting. Notice in figure 13 I had to use the 2-jaw configuration on the puller in order to get access to the pulley with the casting in the way. By sliding the pulley all the way to the left (until it contacts the casting), there's enough room to slide the entire thing to the right to clear the left end of the shaft through the bearing hole in the casting.

Remove the two set screws from the pulley cone before pulling on it!

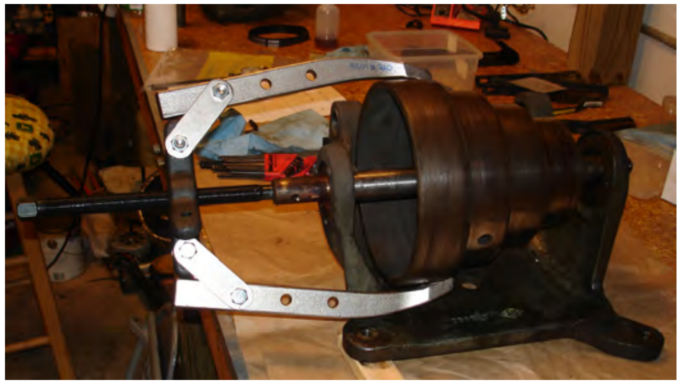


Figure 13: Pulling the shaft through the underdrive pulley. This is being done so that there is enough room to remove the entire pulley from the casting.

Figure 14: Pulley has been removed from the casting and is being pulled off the shaft.

Once you've removed the countershaft from the casting, it's a simple matter of pulling the front bearing (which I also failed to photograph). At that point, the cone pulley can be pulled off the shaft as shown in figure 14. This doesn't take very much force, but just enough to make it more convenient to set a puller on it.

2.1.5 Replacement of Failed Bearing

I dismantled this assembly because I had a squeaking bearing. The original equipment is a New Departure 88026, which fits a 26mm shaft and has an outer diameter of 52mm. The 52mm part is fairly standard, but the 26mm shaft is uncommon. I found that EB Atmus (my usual bearing supplier) had Consolidated replacements for around $30 each. Emerson bearing has cheaper (import) replacements for only $11 each.

The right thing to do is replace these bearings. Instead, I decided to repack

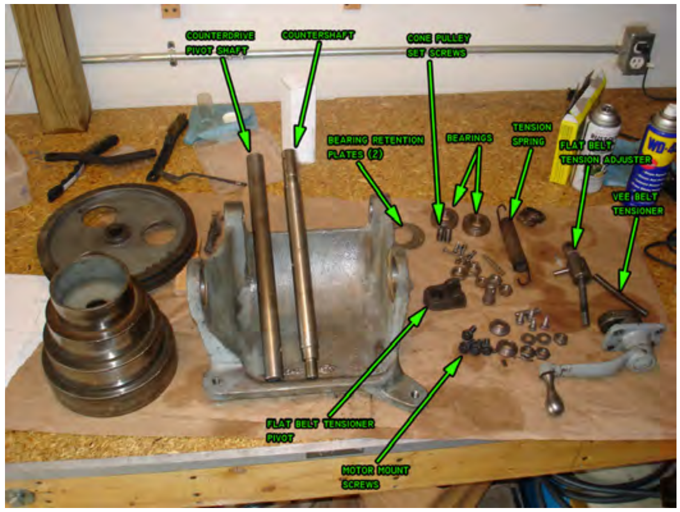


Figure 15: Complete countershaft assembly showing all parts.

the originals. I could detect no flaws in these bearings, except that they were devoid of oil - the only thing remaining of the original grease was the binder.

To repack them, the shield on one side had to be removed. These bearings use a 2-part shield, with a layer of felt between. Figure 16 shows the outer shield removed. Figure 17 shows both shields removed and laying atop the bearing.

I always end up destroying the shields when I remove them from bearings. The problem with going shield-less in this case is the potential for bits of metal from the lathe contaminating the bearings. But since these bearings may need replacement anyway, I'm willing to accept that risk.

I cleaned the bearings as best I could to remove all the old grease binder, then carefully repacked them with Magnalube Teflon grease.

The experiment failed, however, as I found the squeak-squeak-squeak-squeak returned a few hours after repacking. Since the assembly had already been out once, it was a piece of cake to remove it again and replace the bearings with new Japanese-origin bearings from Emerson.

Figure 16: Original countershaft bearing with shield removed.

Figure 17: Failed countershaft bearing with shields removed.

2.2 Reassembly

2.2.1 Pressing On The First Bearing

The bearing for the vee-pulley end of the countershaft is somewhat tricky to press back on, owing to the length of the shaft. My arbor press isn't tall enough to do it, so I used a bench vise (figure 18) to support the bearing with just enough space for the countershaft to slide between the jaws. The press fit isn't particularly strong, and the bearing is pressed in until it contacts a shoulder on the shaft.

Be sure to protect the threaded end of the shaft. I put the takeup nuts on and set a piece of steel on top to strike with the hammer.

Figure 18: Pressing on the first countershaft bearing using a bench vise.

2.2.2 Replacing The Cone Pulley

With the left side bearing pressed on, you'll want to practice putting the shaft into the main casting in order to find a method for yourself that yields good results.

I took some time with steel wool to clean up the casting so that the bearings can slide in and out of their bores with a light hand pressure. That way there's no need to be pounding the shaft into place.

I was therefore able to position the cone pulley as shown in figure 19, then insert the shaft (with left end bearing pressed on) from left-to-right. That's a 2x4 piece of scrap beneath the pulley, which placed the cone pulle at nearly the correct height to accept the shaft.

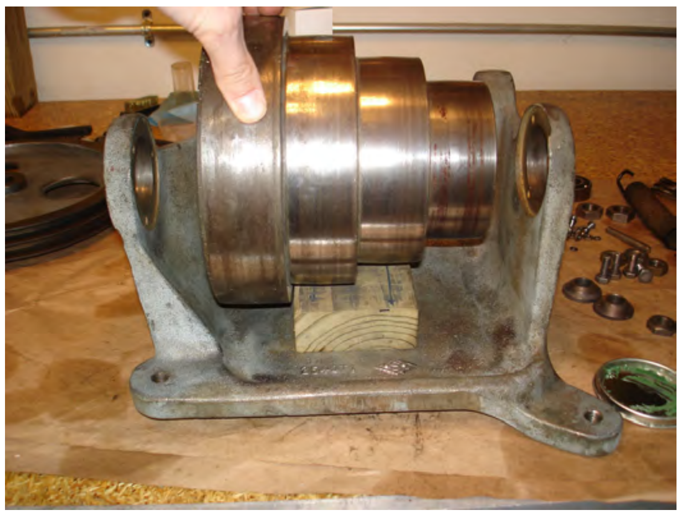


Figure 19: Positioning the pulley cone before assembly.

In figure 20 I'm showing an interim step. The left side bearing is in place, and the backing plate has been installed. The right side bearing plate is still loose, and the right side bearing is being driven in from right-to-left. I used a hammer on a socket sized to contact the inner race of the bearing, since it's being pressed onto the shaft (it slides easily by hand into the casting).

The problem with this process is the need to hold the left end of the shaft securely while the right side bearing is driven on. One way of accomplishing this would be to butt the left end of the shaft against a solid wall or heavy object.

My method is shown in figure 21. I simply set the assembly angled as shown (it will balance in this position), and tapped the right end bearing on. It doesn't require very much force.

Although the left side bearing is pressed up against a shoulder in the shaft, there is no such shoulder on the right side bearing. So the left side bearing must be completely assembled, including the backing plate, so that the right side bearing can be driven into the proper position without the need to measure.

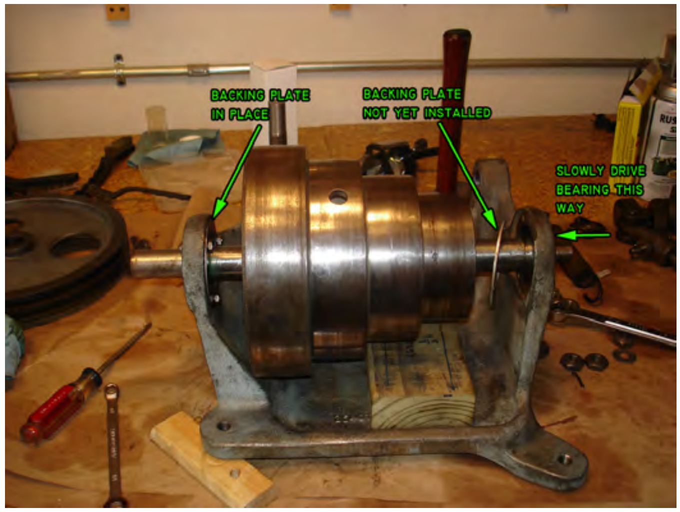


Figure 20: An interim step in installing the cone pulley.

Figure 21: A method for supporting the left end of the countershaft while the right side bearing is pressed into place.

Install the right side bearing plate as well, and press until the bearing contacts the backing plate. This will ensure the assembly is in the proper position. Figure 22 shows the process.

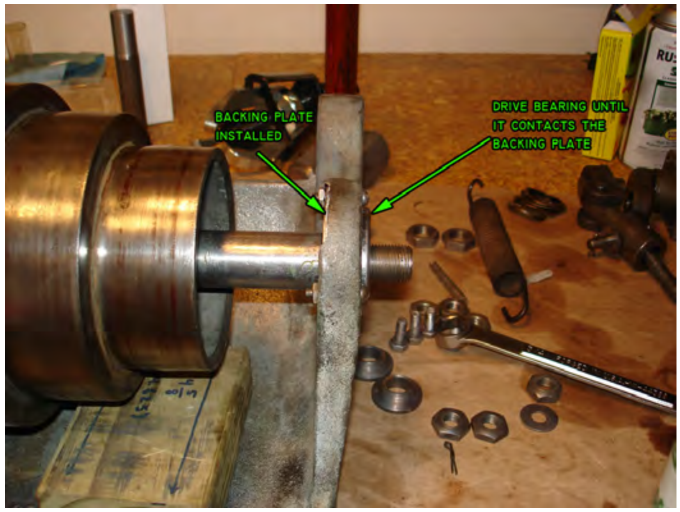


Figure 22: Finishing the process of pressing on the right side bearing for the countershaft.

2.2.3 Final Assembly

Final assembly is completed by reinstalling the vee-belt pulley, which is a trivial task. Figure 23 shows the completed assembly ready to be replaced in the underdrive cabinet.

These parts were all carefully degreased (despite the look of the photo, they're actually very clean looking in reality). As usual, I found the grease residue between the shaft and the pulleys that mount to it forced the need for the puller during disassembly. With the residue removed, these parts slid back together with light hand pressure.

The cone pulley is easy to position properly, since there are deep divots in the shaft where the set screws belong. Simply slide it axially along the shaft until the set screws are properly positioned over the divots, and tighten.

2.3 Tensioner

It's worth taking a quick look at the flat belt tensioner. Figure 24 shows the tensioner dismantled, except that I left the hand lever intact because I couldn't see how it comes apart. I suspect there's a pin that secures the handle, but attempts to drive out what looks like a pin failed. In the photo, the swivel bracket rotates about the pin, which is secured by the set screw as shown.

In figure 25 I've assembled the two parts from the previous section and the tensioner has been added to the photo. Notice the oil hole for lubricating the ball-and-socket joint.

Figure 23

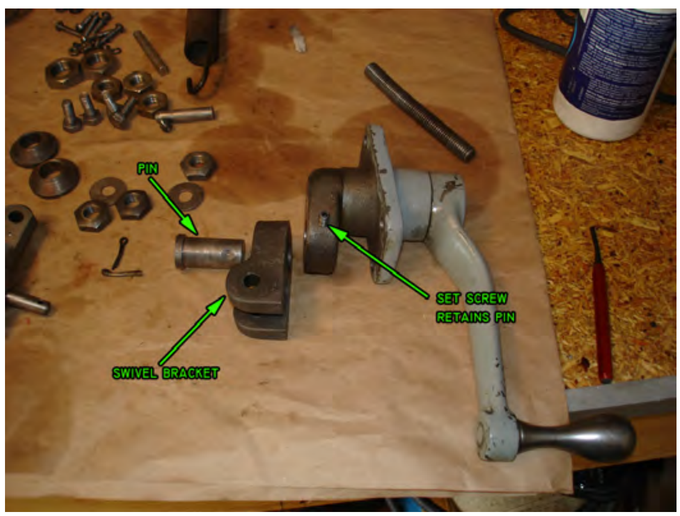


Figure 24: Tensioner assembly.

2.4 Countershaft Reinstallation

I like to paint the insides of my machines gloss white as shown in figure 26. This helps brighten things up tremendously, makes it easier to see leaks, and generally improves the visibility of the various parts. Since it's internal, I don't bother too much with a top-quality finish. I carefully cleaned the inside of the underdrive cabinet with strong degreaser (mostly brake cleaner, in this case), masked a few bits I wanted to keep "original", and sprayed some Rustoleum

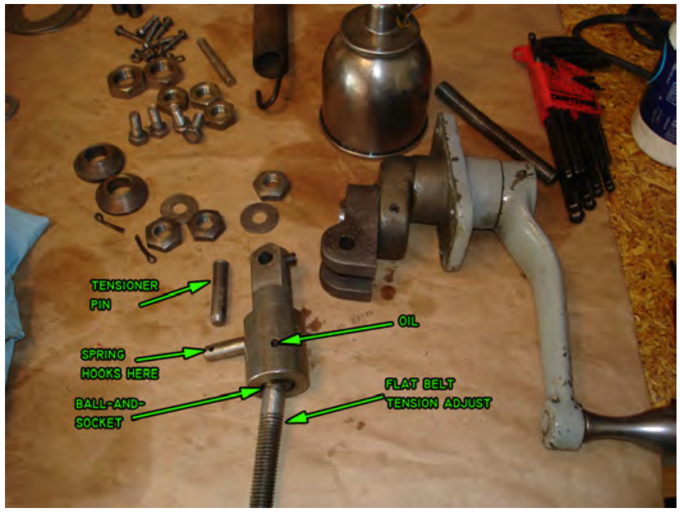


Figure 25: The assembled tensioner to show functionality.

gloss white (several coats).

I used the floor jack method to install the counterdrive. With the assembly balanced carefully on the jack pad, I slowly raised it into position. The trick here is to get the holes in the countershaft hinge aligned with the holes in the cabinet hinges, then drive the hinge pin home.

As usual, the cleaned up hinge pin slid into position with mere hand pressure - no need to pound it into place. A little bit of Teflon grease should keep it nicely lubricated for a long time.

Once the counterdrive assembly is supported on its own, it's a simple matter of putting the tensioner, motor, and belts back in place.

Figure 26: Installing the completed counterdrive assembly in the underdrive cabinet.

3 Motor

The original motor for this machine is a squirrel-cage induction polyphase type made by Century Electric Company from St. Louis, MO, depicted in figure 27. Century doesn't exist as an independent any longer, having been bought out by A.O. Smith some time ago.

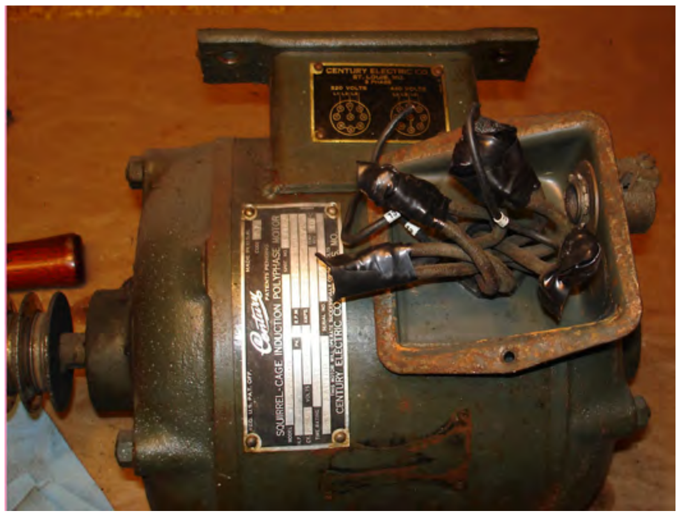


Figure 27: Motor overview.

Specifications listed on the motor plate are as follows (laid out roughly as they appear on the plate):

		Code K
Model SC-203-N		**Spec No.** 13102
H.P. 1	**Phase** 3	**RPM** 1740/1450
Cycle 60/50	**Volts** 220/440	**Amps** 3.8/1.8 - 4.6-2.3
Time Rating: Continuous Open		**Temp Rise** 40°C
Service Factor 1.25		**Serial No.** AG1

Table 1: Motor plate.

The bottom of the plate reads "This motor will operate successfully on 208 volts".

This motor is in remarkable mechanical condition considering its age. Other than a light coating of rubber particles (from the vee-belts), it's relatively clean and free of any grease or oil. The bearings are whisper-quiet and smooth, but I do intend to add some grease to them (ball bearings) to keep them happy. I spoke with a local electric motor repair shop, M&R Electric, and they provided me (free of charge!) some old-timey grease that will be compatible with any existing grease still in the bearings. [Modern bearing grease for electric motors is Polyrex EM, but it's never a good idea to mix grease formulations].

Re-greasing the bearings won't be easy without removing the end bells from the motor, since there's no direct shot to the bearing housings. But I'll do my best to force a bit in there. I will not be using a grease gun, as excessive grease pressure can damage the bearings, so why take a chance?

Century's slogan, at least during this time period, was "They Keep a-Running". The literature abounds with rhetoric about how long lasting (indeed, "invincible") these motors are. They sure are substantially built - that little 1 hp weighs about 40 lb.

The motor is heavy, but can be removed solo if you stack at least 2.75" of blocks beneath it before removing the 4 3/8-16 screws that secure it to the motor plate. The motor plate, however, is easier to remove and install if you use either 2 people or a floor jack, as shown in figure 28. The key is to get the hinge pin out while keeping the motor plate level, thereby preventing the pin binding.

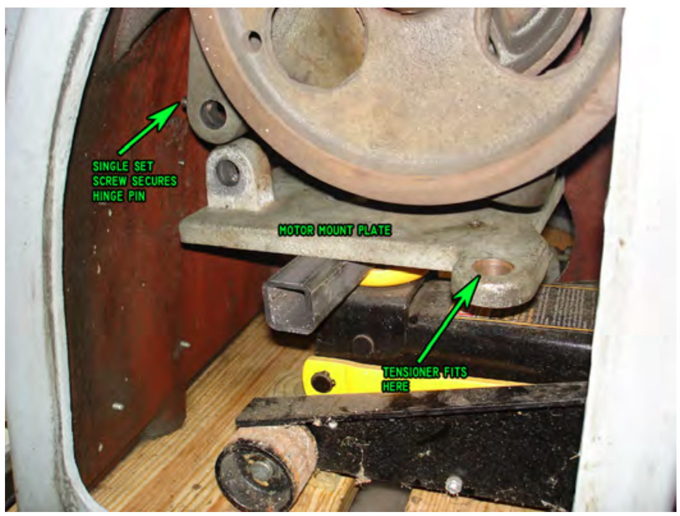


Figure 28: Removing the motor mounting plate from beneath the countershaft assembly.

Figure 29 shows the motor mount plate removed. This is a simple piece, made from solid cast iron roughly 1/2" thick - which means it's remarkably heavy.

Figure 30 shows the rear end bell on the motor with the oil (or grease) fill plug notated. That fill plug, and the corresponding one on the front, gave me fits trying to figure out what should go in there. This is a ball bearing motor, which suggests it should be greased, but there's no drain plug for cleaning out the old grease. After a great deal of debate and discussion with various motor shops I finally decided to use the old timey grease I mentioned earlier, along

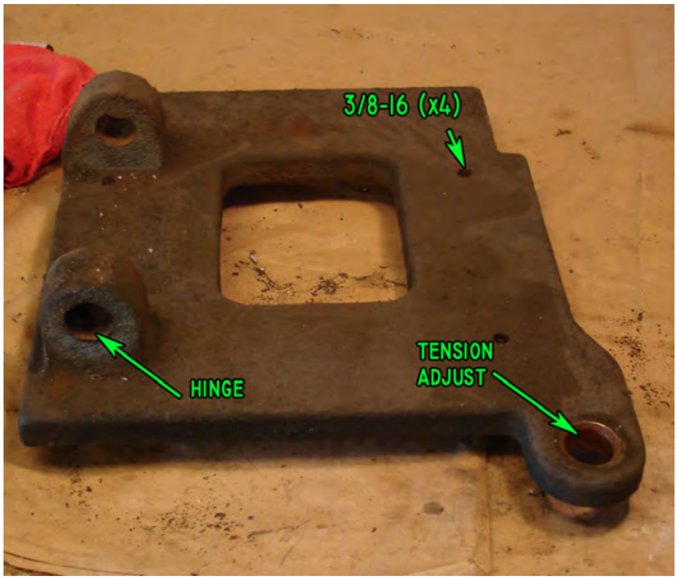


Figure 29: The motor plate.

with a couple tiny drops of Mobilgear 629 gear lube for good measure. I added very little grease. I suspect this motor has never been regreased, as I could find no evidence whatsoever that any grease had ever been pumped into the bearing housings - they were extremely clean inside.

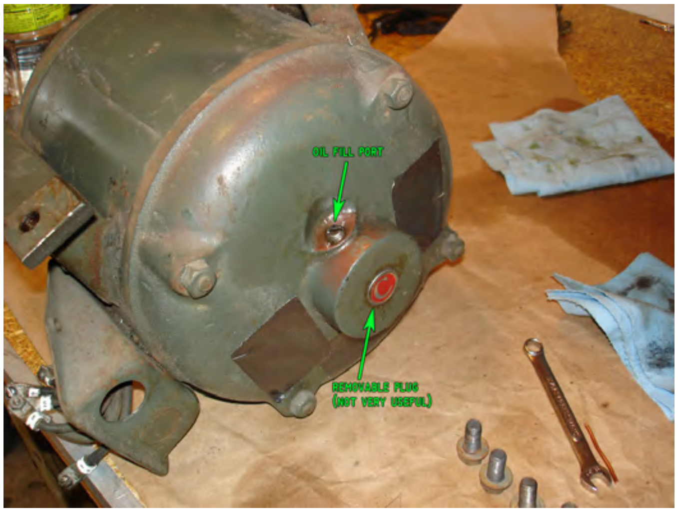


Figure 30: Motor end bell showing oil port.

As you can see in figure 31, the motor has a diagram indicating how to wire it for 220 or 440 volts. I was a bit concerned by the diagram because it suggests (to me, anyway) that there was originally some sort of 9-pin circular connector that was installed and subsequently cut out in favor of electrical tape. I was tremendously pleased, then, when I removed the electrical tape from the motor leads to find the wires all have crimped lugs with the wire number stamped into each lug. (You can't see these stampings in the photos).

The electrical tape will be replaced by self-fusing silicone tape. The wires coming in from the power supply were merely curled and sandwiched between the lugs for each phase. I will eliminate those and use crimped and soldered replacement lugs for 10 ga. wire.

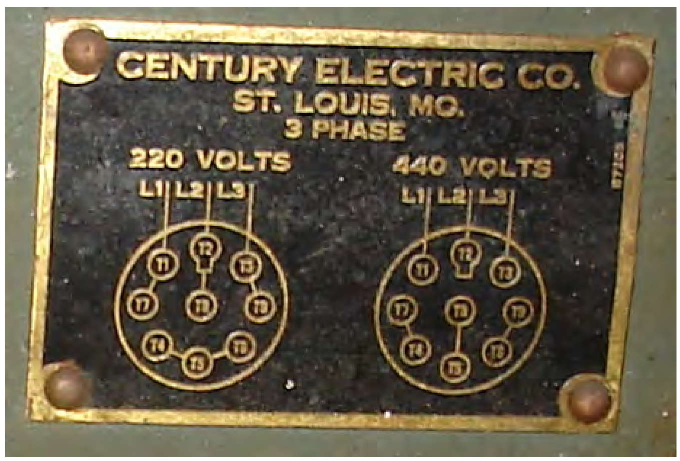


Figure 31: Wiring diagram plate on motor.

4 Back Gear

There's really not much story to tell here, but for completeness I'll go over what I did with the back gear. The back gear is merely a reduction geartrain that permits slow head speeds and very high torque. The pulley cone in the headstock is separate from the headstock spindle, with a large bearing surface between the two so that they can rotate at different speeds.

In normal running, the motor drives the countershaft which, via the flat belt, drives the pulley cone in the headstock, which is mechanically linked (via the bull gear pin) to the headstock spindle.

In back gear mode, the bull gear pin is disengaged, which allows the spindle and the pulley cone to rotate at different rates. The back gear shaft is then engaged, which transmits power from the pulley cone, through 2 reduction gears, then into the headstock spindle at the rear.

Figure 32 shows the basic functionality I've just described. The only thing not visible is the headstock spindle, which runs through the center of the pulley cone. This mechanism worked fine, but I dismantled it anyway for cleaning and inspection.

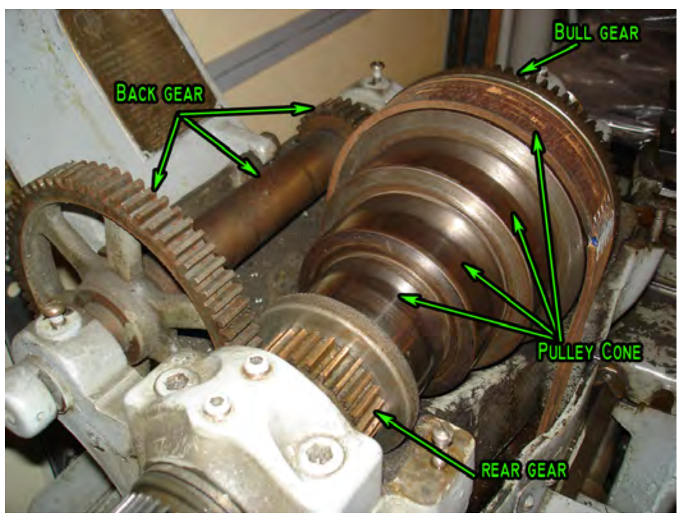


Figure 32: Overview of the important parts of the back gear system.

The back gear has a plug at the center of the shaft which is supposed to be lubricated annually using Teflon grease. Upon disassembly I found there to be a light coat of old oil inside, but no grease. There was also oil residue coating everything.

Removing the back gear assembly is straightforward. First, remove the set screws located beneath the castings in the headstock. Figure 33 shows the rear one, and there's another one at the front of the shaft.

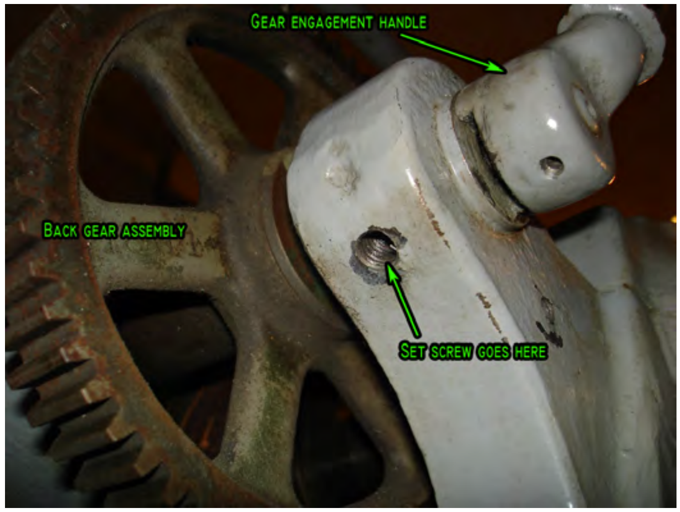


Figure 33: Set screw below the engagement handle that retains the back gear shaft.

At the front of the assembly there's a big bushing that must be driven out (after the set screw is removed), depcted in figure 34. Note: the slotted screw shown in figure 34 is NOT the set screw for the bushing! That particular screw holds down a shield that fits over the top of the headstock there. The set screw for the front bushing is located beneath the casting, similar to the rear one shown in figure 33.

To drive out the bushing I placed a flat-blade screwdriver tip in the position shown in the photo and gently tapped with a light hammer. The bushing doesn't fit real tight in there - in fact, if there weren't an oil residue film on the bushing it would slide right out without the need for a hammer.

The bushing is slotted, and I used a flat blade screwdriver to twist it out the last 1/2 inch or so because at that point it wasn't possible to keep driving it out with the screwdriver from the back side.

On reassembly, I discovered there's a way to adjust the holding power of the back gear shaft. As you tighten the set screw that retains this large bushing it causes the bushing to squeeze the back gear shaft (since the bushing is slotted). That way you can adjust how much torque it takes to pull the back gear lever into position for using the back gear. (It has no effect on the rotation of the back gear itself - only on the effort required to twist the back gear handle into operating position.)

Once the front bushing has been removed, the spindle for the back gear can be pulled out, as shown in figure 35. I had to pull hard and twist at the same time, but it slid out without any trouble.

I soaked the back gear, screws, and bushing in degreaser ovenight. The spindle I cleaned with some extra-fine steel wool to remove the aforementioned

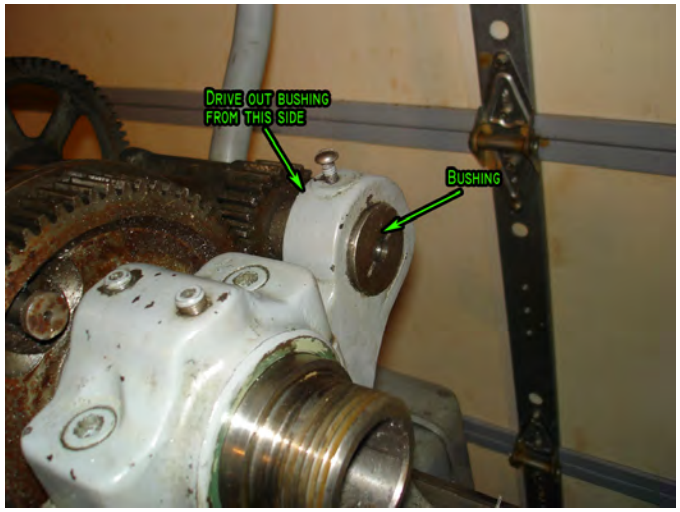


Figure 34: Back gear front bushing being driven out.

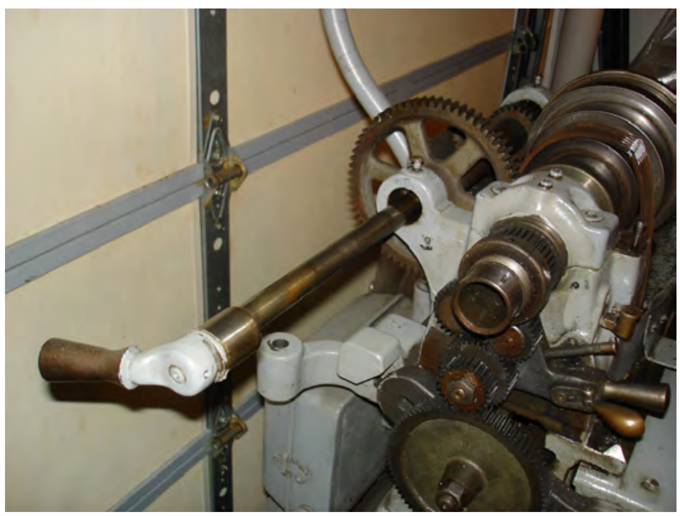


Figure 35: Removing the back gear spindle.

residue, then greased everything up with Teflon grease and set it aside.

I also went back and cleaned up the bores in the iron headstock casting so that the bushings for this slide in and out by hand.

Shown in figure 36 is the fully assembled back gear and the Teflon grease I'm using. The grease came from McMaster-Carr. You may notice that when this photo was taken the back gear shaft is backward! The correct orientation places the larger gear at the same end as the hand lever. It becomes obvious which way it goes when you try to reassemble it on the headstock.

Figure 36: Cleaned and assembled back gear.

As clean and lubricated as the back gear assembly is, it is badly worn and literally sounds like a washing machine full of rocks when used. The reason for this is the gears themselves are heavily worn and now have massive backlash. I believe most of the wear is on the small-end gear attached to the headstock pulley cone (the gear on the left side of figure 37 on page 39). That particular gear is not made of steel - it's made of some kind of yellow metal, and it has worn over time. The back gear system works fine, and I have used it often at high power and speed, but it is awful to listen to.

5 Headstock Spindle

In my opinion the two most important parts of any lathe are the headstock spindle and the bed ways. When evaluating a lathe for purchase it's important to pay close attention to the condition of the headstock spindle; particularly the bearings. These bearings are singularly critical to the performance of the lathe. If they are worn or damaged the lathe cannot produce top-quality work. It is absolutely essential that these bearings are clean, oiled, and smooth.

From what I've read there are two main types of headstock bearings - roller and plain. Most South Bend lathes use plain bearings, which actually offer a better surface finish on machined parts than roller bearings[1].

The headstock bearings are particularly costly to replace. As of this writing, a new bearing for this lathe costs $400, and there are 2 on the spindle.

This particular lathe had very smooth bearings, with good clearance (0.002" as measured according to procedures described by South Bend in their literature). The oil cups were full of clean oil, and the bearings ran silently and generated little or no heat.

Nevertheless, I wanted to dismantle the headstock to check the condition of the bearings, the expander screws, and the oiling system. In my opinion, this is part of regular lathe maintenance to ensure the bearings are getting proper oil.

We begin with figure 37, which shows a complete headstock spindle assembly with names for each important part labeled. It will help the reader understand what I mean when I use various terms related to disassmebly and refurbishing.

[1] Plain bearings in the headstock are NOT lower quality than roller bearings. As proof, consider the lathes produced by Dean, Smith, and Grace, for instance. DSG is widely considered to be the "Rolls Royce" of lathe builders, and plain bearings were offered on their lates as an *option* for operators who needed the best possible surface finish.

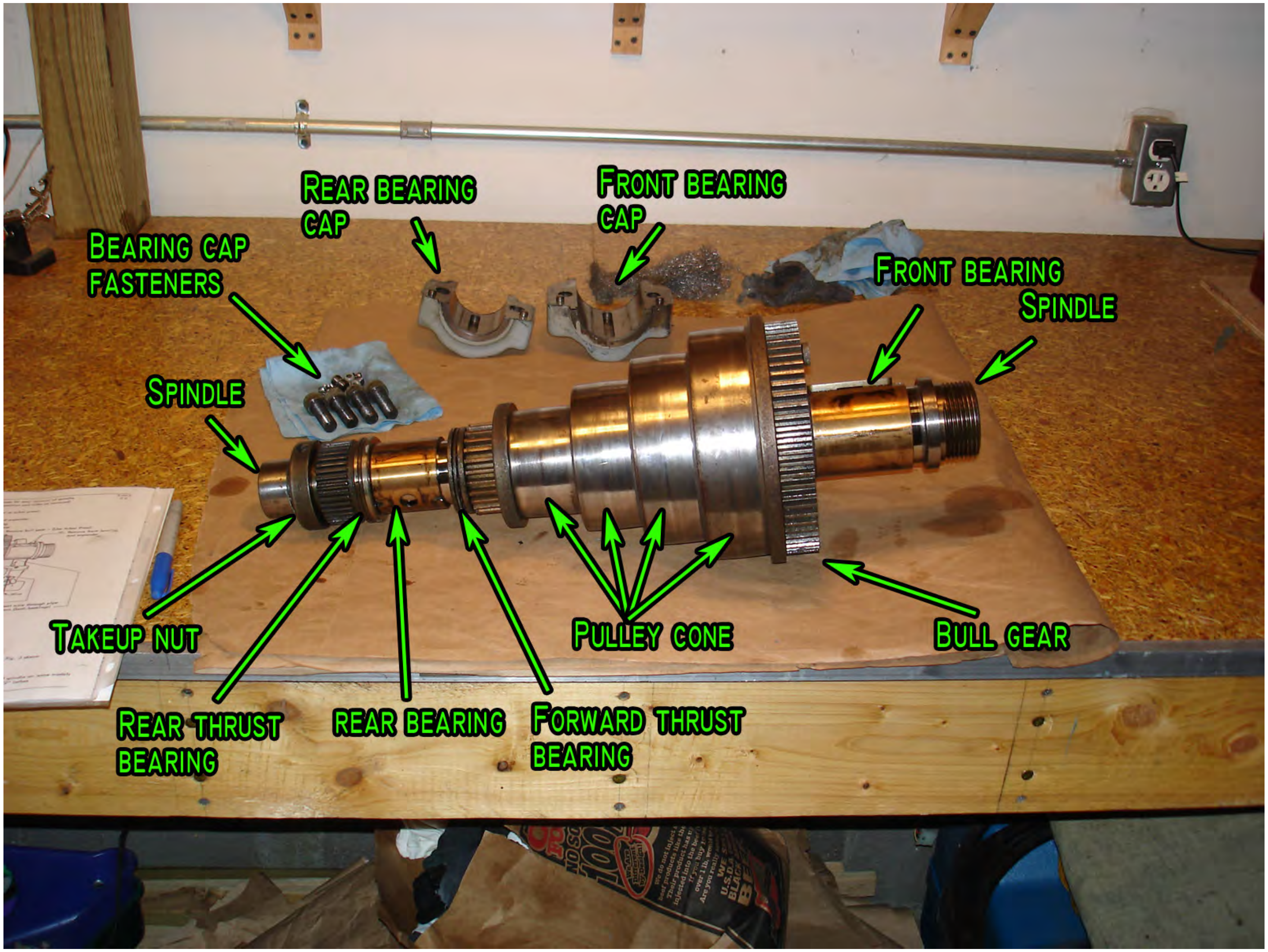


Figure 37: Complete headstock spindle assembly with important parts labeled.

5.1 Removal

Removing the spindle is straightforward, as described in detail by South Bend (look at http://www.wswells.com/data/howto/SBL_form_2002.pdf). We begin by removing the bearing caps **AFTER REMOVING THE EXPANDER SCREWS**! There are small bearing "expanders" installed in slots in the bearings that are used to spread the bearing slightly so that an oil passage between the spindle and the bearing is created.

In figure 38 I've removed the pipe plugs (which are socket-head), expander screws (which are slotted-head, beneat the pipe plugs), and the cap screws that retain the bearing caps. South bend says to use a rod to jar the bearing cap loose, and I agree with them - mine were stuck in place by the factory paint.

Figure 38 is showing the rear cap, but the front is exactly the same (although slightly larger). Notice I've backed off the takeup nut several turns, as instructed by South Bend in their form 2002 (linked above). According to South Bend Form 2002 the takeup nut is threaded on hand-tight, then backed off 3/8" and clamped down when in service.

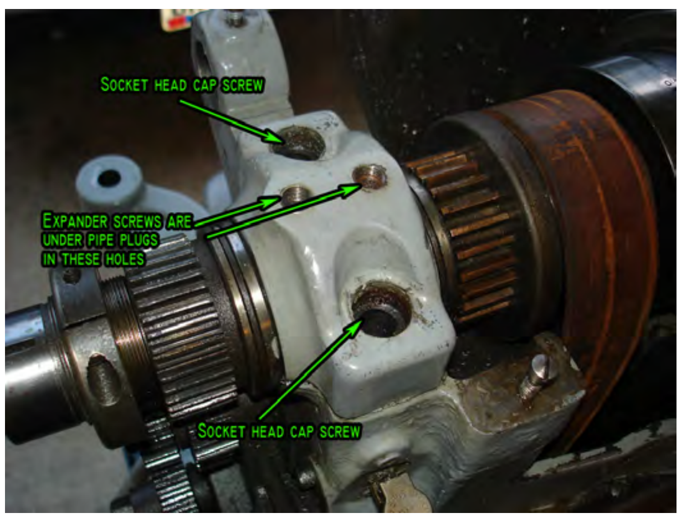


Figure 38: Removing the rear headstock bearing cap.

In figure 39 I've removed the front bearing cap and noted the various parts. I labeled the bull gear pin even though it has nothing to do with this discussion, merely because it's clearly visible in this shot.

It's dirty on the outside here - lots of oil "goo" - but otherwise appears to be in working order. It's hard to see but there's a tiny letter "F" stamped at the front of the bearing expander.

In figure 40 I'm showing the rear bearing with the cap removed, because there's an interesting problem - the bearing expander has (apparently) been installed backward! The little "F" stamped into it should be toward the "F"ront of the headstock, right?

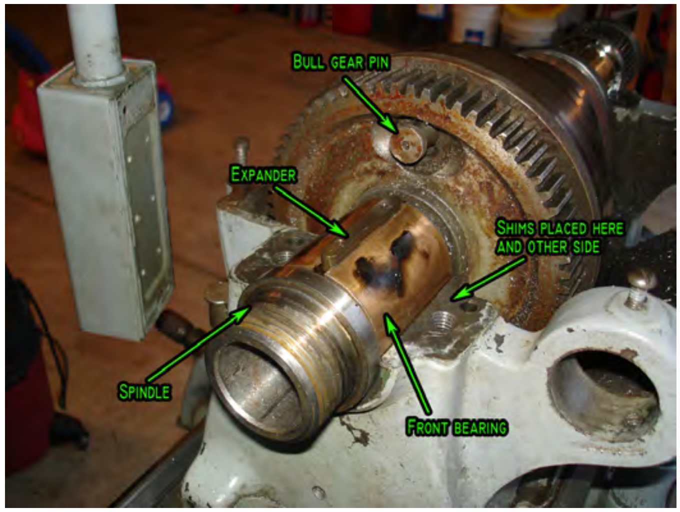


Figure 39: Front bearing with cap removed.

I suspect it was installed this way from the factory, although I could be wrong. It's not clear to me whether the orientation really matters on these, but there is a very subtle difference between the front and rear of the expander. The rear of the expander has a round radius to it, while the front has a tiny flat section. It'll be more clear when I show a closeup of the expanders...

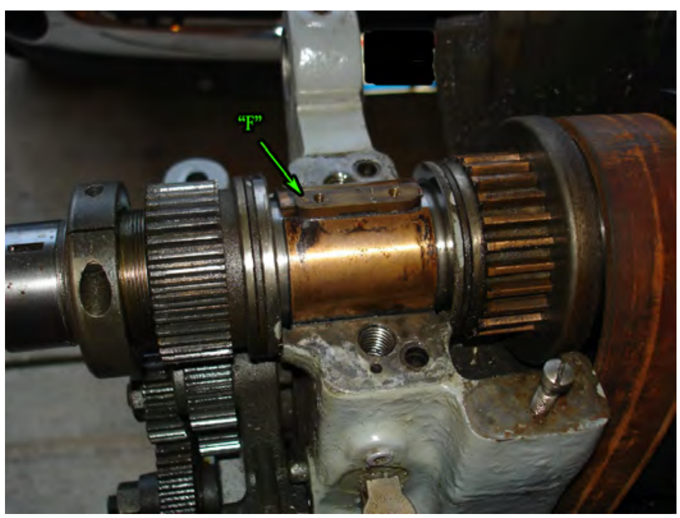


Figure 40: Rear bearing cap removed. Notice the "F" indicates this expander is in the wrong orientation.

With the bearing caps removed the spindle can be lifted out of the headstock.

This isn't necessarily hard, but there are two things to bear in mind:

1. The assembly is heavy - probably between 35 and 45 lb, and 2. The presence of the flat belt makes it difficult for one person to remove the assembly.

I suggest, therefore, that an assistant be employed when it's time to remove the headstock spindle. It's not strictly necessary (I did the job alone), but it really makes things easier. This isn't something you want to risk damaging in any way. I had to lift it out and set it back down 3 times before I got myself in a position where I could get it out through the flat belt. If you have someone else to hold the belt out of the way it would make the job much easier. Or, if you remove the flat belt.

5.2 Disassembly

With the spindle sitting out on the bench it can be disassembled. We begin by removing the takeup nut and the rearmost gear. The gear is not press-fit, so it simply slides off. It engages the spindle via the key as shown in figure 41.

Figure 41: Takeup nut gear and key.

Figure 42 the spindle with the takeup nut and gear removed. Once that little key is pulled out, both thrust bearings and the spindle bearing slide off the spindle. This is followed buy the pulley cone, which also slides right off.

Figure 42: Rear of the spindle with the takeup nut and gear removed.

Figure 43 shows the condition of the spindle in the area that was under the bearing. There are no score marks or damage of any kind. This is in excellent condition.

Figure 43: Spindle with rear bearing removed.

Figure 44 shows the spindle with the pulley cone removed.

Figure 44: Overview of spindle with pulley cone removed.

Figure 45 is a shot inside the pulley cone bearings. They look excellent. No visible damage. There's some tiny oxidation spots here and on the spindle, but nothing significant. When operating with back gears engaged this is one of the two bearing surfaces that permits a difference in speed between the pulley cone and the spindle. Notice the oil grooves.

5.2.1 Removing The Bull Gear

The bull gear is held to the spindle with a press fit, and locked in using a key. South Bend says to use an arbor press to remove the bull gear, but my press's throat is about 5 inches too short (the spindle is 16.5" long). So I had to come up with my own puller made from PVC pipe shown in figure 46.

Figure 47 shows the relevant parts of the press without the spindle. Notice I had to cut a notch in the PVC for the bull pin. This probably could be avoided

Figure 45: Closeup of rearmost pulley cone bearing.

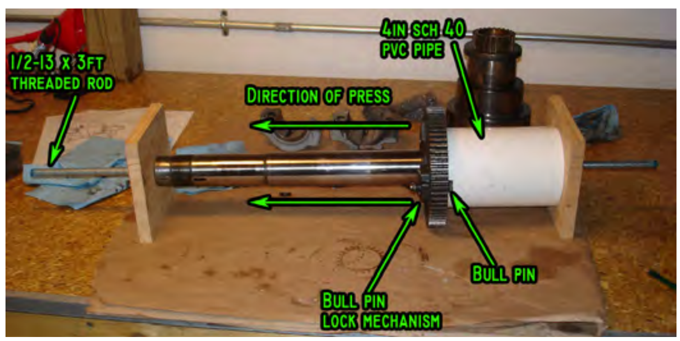


Figure 46: Method for pressing off the bull gear.

by using 6" PVC instead of 4", but I used what was to hand. PVC is nice because no matter what you do you won't harm the steel parts.

Make it at least 6.5" long to have sufficient room to press the gear until it can be moved by hand. The gear has a press fit over the section it's sitting on from the factory, and a very close fit through the area where the cone pulley mounts. But I was able to twist it by hand down the section where the cone pulley bearing surface is, once the gear cleared the keyway of the shaft.

The fit between the bull gear and the spindle isn't as loose as I would've liked, but gave no real difficulty to the tool. I tightened the press, then smacked the gear with a rubber mallet, which would jar it forward along the shaft a little. Then re-tighten the press and repeat.

Be sure to wrap the rear bearing area and takeup nut threads with tape before sliding the gear off as shown by figure 48. You can see a nick in the tape

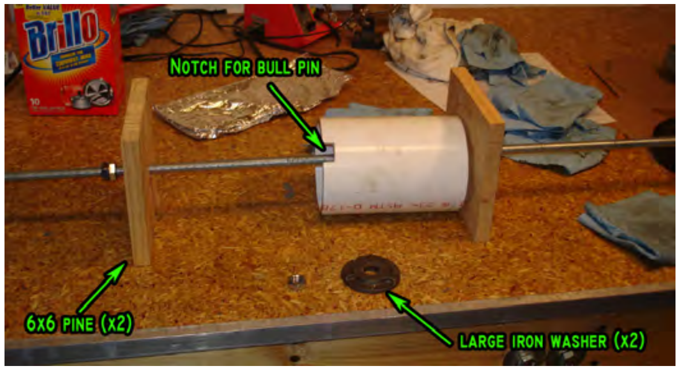


Figure 47: Detail of tool used to remove the bull gear from the spindle.

in figure 48, but it didn't penetrate down to the metal because I double-wrapped the tape.

Figure 48: Tape the rear bearing area of the spindle to protect it in case the bull gear strikes it during removal (as it did in this case).

5.2.2 Condition of the Bearings

Figure 49 is an extreme closeup of the rear sleeve bearing as it was removed from the spindle. Note the scoring on the bearing surface in the photo, which can be felt if you run your finger across the bearing.

And figure 50 shows the front bearing as it was removed from the spindle. Note the scoring, which doesn't appear as dark as the rear bearing because this

Figure 49: Closeup of rear bearing sleeve.

one is simply cleaner. As with the rear bearing, you can feel these grooves with your finger.

5.2.3 Bearing Damage Due To Expanders Being Pulled Out

I thought, given the condition of the paint on this machine, that the bearing caps had never been removed. I now understand I was quite mistaken, as figure 51 proves.

When removing the bearing caps first remove the expander screws completely! Here we see first-hand the carnage that occurs when this advice - which South Bend took the time to print clearly on a brass plate affixed to the inside of the headstock cover - is not followed. Honestly, how dumb do you have to be to do this? Whoever had this apart knew enough to mark the front of the bearing with an "F" (which is in the instructions from South Bend), but didn't know enough to remove the expander screws first?

The rear bearing shows no such damage, which leads me to believe whoever

Figure 50: Closeup of front bearing sleeve.

did this tore into it, broke the bearing, then went back and read the instructions before continuing.

When you don't first remove the expander screws, you end up pulling the expander out from the bearing by force. Something has to give, and in this case it was the bearing shell. It would have been more convenient if the expander had broken - it's a lot cheaper than a new bearing.

Fortunately, I don't think this bearing is trash. I've seen this machine run, and the bearings are silent and smooth. The only issue I had with it is the clearance, which measures 0.002" (it should be betweeo 0.001" and 0.0015"). I should be able to properly set clearance when I reassemble it despite this damage.

It turns out the rear bearing, which I thought was completely undamaged, has suffered from someone reassembling the bearing cap with the expander sitting atop the bearing (rather than in the slot cut in the bearing). This has the unfortunate effect of placing indentations in the bearing which precipitate corresponding raised sections in the slot. I've tried to show one of these raised areas in figure 52. It's difficult to see, as the camera doesn't have a very effective macro mode.

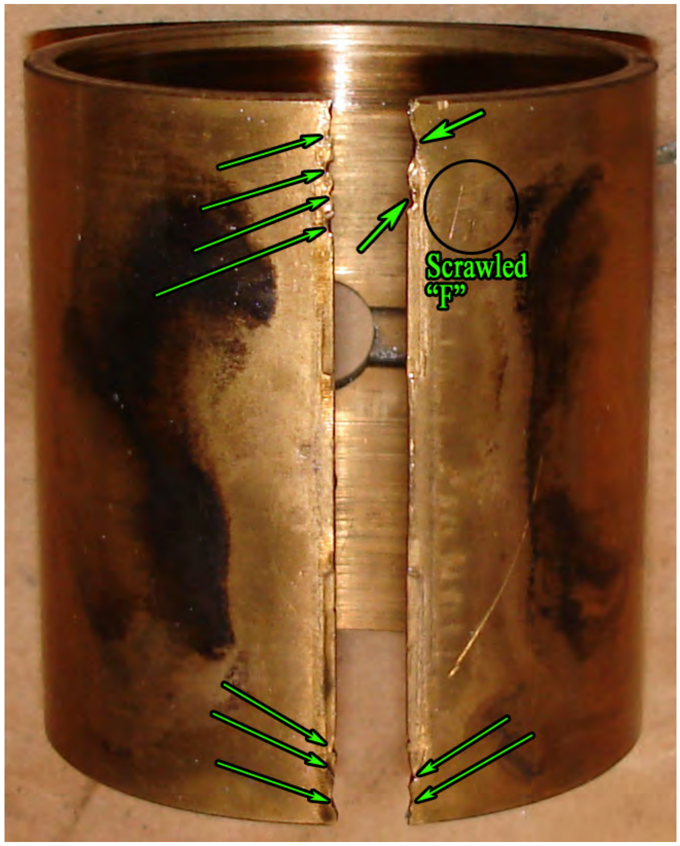


Figure 51: Front bearing showing where damage has occurred from the bearing cap being removed without first pulling the expander screws. The expander has been pulled straight through the bearing shell.

Suffice to say there were two raised sections in this slot, and two corresponding indentations on the top of the bearing. Much better photography of this situation on another machine may be found here: http://www.practicalmachinist.com/vb/south-bend-lathes/16-sb-spindle-bearing-question-s-128253/.

I used a smooth mill file to gently file away most of these protuberances.

5.3 Reassembly

To reassemble the spindle we begin by putting the front bearing in place, ensuring the "F"ront of the bearing and its expander are properly oriented. Once the back gear has been installed it's not possible to remove the bearing, so it's important to get it right the first time if you don't want to have to press the back gear off again. Figure 53 shows the entire spindle.

Figure 52: Cleaned rear bearing showing where expander has damaged the bearing by being reinstalled on top of the slot rather than in it.

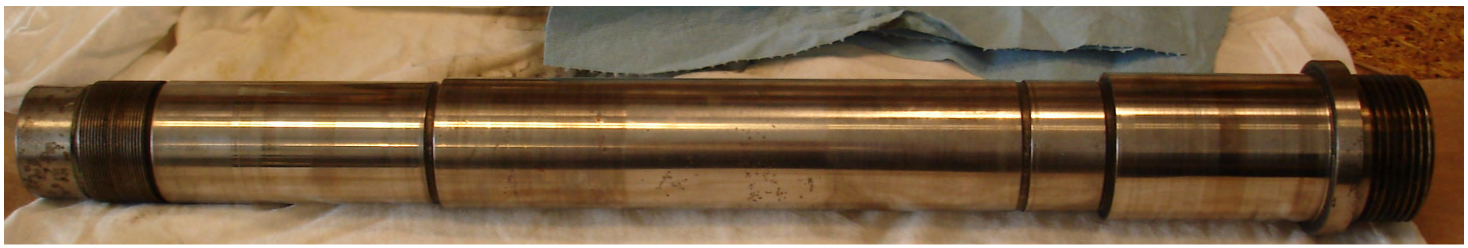


Figure 53: Overview of cleaned spindle.

Before I show the back gear going on, I thought I'd show a couple closeup shots of the spindle. We see in figure 54 the spindle has been discolored with what looks like grooves in a record. These lines are so shallow that I can't feel them with my fingers - neither the skin nor the nails. The spindle comes "superfinished" and hardened from the factory, which means the surface roughness is under 0.00005" (I think). Obviously something has happened to the spindle in this area, but it's not clear what.

Figure 54: Closeup of front spindle bearing area.

5.3.1 Some Detail of the Bull Gear

Figure 55 shows some more detail of the bull gear itself, with particular attention to the locking mechanism. The only part missing in figure 55 is a thin metal plate that helps retain the sliding block.

Figure 56 shows an end-view of the pulley cone behind the bull gear. Notice the pockets where the sliding block engages.

5.3.2 Installing the Bull Gear

Next we slip the front bearing shell and expander onto the spindle and install the back gear press shown in figure 57. As for the removal, this press was made from a bit of 4" PVC, notched in the appropriate areas to clear the bull pin mechanism and a large counterweight cast into the back gear for balancing.

This press worked remarkably well, even though it's pretty much impossible to get it precisely centered on the spindle. As I commented before, the bull gear isn't a very tight press fit, and it didn't take much effort with the wrench to get it to slide back in to place.

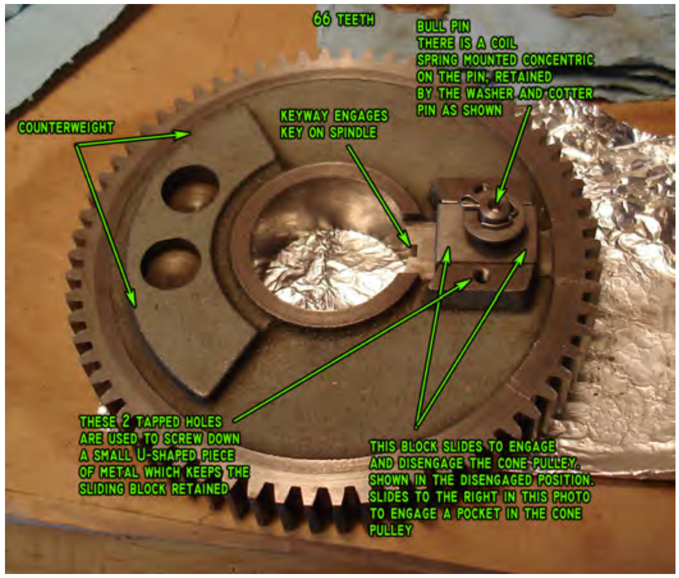


Figure 55: Details of the back side of the bull gear.

It seems somewhat odd that the gear is a press fit at all. There's little reason for a press fit here, since the gear is keyed to the shaft. The presence of that key, in fact, makes the pressing operation that much harder, since you must ensure the keyway on the gear will clear the key during the press. The only reason for the press fit, then, is to prevent the gear from walking off the shaft. But since this is a straight-cut gear, the axial load is going to be tiny (if any), and the thrust bearings can take up any such load with no problem.

Note the proper orientation of the bull gear, with the bull pin facing FORWARD. That's very important. The gear butts up against a shoulder on the spindle when it's been properly positioned as shown in figure 58.

5.3.3 Reinstalling The Headstock Spindle

Note: in the following text, when I refer to "sides" of the bearing I mean the parts closest and farthest from the camera in the photos. The closer side, which is the side where the operator stands while running the lathe, will be called the "operator side", while the opposite side will be called the "far side".

Figures 59 and 60 show the spindle reinstalled, but lacking the bearing caps. For this part you definitely want 2 people and a long dowel rod of some kind placed in the spindle to help carry it. It can be a little tricky to get the oil wick hole on the bottom of each bearing shell to slide onto the oil wick tube. The danger lies in accidentally pressing the oil tube into the casting with the weight of the spindle.

Figure 61 shows my method for reducing the chances of pressing the oil tube in as well as retaining the oil wick during assembly. I used a 3/16" rod through

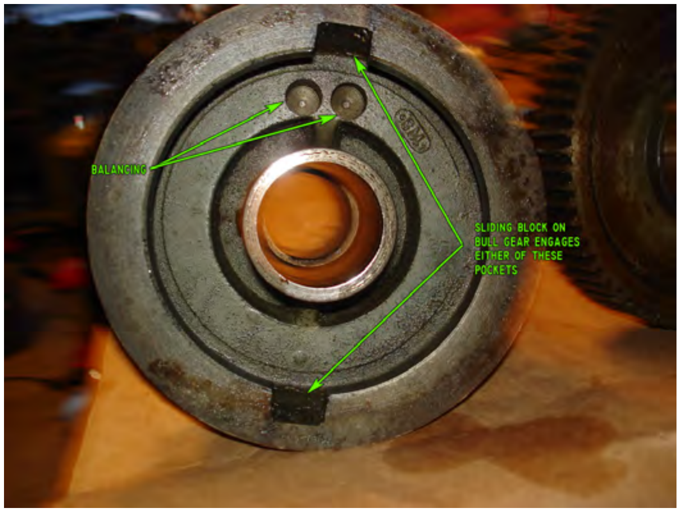


Figure 56: Inside of headstock pulley cone showing features that interact with the bull gear.

Figure 57: Bull gear being pressed on.

the top oil port, which runs right through the hole in the oil tube I showed on the REFERENCE TO HEADSTOCK CASTING SECTION. Before installing the spindle, you press the wick down and put the rod in to hold it. The rod will also retain the oil tube in case you make a mistake and drop the spindle into the casting. After the spindle is installed you pull the rod out and the wick springs up to contact the spindle. This is the method recommended by South Bend.

Figure 58: Bull gear installed.

Figure 59: Reinstalled headstock spindle showing rear bearing.

The next step is to install the bearing caps and set the spindle clearance using shims. On the REFERENCE TO HEADSTOCK CASTING SECTION I describe and show pictures of my initial shims, which were 0.015" brass. When I got the lathe it had 0.0025" clearance (as measured per the South Bend procedure) using 0.017" shims on both sides of both the front and rear bearing.

South bend says to run 0.0007" - 0.001" clearance in the bearings. This is measured by pulling up on the spindle with a force of "approximately 75 lb".

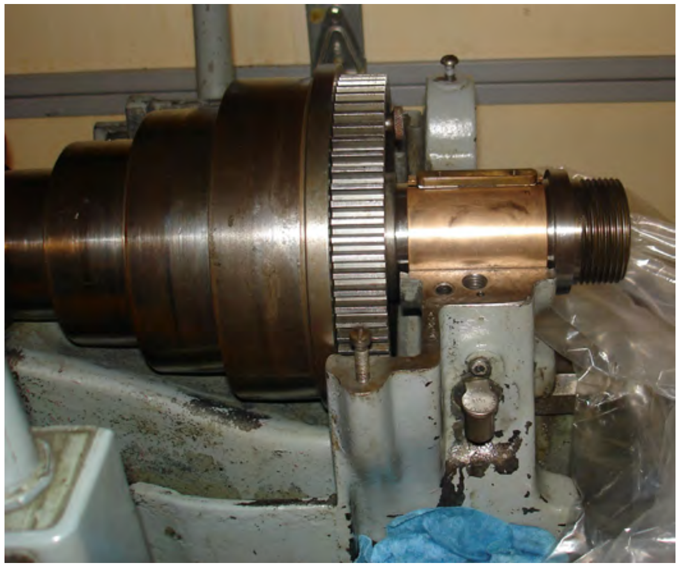


Figure 60: Reinstalled headstock spindle showing front bearing

Figure 61: Wick retention rod.

It is virtually impossible to be precise with that 75 lb specification - I tried it standing on a bathroom scale and found it extremely difficult to do accurately. I'd prefer to run close to the 0.001" specification to keep the bearings from heating up too much. I'm willing to sacrifice some precision in the lathe in exchange for assured bearing life.

With only 0.015" shims the spindle locked. With 0.016" shims on both sides the clearance was something around 0.002" (front and rear).

Front bearing. 0.015" on the operator side and 0.016" on the far side gave an indicated clearance of 0.0012" - 0.0015", depending on how hard I pull up on the spindle.

Rear bearing. 0.016" on the operator side and 0.015" on the far side gave an indicated clearance of 0.001" - 0.0015", again depending on how hard I pull up on the spindle.

These clearances are larger than the maximum specification, but my inclination is to leave them alone. As it stands, it seems like there's a lot of drag on the spindle. If I spin it by hand without the chuck in place I get between 1/2 and 3/4 revolution before it stops. With the chuck installed, I get around 3 turns before it stops.

More disturbingly, I've noticed the drag decreases for about 1/4 of the rotation, suggesting something is binding up for 3/4 of the rotation.

6 Reversing Gear Train

The reversing geartrain is used to control whether the gearbox (and hence the leadscrew) rotate in the same direction or opposite direction of the headstock spindle. Instructions for removing the lower portion of the gear train – the parts that mate with the gearbox – see section 11.1 on page 108.

As shown in figure 62, if the selector level is moved up to the upper detent, gear "A" engages the gear on the headstock spindle, which causes the gearbox and leadscrew to rotate in the same direction as the headstock.

On the other hand, if the selector lever is moved down to the lower detent, gear "B" engages the gear on the headstock spindle, which causes the gearbox and leadscrew to rotate in the opposite direction as the headstock.

In figure 62 the selector is positioned at the center detent, which is neutral. Neither "A" nor "B" are engaging the spindle gear.

As I note in the photo, the nut on the bottom gear (aka the stud gear) is threaded onto the gear shaft, and rotates with the gear. The nut shouldn't be very tight. To remove it you'll need to lock the spindle using the back gear. To do this, simply engage the back gear with the lever and don't pull the bull gear lock pin out.

If, like me, your back gear isn't installed when you get around to working with the reversing gear train, you'll need to find a way to hold the bottom gear fixed whilst loosening the nut. I clamped a pair of Vise Grips to the gear on the front and rear faces (back away from the teeth) to wedge against the central casting. This held the gear while I loosened the nut. I did this with the reversing gear assembly removed from the headstock.

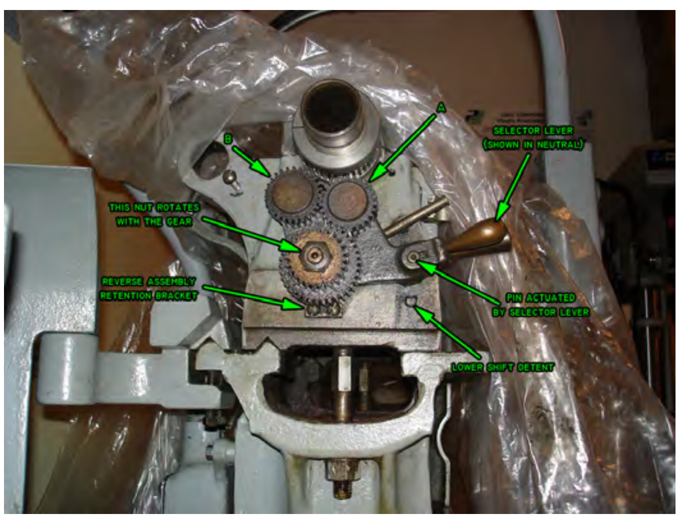


Figure 62: Reversing gear train prior to removal.

To remove the reversing geartrain, simply remove the two slotted screws that retain the reverse assembly retention bracket (bottom of figure 62). The whole assembly then slides right out of the headstock casting. You must remove the takeup nut on the spindle (if installed) to clear the reverse gears!

Figure 63 what it looks like removed from the headstock. The nuts that retain gears "A" and "B" don't rotated with the gear, so they're easily removed.

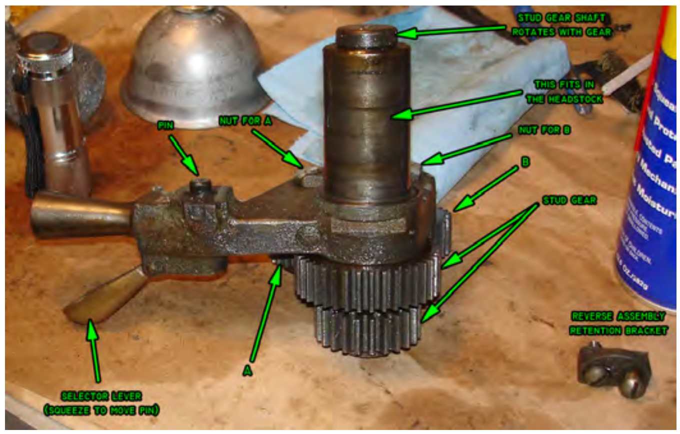


Figure 63: Reverse gear train removed from the headstock.

Dismantling this is straightforward. Remove the stud gear nut, and the two nuts that retain "A" and "B". Drive out the small pin that retains the selector lever to remove it and the pin. There's a strong spring around the pin, which will shoot the pin across the room when the selector lever is removed!

Figure 64 shows gears "A" and "B" removed and sitting in the background on their shafts. It's a good idea to mark which side each gear and shaft goes. If the lathe is old the gears will have worn according to their position, and it's probably worth putting them back where they were.

I removed the smaller of the 2 stud gears using a gear puller, because there's plenty of clearance between them to get the puller jaws in there.

To remove the larger stud gear you'll need to drive the shaft out by pounding with a hammer. But there is great danger in this. I slightly damaged the key in the shaft and the reverse casting because the key was in just the right position relative to a felt wick groove in the casting. Figure 65 shows how I damaged it. There was no way to see what was going on with the stud gear in place, so I had no way of knowing what I was doing. Thank God the key is made of soft steel and the damage to the casting is almost undetectable. To avoid doing this, I suggest:

1. If possible, pull the key out before driving the shaft off. This wasn't an option for me, because the key fit too tight with the stud gear.

2. Rotate the shaft so that the key is in front of a section of the casting away from the felt wick groove. This should cause the casting surface to push the key out as you drive the shaft.

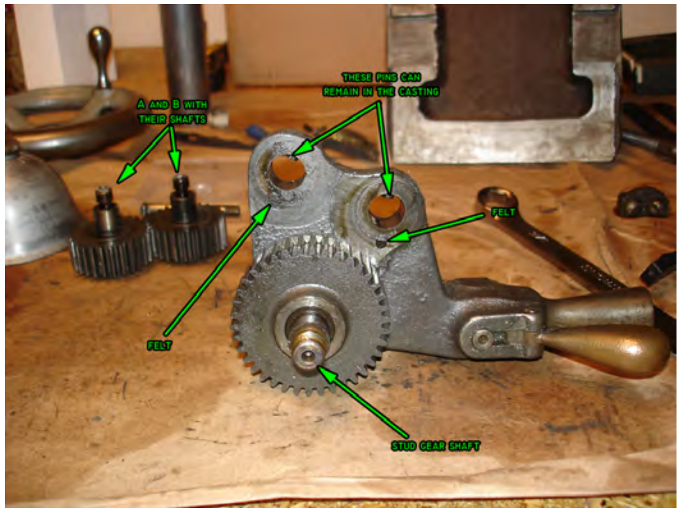


Figure 64: Reverse gear train with gears “A” and “B” removed.

The key cleaned up nicely with a file, and the damage won’t harm the operation of this assembly.

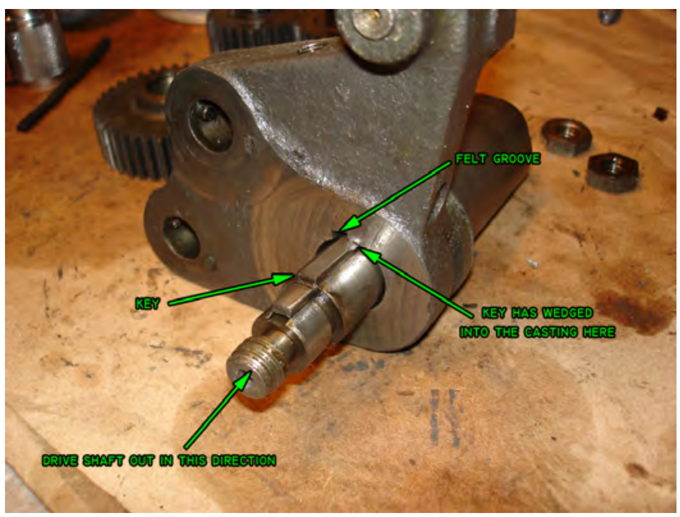


Figure 65: Reverse gear train showing how the main shaft key was improperly installed and damaged.

The reverse gear casting has a series of oil rifles drilled through it which form a sort of oil reservoir for feeding oil (via wicks) to the reverse gears. Figure 66 here shows the position of the oil rifles and the wicks that I found installed. The semi-transparent green lines in the photo are indicating the oil galleys drilled into the casting. This is a fairly complex felt scheme. The top felt carries oil across each of the two holes behind gears "A" and "B", as shown. At each of those holes, oil is transferred to another felt that carries it out to yet a third felt embedded in a groove in each shaft for "A" and "B". There are a total of 7 felt wicks in this assembly!

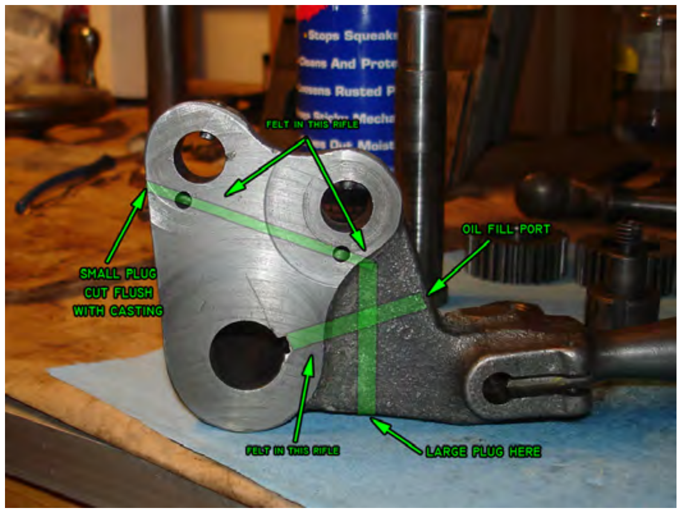


Figure 66: Reverse bracket showing location of felt passages.

6.1 Removing the Large Plug

In order to remove the wicks you'll need to remove the plug in the casting as shown in figure 67. To do this, drill a hole and tap it for a small screw which is then threaded into the plug to pull it out. I used a #10-24 machine screw to do this, but anything between a #6 and a #12 should work fine.

Figure 68 shows my setup on the drill press to bore a small hole (for a #10-24 screw) in the plug. Notice I'm nowhere near center, which didn't have any effect on my ability to pull the plug out. This plug is rather thick, and will take a thread nicely.

Figure 69 shows my crude method for pulling the plug. I threaded a machine screw into the drilled/tapped plug, then held the head of the screw in a vise. I then struck the casting as shown with a hammer until the plug was freed.

Conveniently, the hole size for the plug is compatible with 1/8-27 NPT threads. Actually, it's a little oversized for 1/8" NPT, but since we're only trying to seal against an extremely light pressure it doesn't matter that the threads are exactly the right dimensions. All you have to do is run a 1/8-27 NPT pipe tap in the hole 3/8" or so and you can insert a 1/8 NPT pipe plug. This will permit easier maintenance in the future.

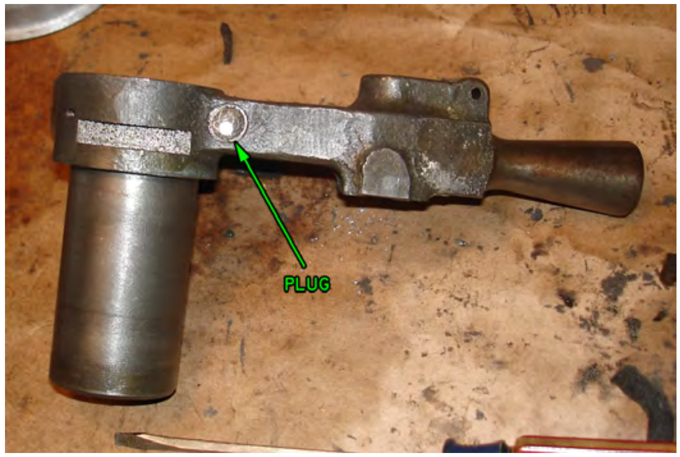


Figure 67: Reverse gear casting showing plug.

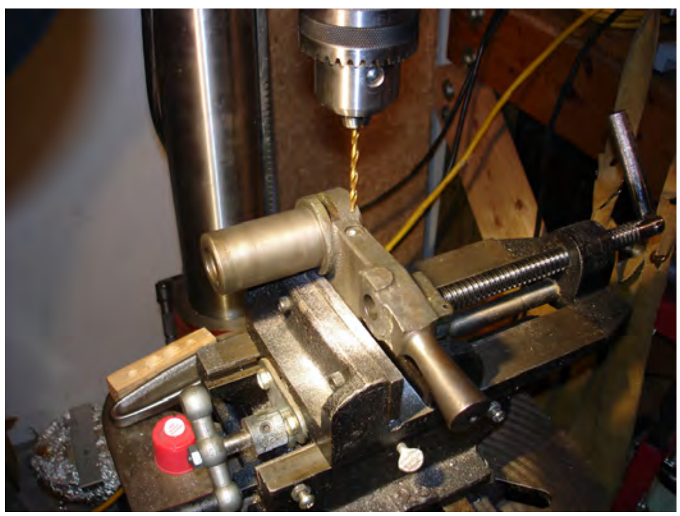


Figure 68: Drilling a hole to remove the plug in the reverse gear casting.

6.2 Rmoving The Small Flush-Cut Plug

With the big plug removed you can fish all the felt out of the cavity with a small pick and pliers. However, there is another plug that you may consider removing as well - one that is substantially more difficult. Figure 70 shows the location of the plug, with the location of gear "B" noted to help the reader understand the orientation of the casting in the photo. This plug is closing off the upper oil rifle, and has been cut flush with the casting. It's not a plug in the same sense as the larger one - it's merely a piece of 3/16" steel rod pressed into the end of

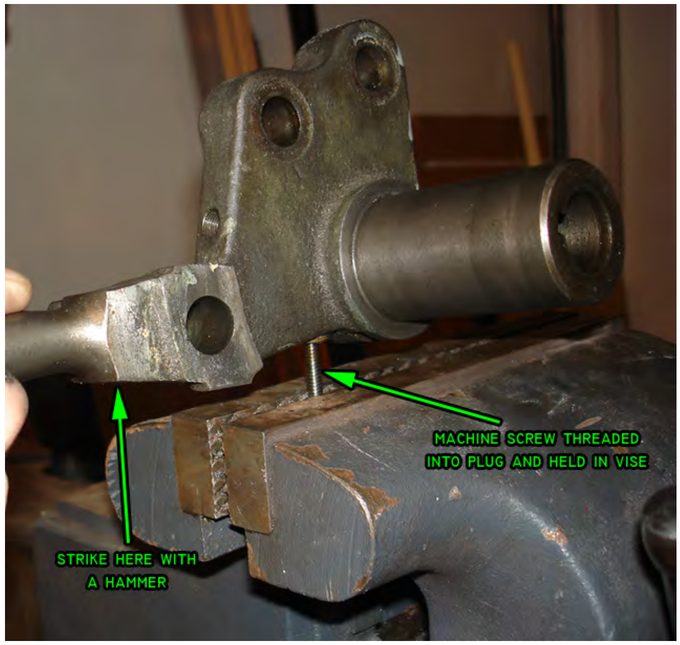


Figure 69: One method for removing the plug in the reverse casting.

the top oil rifle (which is 3/16" diameter).

Figure 71 shows the operation finished, with a 1/16" NPT pipe plug installed. The photo was taken with the casting held in a vise on the drill press where the plug was drilled out, the hole tapped, and the new pipe plug installed.

To begin the process of removing that 1/16" plug in the top oil rifle I used a 3/16" drill bit, which is the same size as the top oil rifle shown in the figure 66. There is danger in doing this! I failed to properly orient the casting with the drill bit by assuming the plug was perpendicular to the casting surface. In reality, it moves at an angle as shown in figure 66. This caused me to bore my hole offset from the oil rifle, and nearly penetrate the hole for the gear "B" shaft! Please learn from my mistake. If you decide to drill out this plug, may I suggest the following:

1. A better way might be to drill a small hole in the plug, say for a #6 machine screw. Tap the hole and try to pull the plug using a similar method what I've shown for the large plug.

2. Or, if you decide to drill out the plug with a 3/16" bit, carefully orient the bit so that you're drilling concentric with the oil rifle! It's okay to be off a little, but too much will result in penetrating the hole for the gear "B" shaft.

After drilling the plug out it's easier to install felt in the top oil rifle, since

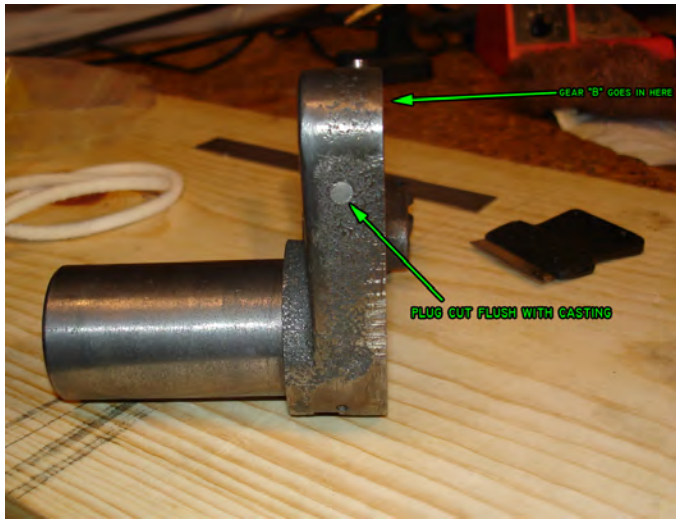


Figure 70: Reverse gear casting showing the second plug to be removed.

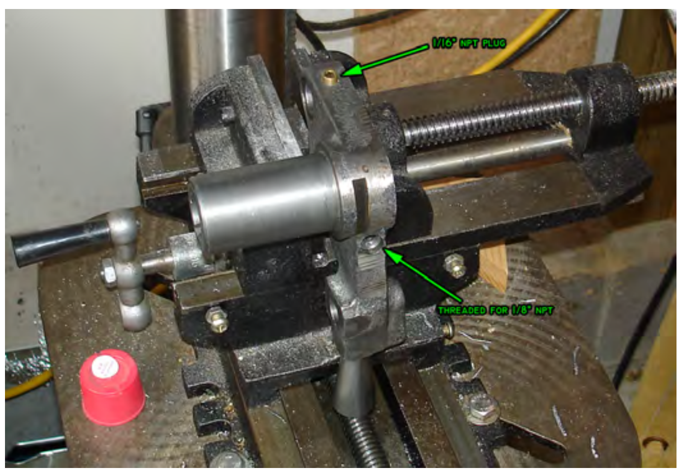


Figure 71: Reverse casting showing where 1/16" pipe plug has been substituted for the 3/16" plug that was previously in place.

you have direct access to it. I attempted to install the wick before removing the plug, and found it too difficult. But I believe with a little patience it might be possible to stuff new wick in the top oil rifle without drilling out the plug. For example, it's probably possible to thread a wick in there via the main (vertical) oil rifle.

I was left with a rather large non-round hole when I got done drilling (since I drilled at the wrong angle, as mentioned). I tried a few different ideas for plugs and finally settled on a 1/16" NPT plug. To do this, I had to drill a 15/64" shallow hole in the casting centered at the top oil rifle. If you do this, you can only drill to a depth of around 3/8" at most, since any deeper would risk penetrating the hole in the casting for the gear "B" shaft. Simply tap the new hole and insert the plug, as shown in figure 71.

6.3 Felt Types

I used 1/8" F1 cord for the felt in the upper oil rifle and the little holes that feed the upper gear shafts. For the bottom where the stud gear shaft runs, I used 3/16" F1 cord at the oil rifle.

The felt grooves in this assembly call for either F10 or F5, since it must be compressed. I decided to use F10.

7 Headstock Casting

Here we discuss the headstock casting, which is the fixed emplacement used to hold the headstock spindle. It includes the spindle lubrication system and the reverse geartrain.

Figures 72 and 73 show the casting just after removing the spindle. Figure 73 has the important parts of the bearing lubrication system labeled. There's an oil reservoir just beneath the bearing area in the photo, and a corresponding reservoir at the front bearing.

Figure 72: Overview of headstock casting with spindle removed.

7.1 Issue With Front Oil Wick Tube

There was a problem with the front bearing, shown in figure 74. There's a brass tube in which resides the wick, both at the front and rear bearing. This tube also serves to orient the bearing shells when they're installed, as they fit into the large hole on the bottom of each shell (see figures 49, page 47 and 51 on page 49 for a look at the holes where these tubes fit).

The tube should be proud of the surface by about 0.1". As you can see in figure 74, it's sitting just slightly below the surface. There's also an oil hole in the tube that should be aligned with a corresponding oil rifle provided in the headstock casting; alignment of that hole is impossible with the tube in this position.

Only the front bearing looked like this - the rear oiler tube was properly positioned proud of the surface by about 0.092" or so. It's not clear to me whether this was old damage, or if I did it when I had to set the spindle back down in the casting 3 times whilst attempting to remove it from the machine

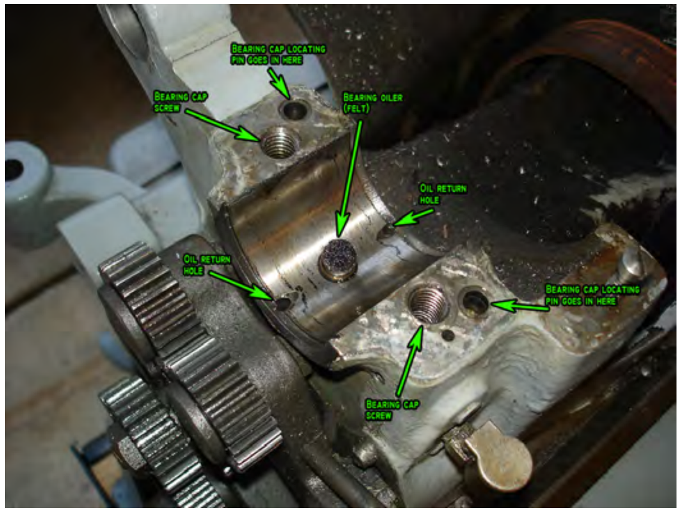


Figure 73

alone. It may not be critical to have it sticking up, but if it can be fixed, it should be.

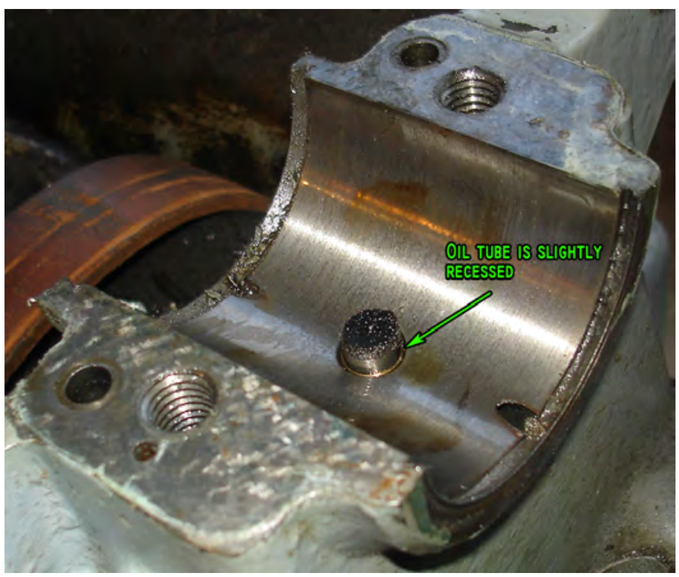


Figure 74: Front bearing showing recessed lubrication tube.

The problem with repairing this is there's nothing to grab on to, and the oil tube is only ∼3/8" diameter. It's pressed into the casting, but initially I wasn't sure just how tight the press fit is.

Turns out the fit is not very tight at all. Figure 75 is a "tool" I made to pull up the tube. It's a piece of 1/8" welding rod (6011, not that it matters) that I heated and bent a tiny (∼1/8") hook into. I inserted this into the oil tube, and hooked it into the quadrant that is farthest from the operator when facing the machine - that area has a void in the casting where the hook could engage the bottom of the oiler tube.

Initially I pulled up by hand, while I was experimenting with whether this was going to work. I managed to move the tube up so that it was flush with the bottom of the casting surface using my bare hands. This made it clear the press fit isn't very tight, which is good.

To go the rest of the way, I clamped a pair of vise grips to the rod, hooked into the tube, and tapped upward on the pliers. The tube easily popped up, with no damage. I pulled it up farther than necessary, then gently drove it back into proper height using a piece of wood and tapping with the hammer. I set it right about 0.1" proud.

Figure 75: Tool used to extract the oil tube from the front spindle bearing casting.

In figure 76 I'm showing the tube a little higher than it needs to be because I wanted to highlight the little hole for the oil passage. The oil passage with which that hole must be aligned is located to the right in the photo, pointing toward the operator-side of the lathe.

7.2 Clean Headstock

Figure 77 shows the headstock cleaned up quite a bit. I used mostly extra-coarse steel wool and mineral spirits to remove the thick cake of crud. I finished up with a careful scrubbing with a rag soaked in acetone.

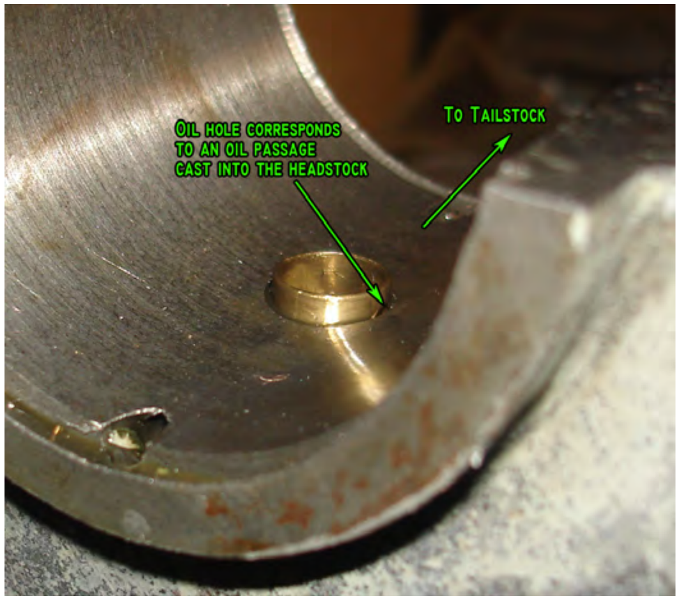


Figure 76: Oil tube properly repositioned.

It's not as good as if I had removed the casting and soaked it in degreaser, but it's really not bad, as you can see. Actually it looks better in person than in the photo. I'm reluctant to pull the headstock casting because I don't want to deal with realigning it.

Let me comment briefly on the paint job here. I thought the paint on this machine was factory original, but now I'm not so sure. There are clearly 2 layers of paint to be seen in the headstock casting, but the color is very similar. The top layer of paint has drips that have run down into the casting. But if it was repainted, whoever did it did a halfway decent job. There are no brush strokes, and only minor drips on various brackets and parts.

However, the top coat hasn't adhered well to the paint beneath, as it chips off very easily. It would really be nice to completly strip this machine and repaint, but I'm reluctant to do so because, 1) the paint doesn't look too bad, and 2) I don't want to have to realign everything.

7.3 Headstock Felts

For about $5 I got a nice little "Felt Handbook" from McMaster-Carr that came from Buffalo Felt Products Corporation. It has samples of 9 common felts with descriptions of what each is used for. Definitely worth the $5, and I recommend it to anyone working on felt-oilers.

With the casting cleaned up I turn my attention to the spindle lubrication system. South Bend used a simple, effective, and basically foolproof method of lubricating the spindle bearings - felt wicks. Shown in figure 78 is a disassembled

Figure 77: Cleaned headstock.

felt wick from the rear bearing.

We find 3 key components - the top felt, bottom felt, and spring retainer. The top and bottom felts appear to be of two different types, but it's not clear exactly what type they are. After some research, I believe the bottom felt was actually a type of yarn, bundled and stuffed into the spring.

I thought the top felt was F1, but when I bought a replacement wick from LeBlond[2] I found it's clearly not F1. It looks more like perhaps F5, which has similar applications to F1 but is less dense. See a description of different SAE felt grades at http://www.sefelt.com/saeover.htm.

It's difficult to tell whether the bottom felt has such low density because it's been partially dissolved by the oil, because it was designed that way (yarn), or because the acetone I used to clean it partially dissolved it. I believe it's actually felt yarn, and was intentionally loose as I found it. Felt yarn isn't readily available anymore, so I intend to replace it with some SAE felt.

Read these descriptions (courtesy Buffalo Felt's website):

SAE F-1 is suitable for oil retention in installations where the felt is not compressed, for feeding low viscosity or light oil, and where unusual strength and hardness are required.

SAE F-5, F-6 & F-7 are recommended for dust shields, wipers, grease retainer washers, wicks, vibration mountings, and in uses where a resilient felt is required.

SAE F-10, F-11 & F-12 are recommended for grease and oil retention where the felt is confined and compressed in assembly.

Looking at F1 versus F10, the F10 is markedly less dense - possibly consistent

[2]At the time this document was produced the entire South Bend inventory was owned by LeBlond corporation.

with the bottom felt that I pulled out of the machine. You need a less dense felt in the bottom portion of the spring so that the entire wick can be compressed by the spindle. F1 is very resistant to compression, and probably wouldn't be "squishy" enough to provide proper spring pressure to the wick.

It's possible to purchase new wicks direct from Leblond for \$15 plus \$6 shipping. As I mentioned earlier, I bought one so I could examine it. I believe what they're using is a lower "felt" made from some kind of cotton-based yarn, and a top felt made from an SAE grade.

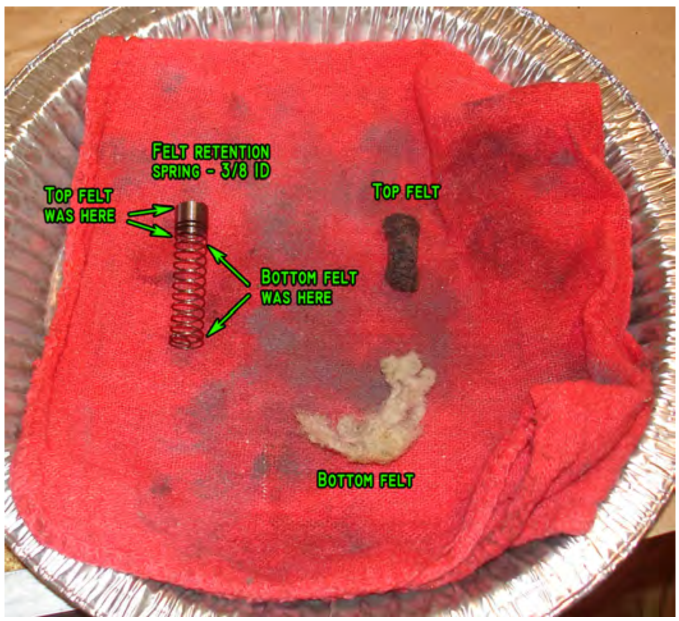


Figure 78

7.4 Making New Wicks

I've chosen to make my own felts - I prefer to be as self-sufficient as possible, and \$15 each for LeBlond-brand felts is awfully expensive. It is my hope that what I've done here will inspire you to make your own rather than giving in to Leblond's price.

I decided to make the bottom felt out of F10. It's not possible to buy F10 in cord form, so I bought a 12"x12"x1/8" sheet from McMaster-Carr.

Some experiment had to be made to determine the proper dimensions and method for getting a bit of F10 inserted in the spring. I settled on cutting a piece 5/8" wide by ∼1.5" long. Such a piece, folded in half lengthwise, twists itself rather nicely into the lower part of the spring. To do this, I first folded the felt in half lengthwise, then "threaded" it into the spring from the top.

For the top felt, I decided to use F5, which is significantly less dense and less firm than F1. F1 is too hard and incompressible to use here, and F5 will flow more oil than F1 in general. Unfortunately, I couldn't locate F5 in cord-form, so I had to buy a strip of it 1" x 3/4" in cross section (again from McMaster-Carr).

I cut myself a small block from the F5 strip, then used a razor blade to trim it until it was mostly round and small enough to fit inside the spring. F5 is much more consistent with the felt at the top of the new wick I bought from Leblond, although it appears the Leblond stuff is very low-grade, low-density, low-firmness felt. F5 is rather high quality stuff.

The resulting wick is shown in figure 79. Indeed, the spring compresses as desired, although the force required to do so is considerably higher than the old felts. That may be because the old felts were quite worn, or it might be that this wick design packs too much felt into the spring.

The nice thing about using the big F5 strip to make my top felts is I was able to customize the shape a bit. The felt I made is slightly larger diameter at the top, so that slightly more of it is in contact with the spindle. That should provide a little more lubricant to the spindle.

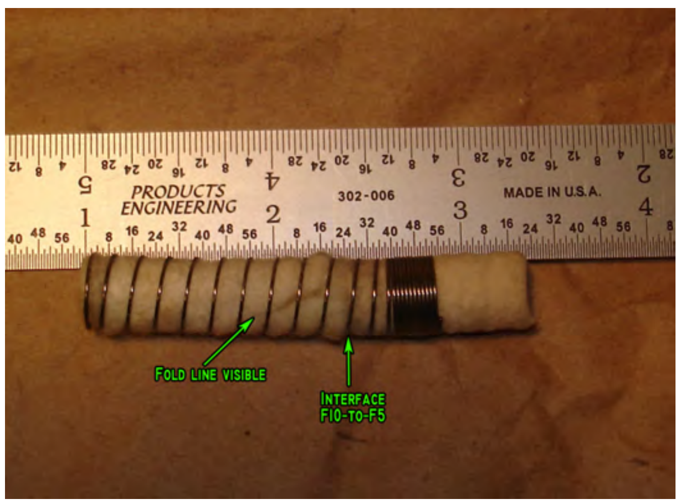


Figure 79: Parts of a newly made felt wick using the original equipment spring retainer.

I wanted to do an experiment to determine whether my wicks would perform properly. So I set them in oil and watched how long it took for oil to saturate the top felt. The experimental setup is shown in figure 80.

I carried out 2 experiments: compressed and uncompressed. In each case the wick was submerged as shown in ∼1" of Mobil Velocite 10 spindle oil, as specified in the South Bend lubrication literature. The uncompressed case is shown in figure 80; the compressed case was carried out on a wick that was compressed as though in the headstock with the spindle installed.

These experiments are worst-case, since in service the oil level is actually

	Uncompressed	Compressed
Time to saturate bottom felt	<60s	<20s
Time to saturate top felt	8 min	6 min

Table 2: Results of new wick experiments in oil. See figure 80 for setup.

within 1/2" of the tip of the wick. That means the wick only needs to pull oil up a very short distance. They show that this arrangement is acceptable. Furthermore, we find that the F10 felt acts to quickly move oil from the reservoir up to the top felt, where it is retained until transferred to the spindle.

After putting the whole spindle back together I ran it at top speed for about 10 minutes. The bearings reached a temperature somewhere between 105F and 110F. Spindle movement is extremely smooth.

Figure 80: Spindle wick experiment.

7.5 Shims

7.5.1 Rear

The shims I found beneath the rear bearing cap were badly mangled. They are obviously not the original equipment - or, if they are, someone really did a number on them. I measured each and found them to be between 0.015” and 0.017” thick.

So I bought a small sheet of brass shim stock 0.015” thick. I used some blue layout fluid to transfer an impression of each bearing cap onto a sheet of paper. The impression was then scanned, and a CAD model was created as a template for making new shims. The rear shims are shown in figures 81 and 82 (there are two drawings because my rear bearing is slightly different on each side). If you print the photos at 1:1 scale they are the correct size for the real thing. The small hole is 5/16” diameter, and the large hole is 9/16” diameter.

After quite a bit of work I ended up with the replacement shims you see in figure 83. It was a lot of work because:

1. 0.015” brass sheet is harder to cut than you think. Use a good pair of metal snips.
2. These were the first shims I’ve ever made
3. The CAD templates are imprecise. They’re close, but not quite - you have to do some filing and trimming to get things lined up perfectly.
4. It takes awhile to drill through 0.015” brass sheet, since you must use very light feed pressure to avoid destroying the sheet.

Notice the new bit of F10 felt I’ve installed in the expander in figure 83. F10 is the right grade to use here because you need something very compressible so as to avoid binding the spindle. I tried initially with F1 and found the spindle bound up badly when the bearing cap was installed.

7.5.2 Front

Not much more to tell here, except that the front shims were in much better condition than the rears. I replaced them anyway.

Both sides of the bearing cap were pretty much identical and the shim drawing is given by figure 84. It took me about 1 hour per side to make these shims, which seems like quite a long time just for shims.

In figure 85 notice the new bit of F10 felt for the expander. F10 is the right grade to use here because you need something very compressible so as to avoid binding the spindle. I tried initially with F1 and found the spindle bound up badly when the bearing cap was installed.

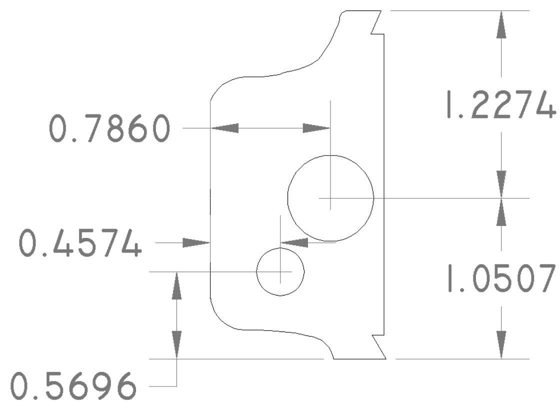


Figure 81: Rear spindle shim drawing for the operator side.

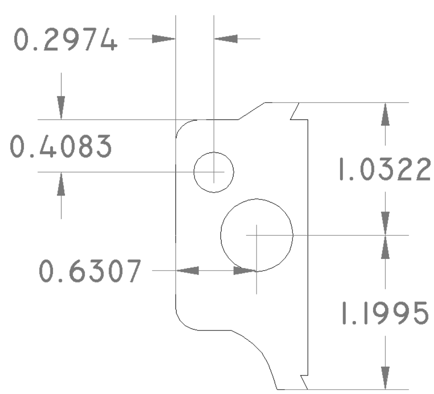


Figure 82: Rear spindle shim drawing for the far side of the machine.

Figure 83: Refurbished rear bearing cap with new expander felt and shims.

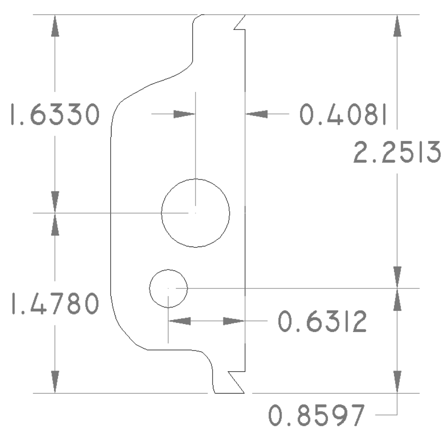


Figure 84: Front spindle shim drawing. Same shim on both sides of the bearing.

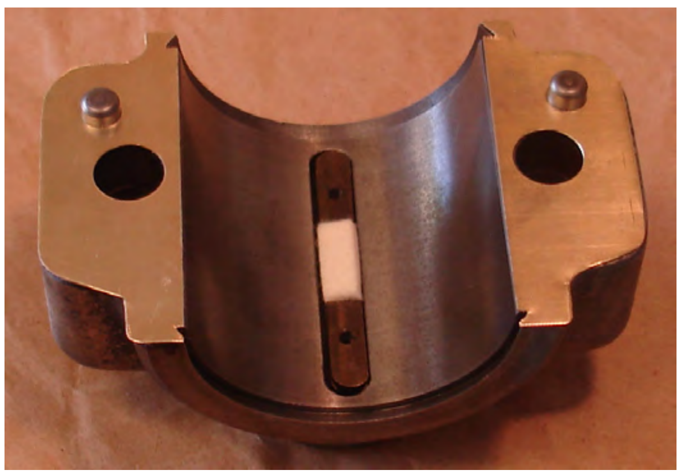


Figure 85: Refurbished front bearing cap with new expander felt and shims.

8 Electrical

Disclaimer: *Electricity is dangerous. It will kill you and burn down your house and everything you own if you fail to pay it the proper respect. If you don't feel competent to work with it, don't. And if you're using electrical tape you're doing it wrong.*

This page does not provide every last detail, and assumes a basic familiarity with wiring. If you lack this basic familiarity STOP and call an engineer or electrician.

8.1 Options for Powering this Lathe

There are two options for powering this lathe (or any 3-phase motor) on my single-phase 220v shop electrical system:

1. Swap the motor for a single phase version. This would require an increase in power rating, since single phase motors are less efficient (produce less torque given an input power).

2. Convert my single-phase power to 3-phase.

It turns out that modern Variable Frequency Drives (VFD) are so cheap as to make options 1 and 2 effectively the same cost. The choice, therefore, is clear - a VFD should be used to convert my 1-phase power to 3-phase. VFDs offer a great many practical advantages over a single-phase motor, chief among these being:

- Infinitely variable speed with near-constant torque.
- The ability to tailor acceleration and deceleration curves
- Provisions for emergency stop
- Automatic reversing

After much consideration, I decided to use a Hitachi X200 VFD rated at 2 hp. The 2 hp rating is required because the output current limit on a 1 hp X200 is 4 amp, but the motor specifications indicate a peak current draw of 4.6 amp. The 2 hp unit limits at 7.1 amp.

8.2 Some Commentary on Choosing a Variable Frequency Drive

I'll take a moment to comment on my choice of VFD. As near as I can tell, the VFD works by converting the input power to DC, then high-speed-switching the DC to 3-phase AC. The DC bus in the Hitachi X200 operates between 350 and 700 volts.

There are two types of modern VFD control systems: sensorless vector and V/f. Both offer the same motor-tuning options (acceleration/deceleration curves, frequency tuning, emergency stop, infinite variable speed, etc).

Many people will tell you that the only appropriate control for a machine tool is sensorless vector. They claim that sensorless vector is a "constant torque" drive, which means maximum motor torque can be achieved all the way down to near-zero RPM. Sensorless vector drives (an example would be the Hitachi SJ200) are significantly more expensive than their V/f counterparts.

I would tend to disagree with most people, after a careful review of the SJ200 and X200 manuals. The X200, which uses V/f control, provides full torque to the motor down to roughly 6 Hz running frequency. Why would anyone ever need to go below 6 Hz at peak torque? The motor on this lathe doesn't even begin rotating until around 5 Hz. At 6-Hz the rotational speed of the motor is probably around 3 or 4 RPM - why would anyone need such a low speed?

The X200 has 3 modes that are user-selectable: variable torque, reduced torque, and constant torque. By default, the unit is set to constant torque.

I believe, therefore, that the important difference between sensorless vector and V/f drives is the minimum rotational frequency at which maximum motor torque can be achieved. Here's what Hitachi has to say about it:

V/f Control	Sensorless Vector
In the past, AC variable speed drives used an open loop (scalar) technique to control speed. The constant-volts-per-hertz (V/f) operation maintains a constant ratio between the applied voltage and the applied frequency. With these conditions, AC induction motors inherently delivered constant torque across the operating speed range.	Today, with the advent of sophisticated microprocessors and digital signal processors (DSPs), it is possible to control the speed and torque of AC induction motors with unprecedented accuracy...The technique is referred to as intelligent sensorless vector control (iSLV). It allows the drive to continuously monitor its output voltage and current, and their relationship to each other. From this it mathematically calculates two vector currents. One vector is related to motor flux current, and the other to motor torque current. The ability to separate control these two vectors is what allows the [iSLV drive] to deliver extraordinary low-speed performance and speed control accuracy.

Table 3: Hitachi commentary on V/f versus sensorless vector.

So it seems to me that sensorless vector control only makes sense if you want to run your motor at very low speeds. In general, that's not a very good idea for a squirrel cage motor, whose cooling capacity is a function of RPM but whose thermal condition is a function of current draw. The X200 will maintain full motor torque down to 6 Hz. The SJ200 will maintain full motor torque down to 0.5 Hz, which is quite remarkable, but irrelevant to lathe (and mill?) applications.

8.3 Executive Summary

Let's examine what I'm trying to do here from a "top-level" perspective. Figure 86 shows what was present on the lathe when I bought it, and is typical of any industrial machine operating on 3-phase house power with momentary pushbutton switches for control. 3-phase house power enters the safety switch on the lower left, where it's routed to the motor starter. The control panel on the right is also wired to the motor starter, and provides the signals that tell the motor starter which direction to rotate the motor. The motor is wired to the output terminals on the motor starter. In this particular lathe, everything was operating at 208 VAC 3-phase except for the control panel, which operated at 110v single-phase.

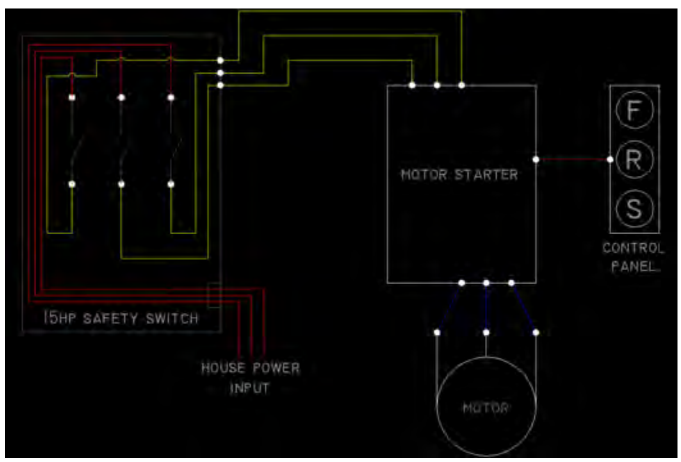


Figure 86: Simple schematic of original wiring.

Figure 87 is where I'm going with the wiring. I have replaced the motor starter with a VFD and the house power is now single phase. Input power is two hot wires (240v across) and one ground wire (the bright green one). The control panel is intact, but is now communicating the desired actions to the VFD.

8.4 Various Wiring Options for a VFD

I will now attempt to describe in detail the new wiring scheme by building up gradually in three steps.

There are at least a million different ways of wiring a VFD, and everyone has their own method that makes logical sense to them. Given the frequency

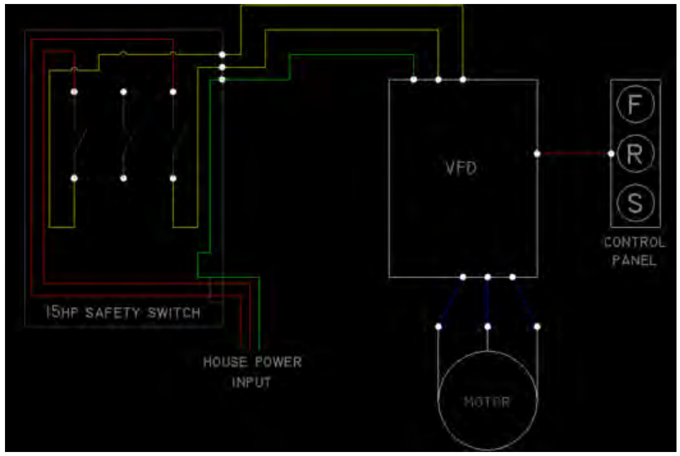


Figure 87: Simple schematic of new wiring.

of VFD and general "how do I wire this" questions I see in various machine tool forums, I will take some time here to explain (as best I can) my personal *opinions* on wiring a VFD. I am not an electrical engineer.

I will present the following in three subsections, arranged in order of increasing complexity:

1. The most basic VFD wiring scheme (which should NEVER be used).
2. A VFD with a safety switch and fused input power (minimum required configuration for safe operation).
3. A VFD with safety switch, fused input power, and external controls (the most sophisticated arrangement).

8.4.1 The Most Basic VFD Wiring Scheme (Never Do This)

I'm presenting this wiring scheme merely to show the most simplistic use of a VFD. **This method alone should never be used for a serviceable machine!** It is presented here only to lead the reader through the process of wiring a VFD beginning from the most basic to the more complex. At the very least, a VFD must be wired with a safety switch (see the next section).

At its most basic level, a VFD is really just a black box that transforms single-phase house power into 3-phase motor power. In that sense, only 6 wires are absolutely required, shown in table 4.

With this configuration, plugging in the VFD to house power will start it working instantly, and will allow the full function of the VFD in operating your motor. As far as wiring goes, that's all you need. Please remember, however, that your VFD will almost certainly require some programming for the characteristics of your motor. That programming is addressed in the VFD user manual, and for this reason I recommend anyone who hasn't ever used a

VFD Input		VFD Output	
Wire 1	Hot House Power	Wire 4	3-phase leg 1
Wire 2	Hot House Power	Wire 5	3-phase leg 2
Wire 3	House Ground	Wire 6	3-phase leg 3

Table 4: Bare minimum wires required for a VFD.

VFD choose one with a good user manual as top priority. I've found the Hitachi manuals are extremely well written and clear.

8.4.2 VFD With Safety Switch (Minimum Safe System)

From the previous section we add one layer of sophistication: a fused safety switch. Don't make this more complicated than it is - I'm simply talking about putting a switch and a fuse (or circuit breaker) between your house power and your VFD. There are a number of good things about this:

1. NEC (National Electrical Code) requires all motors to have a manual power disconnect.
2. You'll be able to have the machine plugged in, but off. In other words, the machine won't be "live" just because it's plugged in.

Don't get hung up on the safety switch idea - we're just talking about a simple switch, as shown in figure 88. This particular one came with the lathe, and you can see there's a terminal for each of the 3 phases. Although this was meant to be connected to 3-phase power (hence the 3 terminals), you can connect it to any power source. In my case, since I'm wiring in single-phase house power, I simply used one of the terminals for the hot line, one for the neutral, and the last for the other hot line. It makes no difference what order these wires go. I chose to place the neutral in the middle because it "made sense". this makes a positive disconnect of each individual line (which actually exceeds the requirements in the NEC, I think).

Figure 88 shows the inside of the safety switch during assembly. It's missing the fuses I installed, and a few other parts, but it shows the wiring nicely. The output terminals at the bottom aren't visible here, but the house power input is visible. You want to wire the house power to the terminals shown because they are live when the machine is plugged in, and you want to minimize the danger of electrocuting yourself if you open up the box while live. (The other terminals are connected to the knives, which would be very easy to touch and die).

Figure 89 shows the switch completely assembled and wired. In many respects, this switch (which is typical of industrial safety switches) is no different than the big knife switches from the original Frankenstein movie (also Young Frankenstein), the main difference being that the knives are enclosed and a mechanism for activating them is included.

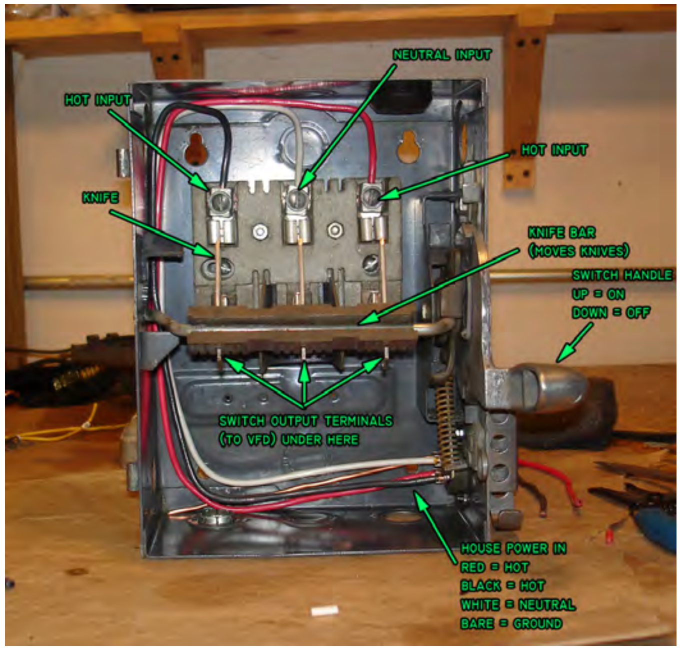


Figure 88: Safety switch showing internal components.

Figure 90 is a schematic version of figure 89. Yellow wires are headed for the VFD. Red and white wires are house input. The green wire is ground. Notice I added two fuses - one for each hot line. I didn't bother with one for the neutral. I did this only because the VFD I bought specified 20A fuses on the input line, and the circuit I'm using at the house is 30A.

Also note the neutral line isn't required if you only need 240v power! I included it because it was convenient to do so, and it will offer a simple way to get 120v power if I ever need it. **Never use the 120v power you get between any hot line and the ground!** Never! That's a great way to kill yourself (or others) and burn your house down. So if you think you'll need 120v power on the tool some day, go ahead and provide yourself a neutral line.

Pretty much all industrial safety switches since the dawn of time have looked like this one. But there are other ways of accomplishing the same thing. For example, some machines may have a simple two-button switch that looks very much like an ordinary machine tool switch. They all serve the same purpose - a means to disconnect the machine from house power even while it's still plugged in.

There is another way of doing this. It turns out the NEC allows a circuit breaker to be used as the disconnect for a motor. So if you really wanted to, you could use the circuit breaker in whatever load panel you've tapped for your 240v (or 120v) power as your motor disconnect. Having a safety switch, however, is generally preferred.

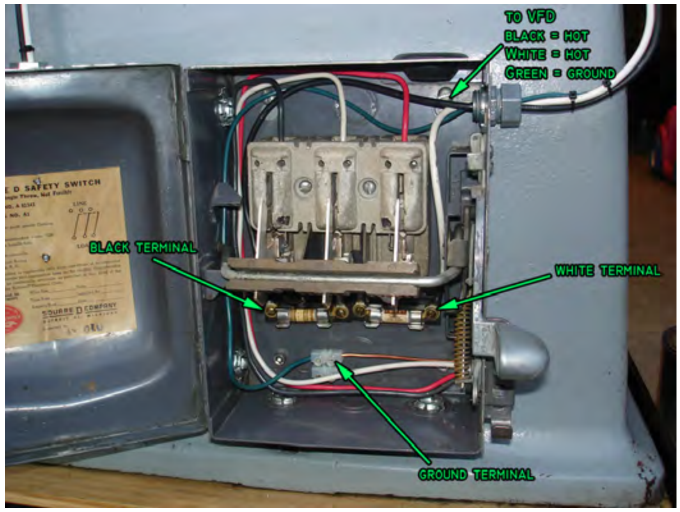


Figure 89: Completed safety switch.

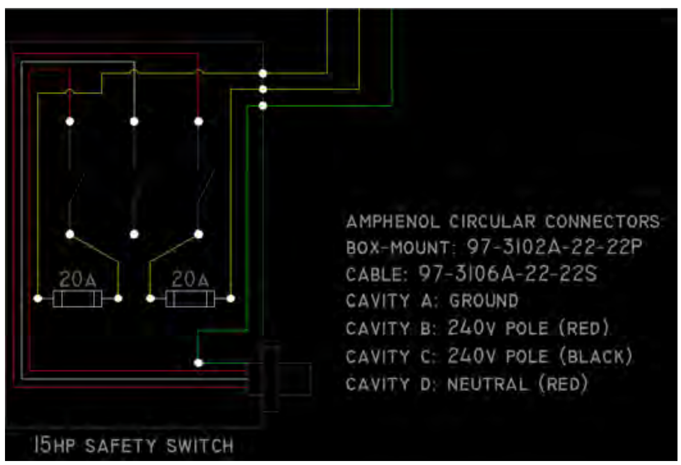


Figure 90: Safety switch wiring diagram.

To get power to the safety switch, you want to use a quality service cord if you're going to put a plug on it. (If you're wiring directly into house power without a plug, then you could use something else such as individual wires in electrical conduit). Whatever you do, use at least the minimum gauge for the current you're handling. Even better, use the next larger gauge.

I'm a bit of a stickler when it comes to wiring terminals, so I'm using a 46-amp rated Amphenol MIL-SPEC circular connector to connect house power. That's why in figure 91 you don't see any wires going into the box from house power - I didn't have the cable connected when I took the photo.

Figure 91: Installed safety switch.

8.4.3 VFD with Fused Safety Switch and External Controls (maximum complexity)

Here's where things get a little tricky, and particularly hard to explain. Most (all?) VFDs have a front control panel, whereby every function of the VFD - including complete motor control (on/off/stop/speed/etc) - is available. You can use these controls to operate your machine, and don't even bother reading this section if you want. But there are a couple disadvantages to operating that way:

1. It requires the VFD to be mounted close, so you can access the controls. This reduces your flexibility in choosing where to mount it.
2. There's a bit of a safety concern here, since the buttons are typically pretty small on a VFD and if you need to STOP in an emergency it might be difficult to nail the button on the first try.
3. Most VFD control panel buttons are very light duty, and not really meant for regular use, especially with grimy hands.

To overcome these issues, most (all?) VFDs have an option for external control. This allows you to wire your own switches (of pretty much any type) into the VFD to control it. Every VFD is different with respect to the way this is done, and the VFD user manual is the only way to get the instructions specific to your VFD. But they're all going to be pretty similar to what I'm about to describe.

Before we dive into the VFD itself, we need to address something that can be intimidating - the motor starter. If your machine has a “drum” switch or other push-and-stay-engaged or toggle-type switch, you probably don't have a motor starter. A motor starter allows the use of momentary pushbutton switches to control the motor. There are some very good reasons for this arrangement, which I'll discuss shortly.

Figure 92 shows the motor starter that was on my lathe. This looks complex and intimidating, but it's actually not too bad, once you understand the logic. This is really just 2 relays (one for motor forward, one for motor reverse) and a couple big terminal blocks to hold all the wiring. This allows momentary pushbuttons to start and stop the motor.

See, the "problem" with a momentary pushbutton is it's, well, momentary. It's only making a connection as long as you have the button pressed. Since it's impractical to operate a piece of equipment while holding your finger on a button, you have to have some way of "latching" the motor on with just a momentary connection. That's what this type of motor starter does - it "latches" the motor in the "on" state until you press the STOP button on your operator control panel.

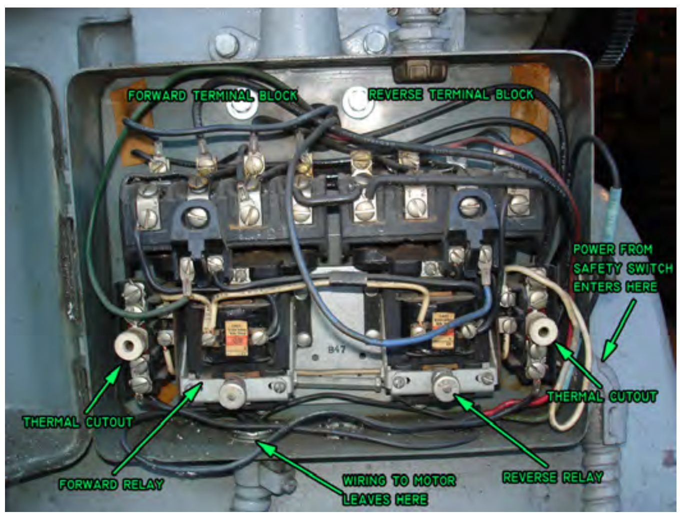


Figure 92: Inside the original motor starter.

So how do we make a latching relay? Figure 93 is a schematic of a simple latching relay of my own design. The trick is to wire the positive power input line in a "feedback" loop through the relay terminals, so that once the power is engaged - even for a split second - the relay will engage and remain so.

I will now attempt to explain this in detail, referring to the letter-labeled wires in the diagram. To do this, you need your "Run" switch(es) to be momentary normally-open type and your "Stop" switch to be momentary normally-closed type. In the diagram, SPST means "Single Pole, Single Throw" and DPST means "Double Pole, Single Throw". Notice I'm only using the normally-open pole on the DPST run switch. You could achieve the identical circuit using a SPST run switch, as long as it's normally open, which would look identical to the pictured STOP switch except that the switch terminals would be in the open-circuit state at normal rest. So why did I use a DPST switch instead of SPST? Because that's what came on the machine, and there's no reason to go buy new switches if I don't have to.

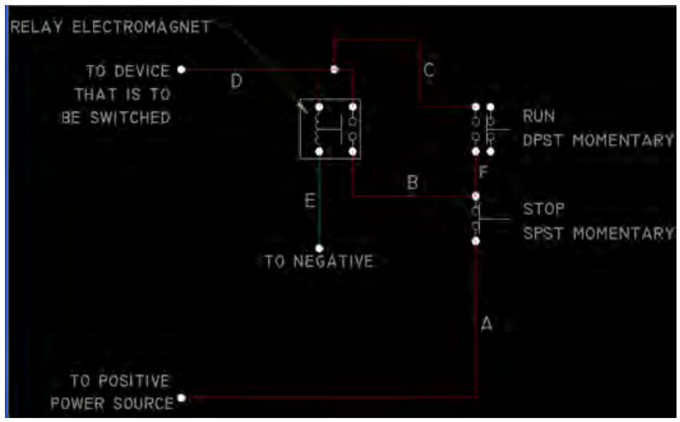


Figure 93: A simple latching relay design.

In the off state, which is shown in the diagram, relay input power is traveling into the STOP switch via wire "A". It moves through the STOP switch itself, into the normally-open side of the RUN switch via wire "F". Power is also routed to one of the switched terminals in the relay via wire "B".

When the RUN button is pressed, power travels through "A", "B", and "F" as before, but now it also travels through the RUN switch via "C", which is wired to both sides of the relay - both the electromagnet terminal and the switched terminals. The negative wire (green) is completing the circuit for the electromagnet, so it turns on (connects) the switched terminals in the relay. This effectively connects input power, "A", to the output power, "D", as well as to the switched terminals!

Now, when the user releases the RUN button, power is traveling through the stop switch via "A", to the switched-side of the relay via "B". From there, it travels to the electromagnet side of the relay and to the device you want to recieve power via "D". In effect, the relay is now "stuck" (latched) in the ON position. The electromagnet inside the relay which activates the switched terminals is being supplied with power right through the stop switch.

Finally, when the user presses the STOP switch, power to the relay is cut off, since the input power only has access to the relay via wire "A" and "B". This cuts power to wire "D", and turns off your switched circuit.

This is exactly what the motor starter in figure 92 is doing! It's a little bit more complex because in reality we have 2 relays - one that is wired to spin the motor forward, and one that is wired to spin the motor in reverse.

Why do it this way? Well, the main motivation is safety.

1. If the power goes out while the motor is running, the system will not restart when power is restored, which makes the whole thing quite fail-safe.

2. Only a very tiny current is traveling through the control switch. This minimizes the chances that an operator can be electrocuted, and allows small-gauge wires and light-duty switches to be used if desired.

So how does this relate back to the VFD? Well, the external control bus on most (all?) VFDs is a low-voltage DC signal that is meant to be wired in such a way as to send signals to various terminals on the VFD that tell it what to do. Figure 94 shows the full schematic of the motor starter that I built to operate the VFD using the original pushbutton controls that came with my lathe. Remember, if you've got a drum switch or toggle switches you don't need this relay setup, since your switch is "latching" all by itself!

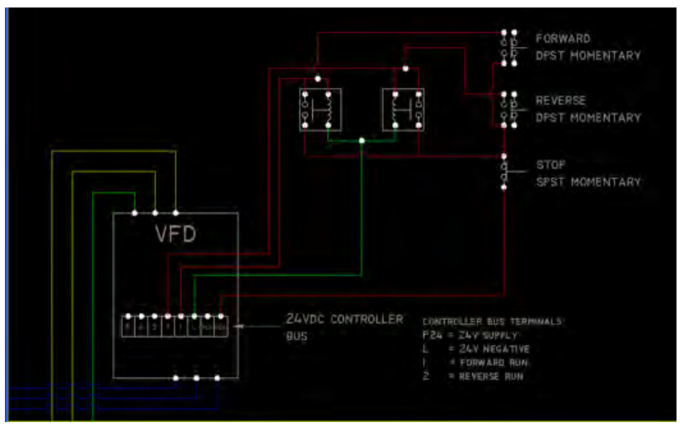


Figure 94: Complete bidirectional motor starter diagram.

The Hitachi 24VDC controller bus has a number of terminals, but the most important are:

- P24 - this is +24VDC constant
- L - this is -24VDC constant
- 1 - a +24v signal at this terminal tells the VFD to engage the motor on forward rotation
- 2 - a +24v signal at this terminal tells the VFD to engage the motor on reverse rotation

No signal on either 1 or 2 tells the VFD to stop the motor. A +24v signal to BOTH 1 and 2 will stop the motor (a failsafe in case the operator presses forward and reverse at the same time).

Other VFDs will vary in their terminal labels, and even their bus voltage, but they're all going to work the same basic way. All of this is explained, of course, in the VFD instruction manual in greater detail, but they generally don't show you how to wire your relays as I have here.

Given the terminals I described, you can imagine how this would work with toggle switches or a drum switch - you merely route the P24 signal though your switch and back to terminal 1 or 2 (whichever is appropriate) - no need to use the ground signal at "L".

Figure 95 shows the actual implementation of the relay system (motor starter) as I designed it. Those are two 24VDC relays I picked up at the local electronic surplus shop (very cheap). One for forward, one for reverse. They're so small they fit inside the little junction box that came on my lathe. I no longer have any need for the huge motor starter shown in the first photo here, because I've exactly reproduced it's functionality.

(You might ask, why is there Velcro on the back of those relays? Originally I was going to Velcro the relays into the junction box.)

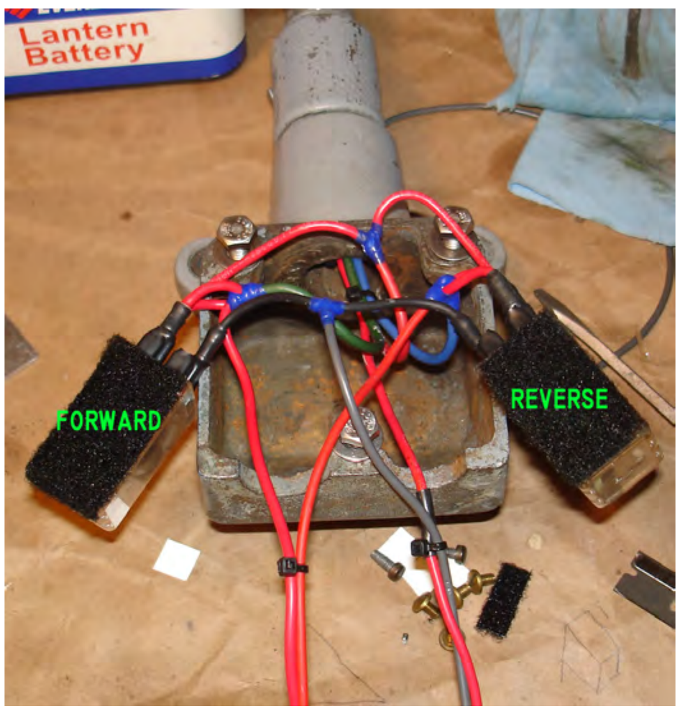


Figure 95: Completed motor starter.

To be fair, that old motor starter also provided thermal protection for the motor. In cases where the motor current was sufficiently high for a period of time the thermal cutouts would cut power to prevent overheating the motor. However, the VFD which I have installed has automatic thermal protection built in.

And that's it! Don't get caught up making this more complex than it is. All we're doing here is switching power around to make things do what we want. Spend some time with the schematics I've shown and convince yourself how they work. Once it "clicks" in your mind you'll realize it's really very simple.

8.5 How to Buy a Relay

The topic "how to buy a relay" could conceivably consume quite a few words. Anyone who takes a few minutes to look for relays quickly discovers there are at least a million different types. To help you narrow down the choices, let's look briefly at the criteria necessary for a relay specification. These are, in order of importance:

1. Coil voltage. The relay coil voltage rating must equal your control signal voltage. In my case, the X200 external control bus is 24VDC, so I need a 24VDC coil. When dealing with automobiles you'd need a relay with a 12VDC coil.

2. Contact rating. This is the current rating of the relay contacts. Be sure to get one that can handle the current you're going to be switching. In the case of the X200 external control bus, the current is very low (<<1 amp DC), which almost any relay can handle. But the current of the load you're trying to switch also sizes the relay. Since I only need to switch a few milliamps, I certainly don't need a giant relay capable of handling 200 amp.

3. Terminal type or contact form. There are quite a few options in terminals. The most common are PCB (Printed Circuit Board) mount and quick connect. PCB mounts are small pins and are meant to be soldered directly to a circuit board. Quick connect terminals are often called "spade" terminals, and are the most convenient in most cases.

Obviously if you look at the photo of the relays I used they probably don't look anything like thetypes you see in general purpose electronics stores. Remember, there are millions of different relays out there that will work with each application. I bought what the surplus shop had in stock the day I was there based on the size and the ratings.

8.6 A Note About Wire Sizes

In any wiring job it's always necessary to consult a good wire ampacity chart. If you search on "wire ampacity" you'll find many examples. Your wiring should be large enough to handle at least as much current as the fuse or circuit breaker that is protecting the circuit it's in.

The main power input to my lathe uses 10ga. wire rated to 30 amp, which is the same rating as the circuit breaker protecting the load center where I plug it in. That doesn't mean the wire will burn up at 30 amp, it only means the wire is certified to carry 30 amp continuous in open air.

The wiring within the safety switch is 10 ga. solid copper house wire that I had laying around, good to 30 amp.

The wires between the safety switch and the VFD are 10 ga. stranded copper machine tool wire, with insulation designed to be resistant to grease, oil, solvents, and most acids.

The control panel wires are 18 ga. automotive type wires with SXL cross-linked polyethylene insulation resistant to oil, grease, fuel, solvents, and most acids. These wires can be small gauge since the control signals are very low current.

8.7 Specifics For This Machine

Figure 96 shows what the VFD looks like straight out of the package. Pretty simple, really. I went with Hitachi for a couple reasons, principle among them the excellent quality of the instruction manual. It's written in pretty clear English, which is much better than what you get with certain other brands, such as Teco. This is my first VFD setup, so I wanted something with good instructions.

Hitachi is Japanese made, so I'm confident it's top-quality electronics. The range of features and fine tuning available with this is nothing short of remarkable. Most of the settings were not required for this simple lathe.

Shown in figure 97 is the safety switch as I got it on my lathe. The two yellow wires were running to a 208/460 volt 3-phase transformer mounted atop the switch box to provide 110v single-phase power to the motor starter. The relays on the motor starter are 110v, hence the need for 110v single-phase power.

I've also provided a picture of the notice posted inside the switch cover in figure 98. Square D has been around a long time, and their stuff seems generally well-made.

Figure 99 shows the safety switch cleaned up and reassembled. Notice the new Amphenol 97-3102A-22-22p circular connector that will receive power from a service cord down in the lower right corner of the box. The connector is rated to 46 amp. I ran both hot wires and the neutral (pole ground) even though I only need the 2 hot wires. The neutral will provide a convenient source of 120v power if I ever need it in the future.

Notice I've added two fuses to the box, thereby making the "non-fusable" switch fusable. I didn't plan on doing this, but the variable frequency drive specifies 20 amp protection and the main breaker at the load center for the shop is 30 amp. Better safe than sorry, I guess.

I stripped all the paint from the switch and even cleaned up the Square D label attached to the front of the door.

I'm using 10 ga. solid copper wire for the main input power, with 10 ga. stranded machine tool wire for all the output lines except ground, which uses 14 ga. machine tool wire. All screw terminals use tinned copper ring connectors, which are crimped and soldered in place.

Figure 96: Freshly unboxed Hitachi X200 VFD.

The hardest part about using the X200 was figuring out how and where to mount it. The housing is very "porous" for heat rejection, and has a huge aluminum heat sink attached to the back. Any enclosure has to be large enough to provide adequate heat transfer away from the box.

After much consideration, I decided to mount the X200 to the gear train cover on the left end of the lathe, as pictured in figure 100. I did not enclosing it. When not in use, I have a small nylon cover that keeps welding/grinding debris out of the holes.

Initially, I had planned to simply control the lathe directly from the X200 front control panel. After doing so for the programming and setup, it became clear the front panel buttons are not ideal for regular use controlling a lathe. They're very small membrane switches that are likely to wear out from grimy fingers pushing them all the time.

So I decided instead to re-install the lathe's original Westinghouse forward/reverse/stop switch. The X200 (and most VFDs) comes with all the provisions necessary for external control. With external controls, I will only need the front panel of the X200 to change speed (if necessary) and check status. (The X200 can display some interesting statistics including frequency, motor current draw, and operating hours).

During otherwise normal operations one evening, the X200 suddenly quit working. As the lathe suddenly spooled down, I looked at the unit and I swear I

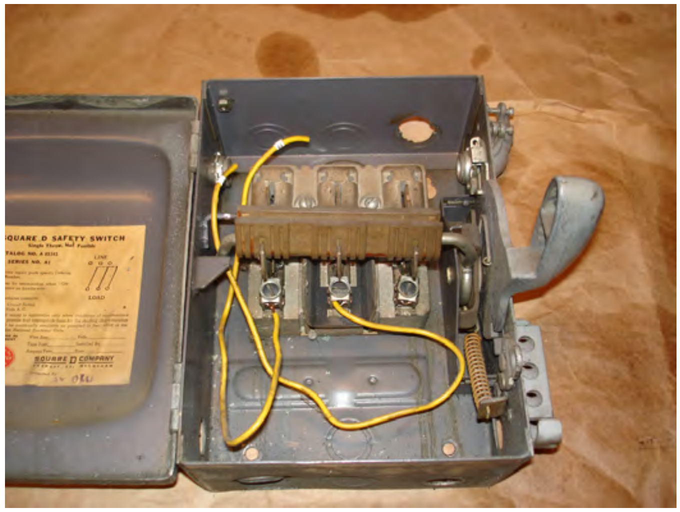


Figure 97: Safety switch before refurbishing.

Figure 98: Notice page inside safety switch.

saw a small puff of smoke emminate from the top vents. The display was blank, and the power light was blinking.

And that was the death of my first X200. The unit had fewer than 50 hours of use, and I hope its death was premature. It may or may not be significant that shortly before and at the moment of the unit's failure the lathe was chattering badly. I have speculated that the vibrations may have shorted the plates in one

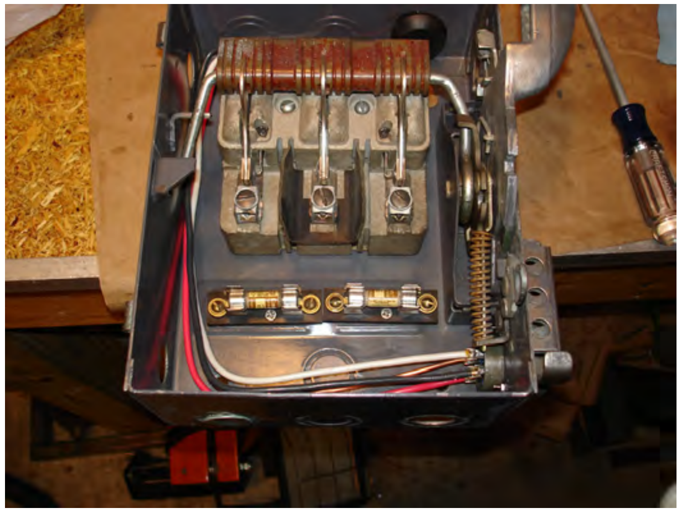


Figure 99: Safety switch cleaned up and rewired.

of the capacitors, but I won't know whether this is true until I disassemble the X200. It's interesting, however, that the maximum vibration specification from Hitachi is 0.6g.

In the meantime, I replaced this unit with an identical one, but decided to make two major changes:

1. Move the unit to one of the building's walls to eliminate the possibility of machine vibrations causing damage.

2. Wire a remote potentiometer so the unit can be fully remote controlled.

Figure 100: One VFD mounting option.

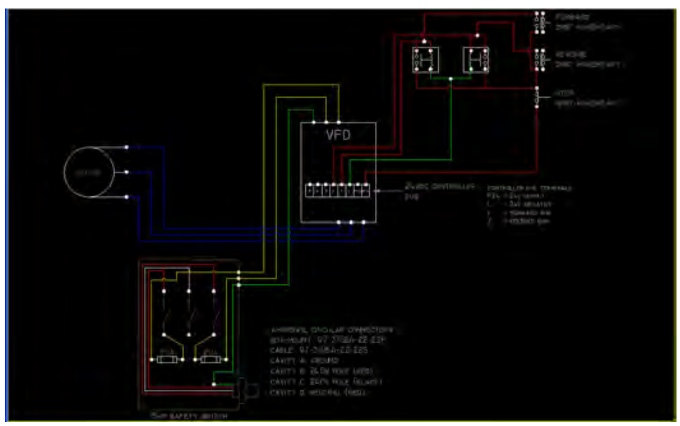


Figure 101: Complete wiring diagram.

9 Compound Rest

Begin by removing the compound rest from the carriage assembly by removing the set screws on each side. These are accessed from the back of the lathe. There's one on each side. I had to completely remove the screws before the pins would release the compound. Figure 103 shows the cross slide with the compound removed. Arrows indicate the retaining pins.

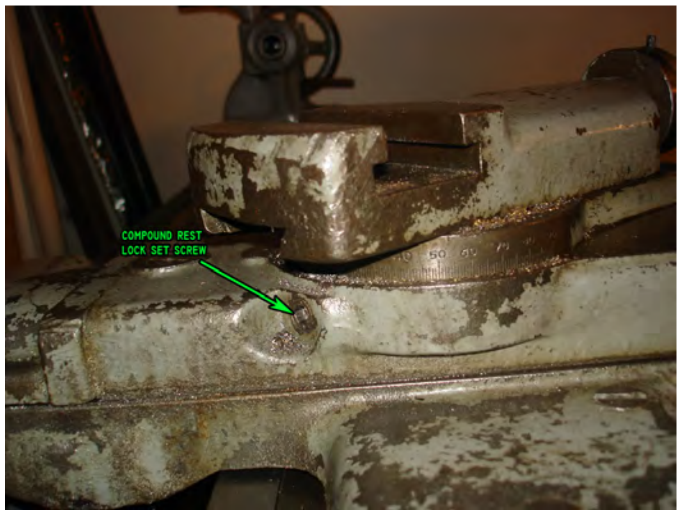


Figure 102: Compound rest lock screw. There is a second one on the other side.

To dismantle the compound, first remove the handle. This is straightforward, once you remove the nut that retains it. Be careful not to lose the little roll pin that fits in the slot in the handle and engages the cutout shown in figure 104 With the handle removed, the graduated dial simply slides off the shaft, once you back off the locking screw.

The graduated dial has a locking screw on it as shown in figure 105. South Bend originally used a thumb screw, but this lathe has a set screw - apparently a replacement stuck in there by a previous owner. The threads are #10-32. I plan to replace the screw-rod-shoe assembly with one long brass set screw for simplicity. I found that the shoe is too large (diameter) for the hole, and the locking mechanism wasn't working properly.

With the handle removed, slide off the graduated dial. To remove the leadscrew, I first unscrewed the "backing dial" (my term) from the compound rest casting. It shouldn't be particularly tight. Once it's free of the casting, you simply unscrew the leadscrew to remove it. Figure 106 shows the parts of the dial assembly that mount in the casting.

Next the gib must be removed. This is a tapered steel bar that enables wear in the compound dovetail to be compensated. To remove it, begin by removing

Figure 103: Carriage with compound rest removed.

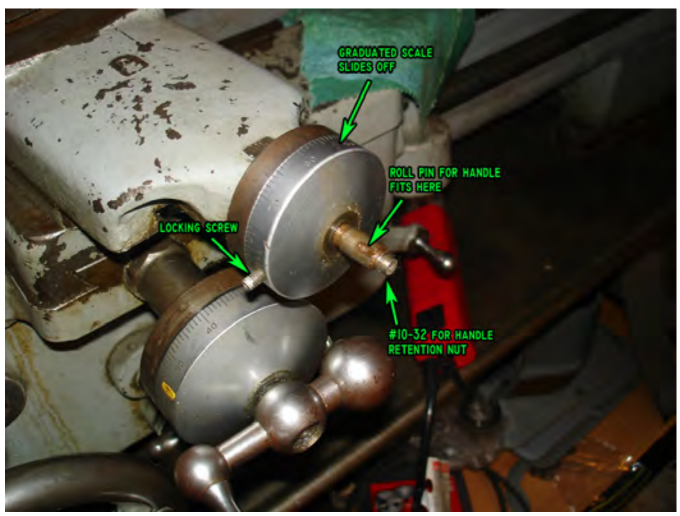


Figure 104: Removing the compound rest handle.

the set screw shown in figure 107. Behind it is a little ”shoe” (South Bend’s terminology), which my or may not drop out of the hole. Be careful, it’s tiny.

To remove the gib, simply remove the adjustment screw, shown in figure 108. What comes out is shown in figure 109.

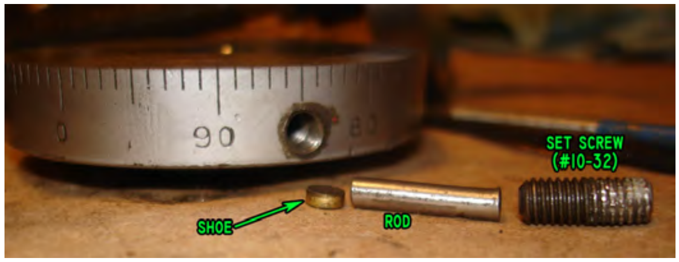


Figure 105: Parts of the compound rest dial lock.

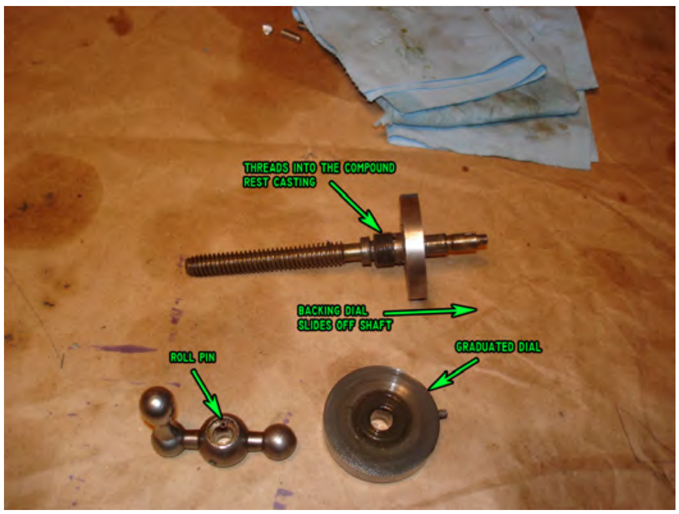


Figure 106: Parts of the compound rest dial.

Figure 107: Compound rest gib screw location.

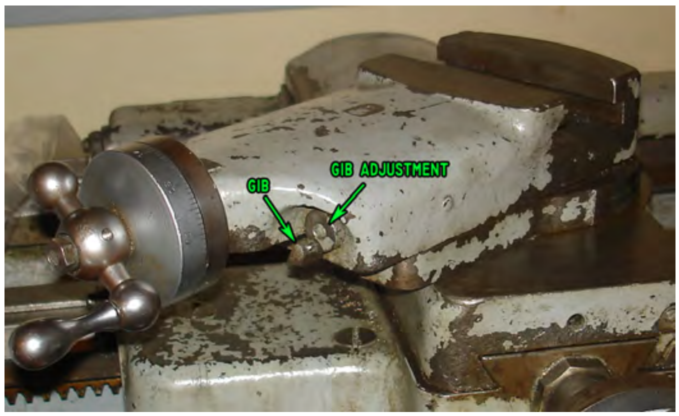


Figure 108: Compound rest gib adjustor.

Figure 109: Compound rest gib removed.

With the gib removed, there's sufficient slop in the compound assembly to permit removal of the leadscrew nut. To do so, first remove the retaining screw shown in figure 110. Then, the leadscrew nut will probably be lightly pressed into the casting, so you'll need to drive it out by tapping it with a hammer and a pin punch via the retaining screw hole. On reassembly, I slightly filed mine to reduce the strength of the press fit a little. If you do this, don't go overboard with the filing - you want a press fit here to maintain precision of the leadscrew action.

With the nut is removed, the two halves of the compound slide apart.

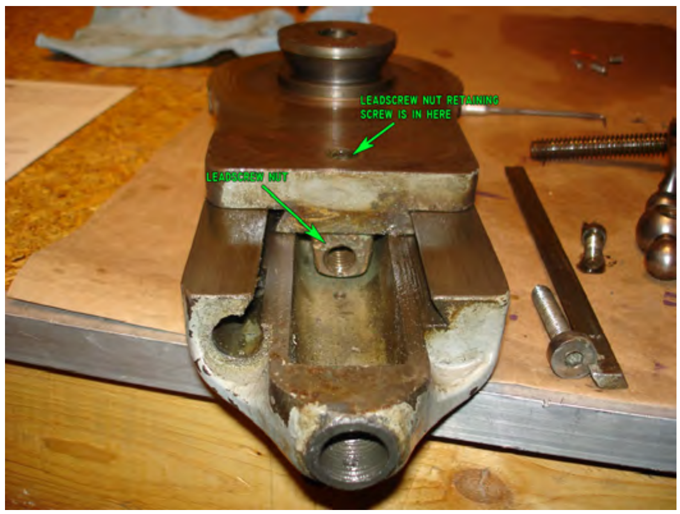


Figure 110: Location of compound rest leadscrew nut retaining screw.

Figure 111: The entire compound rest disassembled.

10 Cross Slide

The cross slide forms a mobile base for the compound rest. To remove it, you must first remove the graduated dial and unscrew the backing dial (my term), similar to what was done with the compound rest. Figure 112 shows the relevant parts.

In my case the handle retention pin was 1/8" and there was no nut screwed into the handle. 1/8" is too large for the pin - which probably should be a spring pin like the compound rest has - and I had to use a gear puller to get the handle off. The pin damaged the threads on the end of the leadscrew when it came out, but not irrepairably.

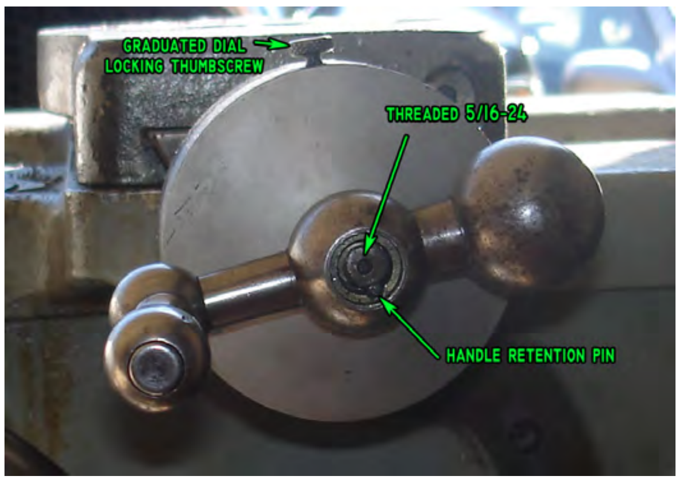


Figure 112: Cross slide handle.

Figure 113 shows the leadscrew with the graduated dial removed. The backing dial is threaded into the cross slide casting as shown, but you must first remove the set screw (which is labeled "oil") in order to unscrew it. Once unscrewed, the entire leadscrew itself can be simply unscrewed from the cross slide casting.

To remove the cross slide casting, push it off the back of the saddle, which is grooved along its entire width to accomodate the cross slide leadscrew nut. Although not strictly necessary, I found it much easier to loosen the gib adjusting screw (figure 114) before sliding it off.

Once you've removed the cross slide casting, you can dismantle the leadscrew assembly easily. For me, removing the backing dial from the leadscrew itself was a bit of a challenge. There's a pin that retains the bushing and backing dial as shown in figure 115, but the pin is a very strong press fit (about 0.005" interference). You want to be careful with this assembly, as it's a precision leadscrew and you don't want to risk bending it. I punched out the pin as shown, with the back side of the leadscrew resting on a stack of blocks and the

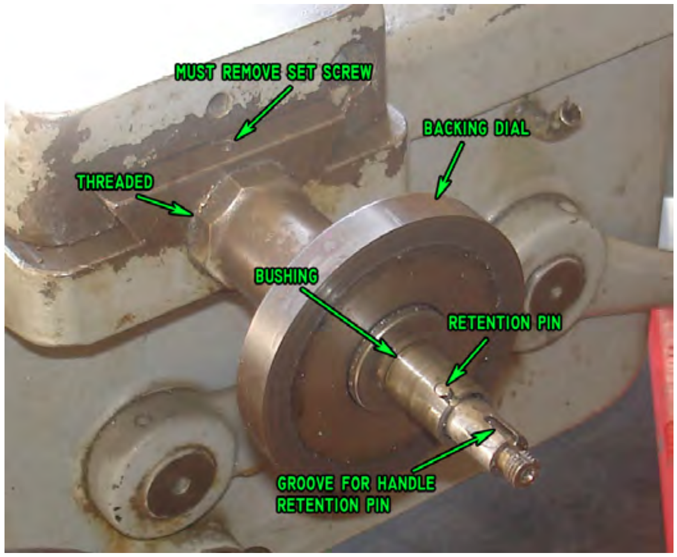


Figure 113: Cross slide with dial removed.

front supported on an aluminum bar close to the pin so I wouldn't mar the steel surface. You need a 3/32" pin punch.

You want to remove the backing dial because there are 2 ball thrust bearings on the leadscrew that should be inspected. Figure 116 shows the bearings in their approximate positions on the leadscrew shaft. They bound the backing dial.

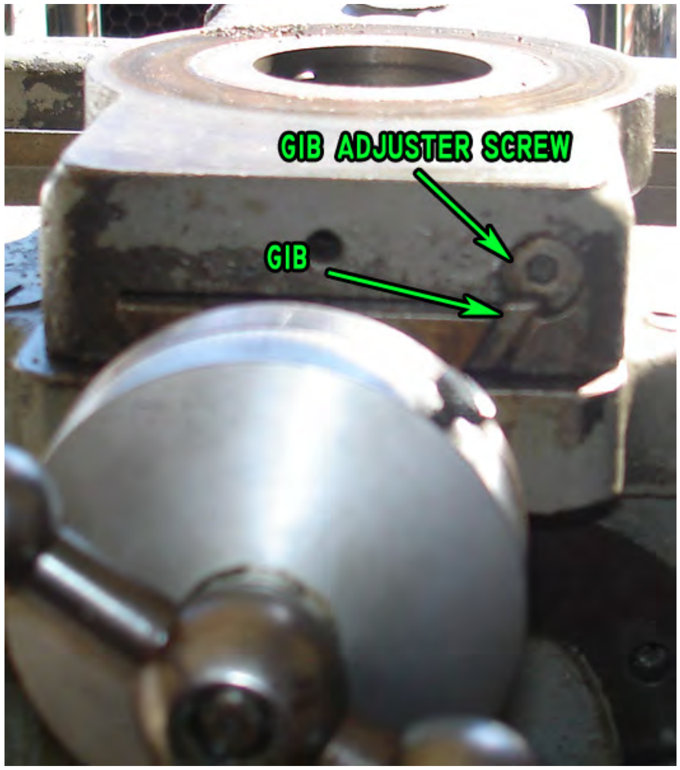


Figure 114: Cross slide gib adjustor.

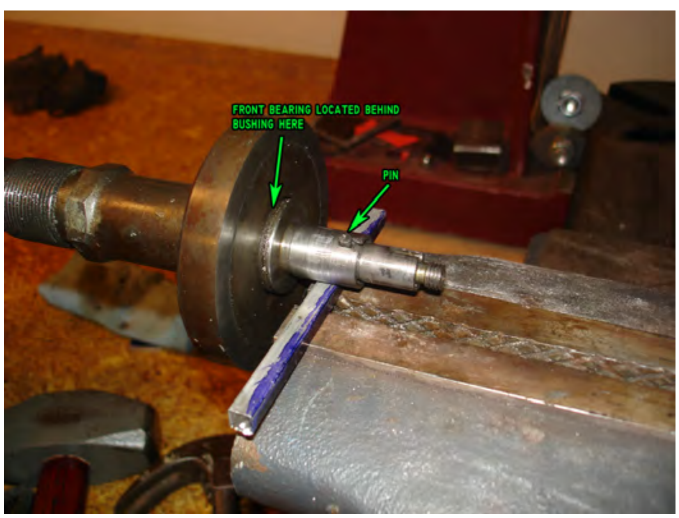


Figure 115: Removing pin from cross slide leadscrew.

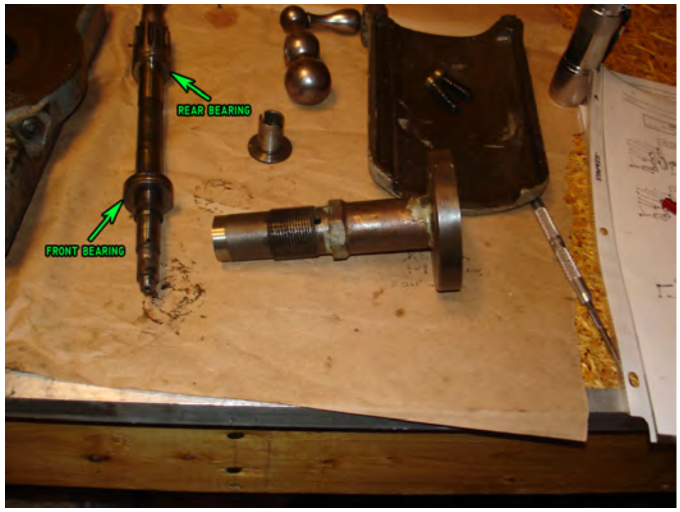


Figure 116: Cross slide parts.

Figure 117: Front and rear cross slide leadscrew bearings.

Figure 118 shows the entire cross slide assembly (except the gib isn't shown, but that's just a metal wedge). The ball thrust bearings are likely to be in good condition, as long as the lathe was lubricated periodically. They don't have to handle much load or speed, so they should last almost forever.

To remove the leadscrew nut you must first remove the oil plug at the center of the screw. Then the leadscrew nut screw has a giant slotted head. You need at least a 3/8" wide flat blade screwdriver to unscrew it, but I found that a screwdriver that large is too thick to put in the narrow slot. A 9/16" drag link socket might work, but I don't have one, so I ground down a 3/4" wide piece of scrap steel on one end and used that as a makeshift screwdriver, which worked remarkably well. Technically, I suppose there's no reason to remove the leadscrew nut, since it can be cleaned pretty well right where it is.

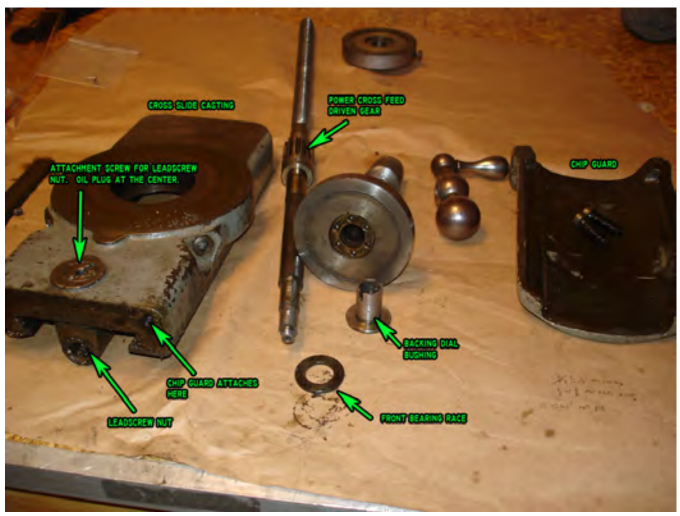


Figure 118: Complete cross slide in pieces.

11 Gearbox

11.1 Removing Reversing Geartrain in Preparation for Removing the Gearbox

Before removing the gearbox the reversing geartrain must be partially removed. Specifically, remove the idler gear, 48-tooth stud gear, screw gear, and banjo casting (in that order). These gears are labeled in figure 119. The nut holding the idler gear in place is captive to a square-head screw in the banjo casting that prevents it from turning with the gear.

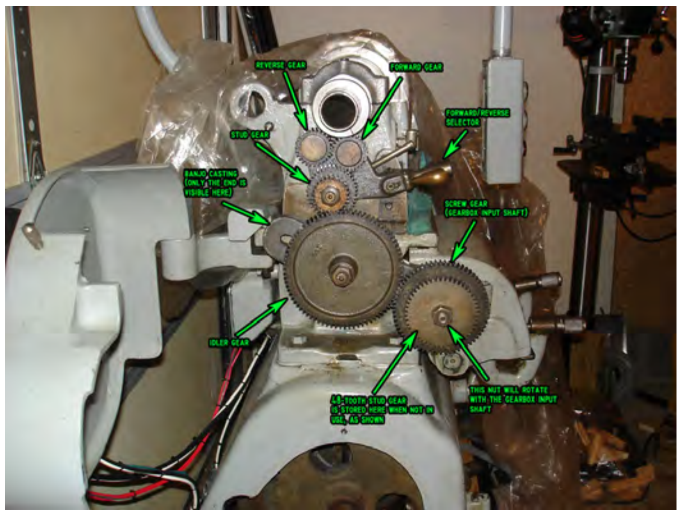


Figure 119: Overview of the reversing geartrain.

11.2 Removing the Gearbox

The nut holding the screw gear, however, is attached to the gearbox input shaft and will rotate with it. This made it tricky to remove without a back gear in place to lock the spindle down. The nut isn't tight, but too tight to hold the gear by hand while unscrewing it. My solution, shown in figure 120, was to clamp a pair of Vise Grips to the screw gear. I used a light pressure on the pliers, and the jaws are contacting the gear only on the front and rear faces, in an area that is not used as a bearing or sliding surface and has no impact on the function of the screw gear. Clamping pressure was so light that the jaws left no discernable marks on the gear.

If your back gears are installed, you can achieve the same result by engaging back gear and leaving the bull pin locked. This will lock the spindle, which will also lock the gearbox as long as the reversing geartrain isn't in neutral. The only advantage to my method is it prevents any possibility of chipping a gear tooth if undue torque is required to remove the nut.

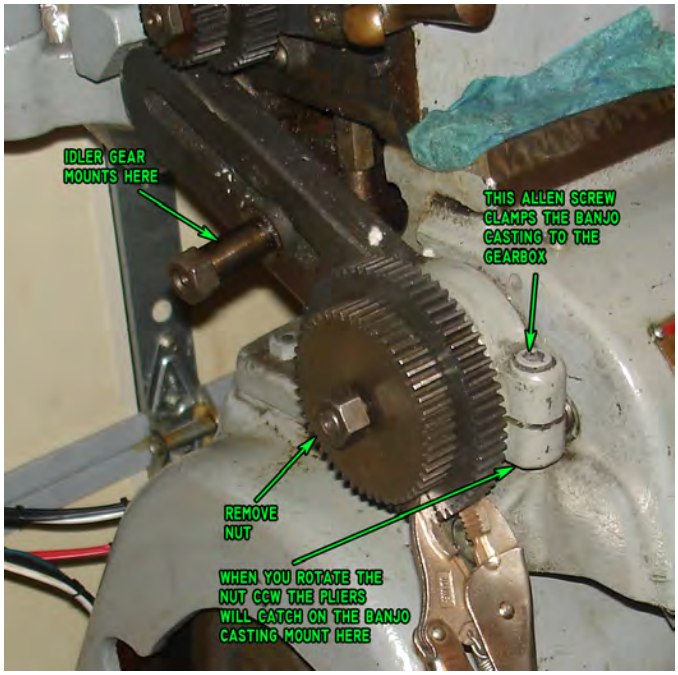


Figure 120: Method for removing gearbox input shaft nut. This is easier if you remove the nut before removing all the other gears.

Figure 121 gives the rough sizes and tooth counts for all the gears in the reversing geartrain. There are 2 stud gears for this lathe - a 24 tooth and a 48 tooth. For all threads above 7 TPI, the 24 tooth gear is used. In Figures 119 and 121 notice the 24 tooth gear is installed in the stud gear position while the 48 tooth gear is merely "stored" in position on the end of the gearbox input shaft. This is the way it came from the factory.

Figure 122 shows what the box looks like with all the necessary gears removed. All that remains in that photo is to loosen the allen head screw that clamps the banjo fitting to the gearbox casting. I found even with the screw removed it's a tight fit, so pull hard and rotate.

To remove the box from the bed there were 4 screws on my machine. It's possible there are more on later-model lathes, so be careful. Figure 123 shows the top 3 screws, all slotted-head, that penetrate through the lathe bed right at the front vee-way. These screws were not abnormally tight, and I was able to remove them with an ordinary screwdriver.

The fourth screw was a hex-head cap screw located perpendicular to those shown in figure 123, down in the lower right corner of the gearbox.

The best thing to do is remove the bottom-right-corner screw first, followed by the top 3 screws. The gearbox is somewhat heavy (maybe 25 lb without

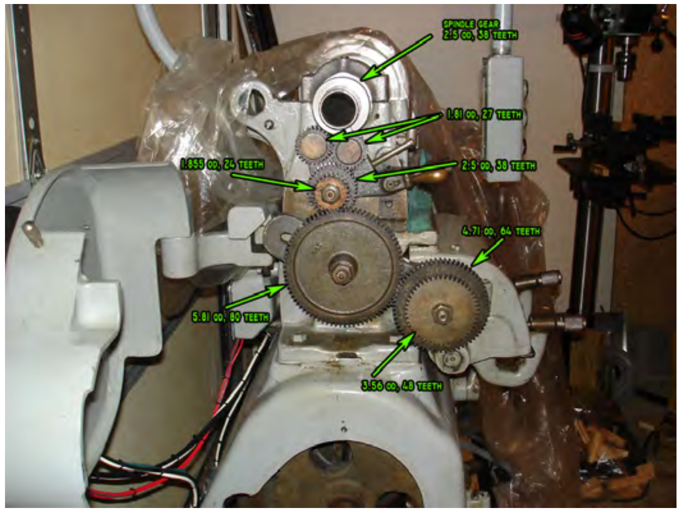


Figure 121: Reversing gear sizes.

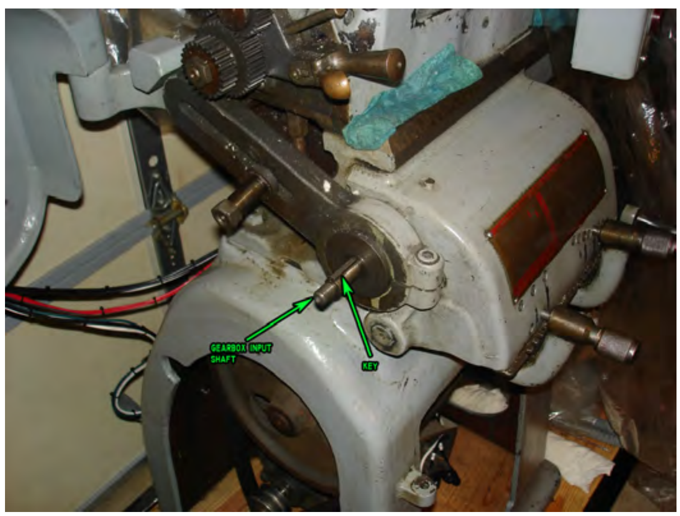


Figure 122: Reversing gear train removed to access gearbox.

the leadscrew), so gravity will want to pull it away from the bed. *Be sure it's supported when the last screw is removed. Don't let it hang from the end of the leadscrew or almost certain catastrophe will result!*

Figure 124 is the complete gearbox and leadscrew assembly as I removed them and placed them on the bench. It may be possible to remove (and install) the gearbox alone, but for the first time you remove one of these you'll want to have 2 people present. Above all, you want to avoid bending the leadscrew. And remember you'll need double the length of your lathe in clearance on the

Figure 123: Screws that secure the gearbox to the bed.

left end to have room to pull out the entire leadscrew.

First, rotate the leadscrew until the keyway is pointed straight down. This is done so that the key in the apron worm drive assembly doesn't drop out of it's slot when the leadscrew is pulled out.

Move the carriage so it's roughly at the center of the bed. Have your assistant stand at the tailstock-end of the leadscrew.

First loosen all four screws. Then remove the hex-head screw (the one at the bottom right corner of the gearbox). Now you want to support the load of the gearbox with one hand while you unscrew each of the top screws, working from right-to-left. When you get to the last screw, you'll be bearing the entire weight of the gearbox with your hand. Of course, an alternative method would be to place some kind of support beneath the gearbox.

Once the screws are removed, begin sliding the leadscrew out of the apron to the left (in the direction of the headstock). Your assistant should be supporting and guiding the far right end of the leadscrew. Once the right end disappears into the apron, have him support it at the left end of the apron until the end re-emerges. Bring the entire assembly somewhere convenient at set it down as shown in figure 124, with a block to support the end of the leadscrew.

You'll need to do most of the work with the box upside down, so it might be a good idea to turn it over while your assistant is still present.

Figure 124: Complete gearbox assembly removed.

Figure 125 shows a closeup of the lower-right corner of the gearbox with the "parellelism adjustor" (my terminology). It's a hollow hex-head screw that butts up against the lathe bed to define the distance between the gearbox and the bed. By adjusting it in or out you can adjust the alignment of the gearbox (and leadscrew) parallel with the bed. Only minor adjustment is possible, since there's only a little "slop" in the 3 screws that secure the box at the bed. I was careful not to move the position of that adjustor, and thereby avoid having to adjust the gearbox position later.

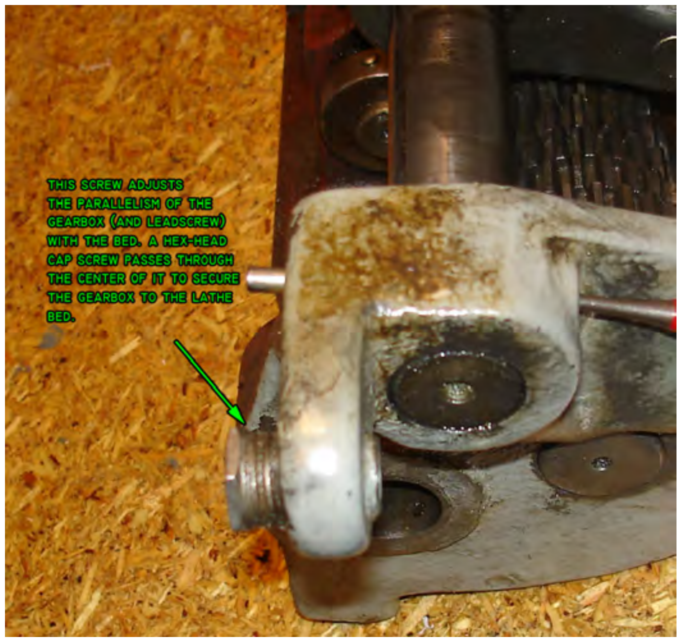


Figure 125: Gearbox parallelism adjustor.

11.3 Disassembly

Figure 126 the gearbox from the back, freshly removed from the lathe bed. I have labeled the major portions with my own terminology.

This is a simple 40-speed constant-mesh gearbox with 4 shafts: input, shift rail, mainshaft, and output. The design is robust, easily serviced, and strong. My only complaint is the lack of an oil sump. It uses a wick lubrication scheme. The red arrows in figure 126 are an attempt to indicate the power flow through the gearbox.

1. Power enters through the input shaft.

2. The input shaft transfers power over to the left side mainshaft gears, which rotate independently of the mainshaft.

3. The left side mainshaft gears transfer power into the left side gear shifter, which contains 2 gears.

4. The left side gear shifter transfers power to the shift rail, where it's picked up by the right side gear shifter.
5. The right side gear shifter transfers power to the right side mainshaft gears, which are keyed to rotate with the mainshaft.
6. The right side mainshaft gear transfers power to the output shaft.
7. The leadscrew is attached to the output shaft.

As you can see, gear changes are affected by sliding the two shift levers along the shift rail, thereby engaging different gears on the left and right side mainshaft gearsets. In my opinion, this design should never be shifted during rotation.

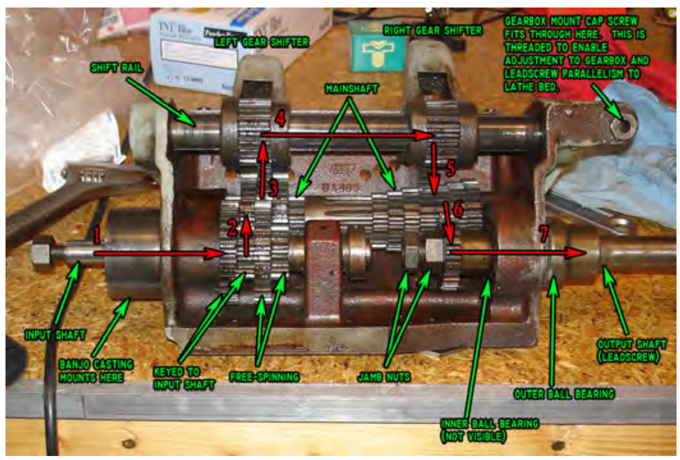


Figure 126: Gearbox showing parts and power pathway. Red lines trace power as it moves through the assembly.

Begin dismantling by removing the jamb nut and retaining nut for the lead-screw. If you look carefully in figure 126, you'll see I've already loosened the jamb nut (lower right corner of the photo). You'll need 2 big (¿1") open-end wrenches to grab these nuts. I used 2 Crescent wrenches. The jamb nut isn't particularly tight, and the inner nut sets a sort of bearing preload, so it's not very tight either. In fact, mine was little more than finger tight.

With the nuts removed, the gear slides off when you rotate the mainshaft so the gear teeth line up to just the right position.

The leadscrew is NOT pressed into either it's inner or outer bearing. But if you've got it sitting horizontally there's a good chance it'll bind in the bearings just enough to prevent removal. I found it's best to swing the gearbox 90 so that the leadscrew is pointed straight up. This relieves any binding and allows the shaft to slide out.

The drive gear and outer bearing are shown after removal in figure 127. The inner bearing remains pressed into the gearbox case as shown in figure 128. The inner leadscrew bearing is lightly pressed into the casting as shown. It will be removed after the mainshaft has been removed (shown in figure 136 on page 119.)

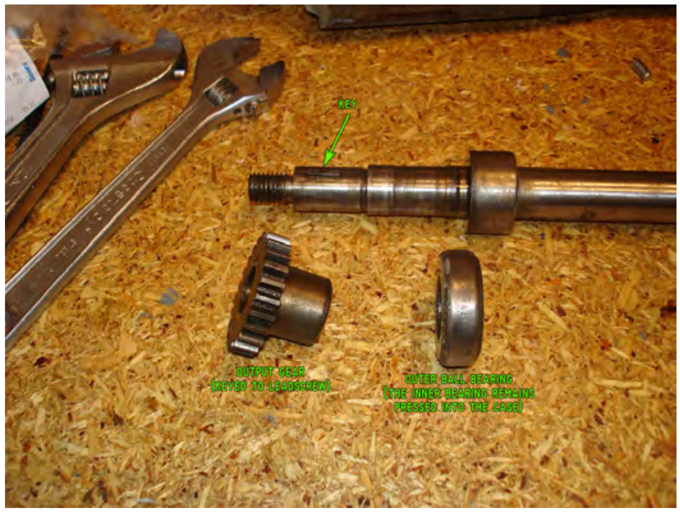


Figure 127: Detail of leadscrew where it enters the gearbox.

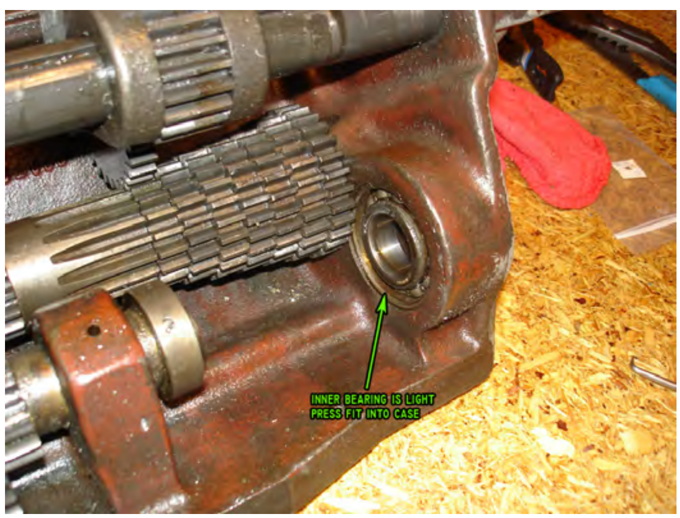


Figure 128: View of inner leadscrew bearing with leadscrew removed.

Notice there is a tiny felt wick inside the bore where the output shaft mounts as shown in figure 129. It must be gently pried out with a small pin of some sort.

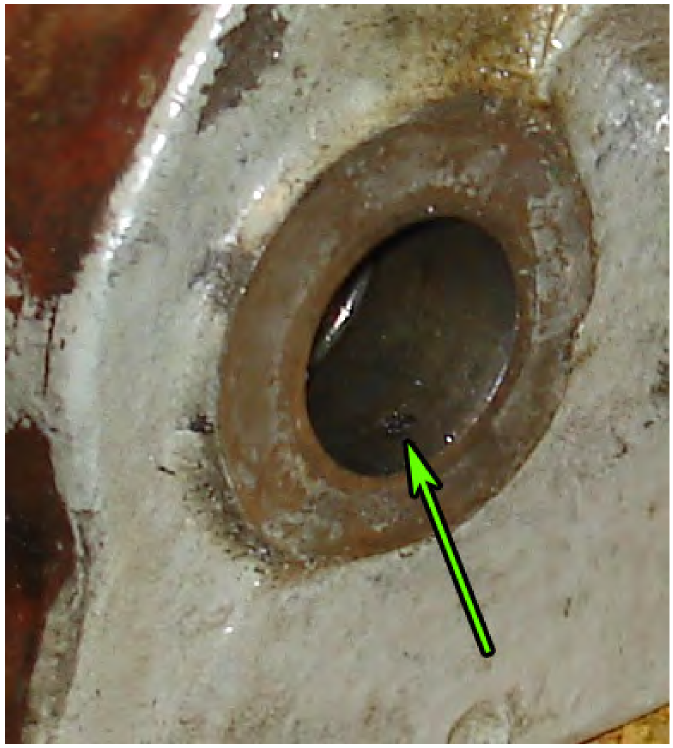


Figure 129: Location of a small wick in the leadscrew output port of the gearbox.

Next to be removed is the shift rail (perhaps more accurately called the countershaft). To do so, use a punch to drive out the retaining pin as shown in figure 130. The pin engages a groove in the shift rail. Once the pin is removed, drive the shift rail out as shown in figure 131. It must be driven this way - attempting to remove it from the other direction won't work because each end of the shaft is a different diameter.

There are felt wicks in the keyway at the smaller-diameter end of the shift rail which are obvious when the shaft is removed. At the large diameter end, there is one wick in the gearbox casting itself, as shown in figure 132.

The next step is to remove the mainshaft, which is where most of the gears are mounted. It is held in place by a single taper pin, located toward the edge of the smallest gear, as shown in figure 133. This is a tricky location for a taper pin, because you're near the center of the mainshaft and you don't want to risk bending it by wailing on the pin.

I pounded on the pin until I was no longer comfortable with the amount of force required to remove it. So I decided to drill out the pin instead. There are pitfalls to doing this, and I fell right into one. When I drilled I was off center slightly, which placed the bit on a path at a slight angle to the actual pin. So

Figure 130: Removing the gearbox countershaft (or shift rail) pin.

I ended up with an enlarged hole at the bit entrance and almost 2 separate holes where the bit exited (the original hole and the hole made by the drill bit offset from the original by almost 1 drill diameter). I used a number 16 drill bit. *Avoid this mistake! Drill it accurately on a drill press instead.*

Fortunately, I was able to save some bits of the original pin, so I placed them back into position in the shaft. The pin hole diameter is around 0.165", so I filed down a piece of 0.1875" stainless rod until it fit "snug" in the now-enlarged hole. I believe the repair will hold fine, but learn from my mistake: if you need to drill out this pin, be careful your bit is precisely aligned with the centerline of the mainshaft!

Figure 134 shows the mainshaft being removed, which must be done left-to-right since the diameter is larger on the right side of the shaft. It's not press-fit into anything, so it slides out pretty easily with some taps from a hammer. If possible, I recommend preserving the left/right orientation of each of the gears in the stackup so that they can be reassembled the same way. Decades of use will have worn the gear teeth in a certain pattern that is probably worth preserving.

With the mainshaft removed, you can remove all the main gears. In figure 135 I'm showing the two stackups: on the left are the gears which are keyed to the mainshaft, on the right are gears which rotate independently of the mainshaft. Notice I've run wire ties through the center of each stack so I can keep the gears in their original orientation.

Once the mainshaft and gears have been removed the output shaft inner

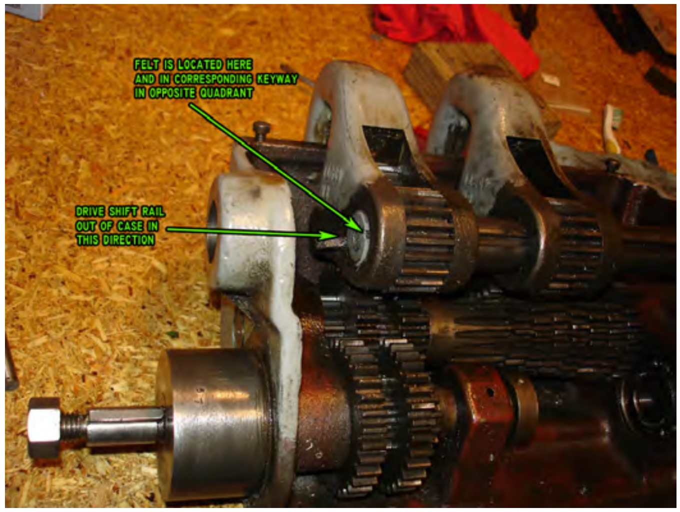


Figure 131: Direction to remove the shift rail.

Figure 132: Shift rail hole showing felt wick.

bearing can be removed. I did this by carefully tapping it out from the back (the right side in figure 136) at the inner race. It's not very tightly pressed into the casting, but there remains the possibility of separating the bearing inner race from the outer race by this method. If this should happen, removing this bearing may prove singularly troublesome, since there's no convenient way to access the outer race with a removal tool.

Fortunately, it's a standard size ball bearing, and if you must destroy the old one to remove it finding a replacement will be simple. The bearing I removed

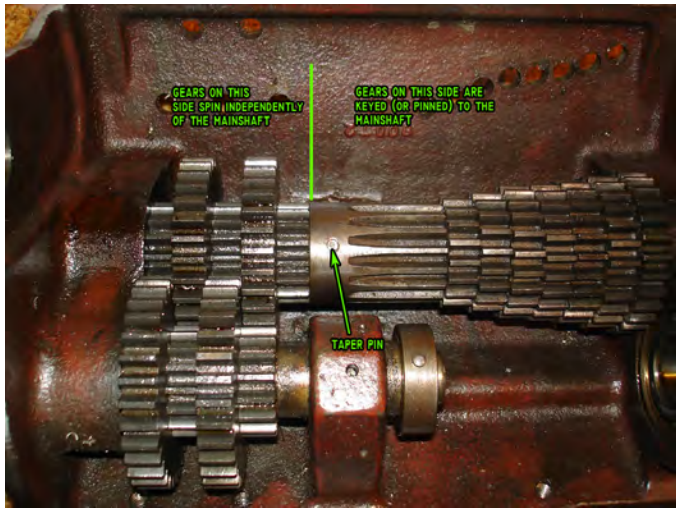


Figure 133: Mainshaft showing taper pin.

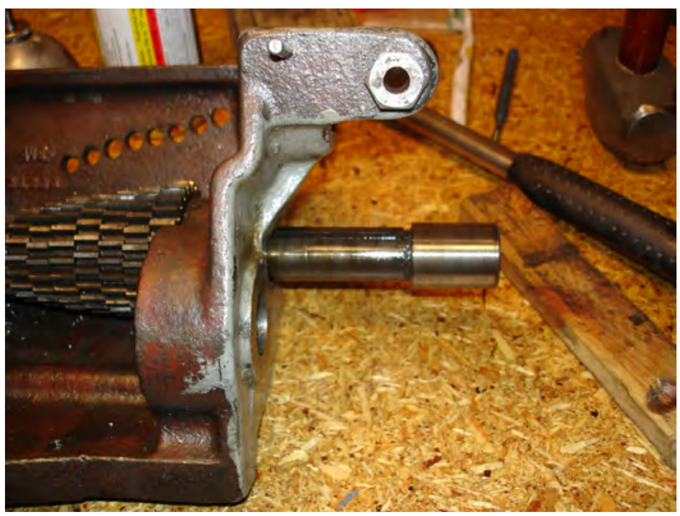


Figure 134: Mainshaft being removed.

was a New Departure number 20205.

At this point I found the only major damage to this gearbox as shown by figure 137. The bearing shown is for the inner portion of the input shaft, and it's badly scored. The input shaft is also scored, and it looks like something solid went through this bearing. It's not clear whether that's what happened, or whether there was a lubrication issue. It is interesting to note the lack of an oil wick here. However, on reassembly, I decided that any shaft with a wiper embedded in it probably doesn't need a wick in the bearing. The input shaft

Figure 135: Gears stacked to preserve orientation.

Figure 136: Removing the output shaft inner bearing.

has a felt wiper at this location, so I didn't bother to install a wick in the hole. This may or may not be correct, but at least if this bearing completely degrades it's easy to replace.

I removed the bearing from the casting - it's press fit, and I reduced the tightness of the fit by filing down the bearing OD slightly. I don't necessarily recommend doing this. It created no problems, but doing it is dangerous because you can easily end up with the bearing center being misaligned with the shaft center.

The bearing is a standard size - 1" OD x 3/4" ID (for a 3/4" shaft). I was able to buy an inexpensive replacement from McMaster-Carr, in case I decide to replace this damaged one. It's interesting to note that although this bearing has suffered severe damage, the clearance remains right about 0.001" and the shaft rotates very smoothly. For those reasons, I've returned the bearing to regular service and will monitor it carefully.

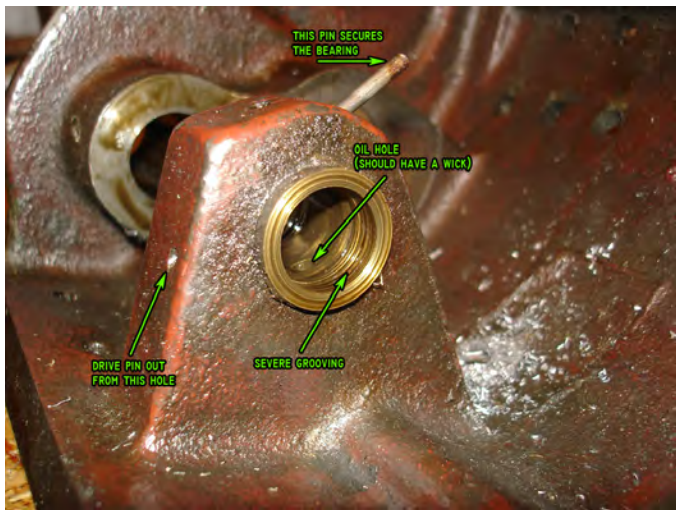


Figure 137: Damaged gearbox input shaft bushing.

Figure 138 shows the gearbox empty of its gears showing the main oil rifle. That rifle feeds the input, output, and mainshaft bearings.

The lubrication scheme is worth taking a moment to examine. Figure 139 shows the output side of the gearbox with relevant portions labeled. The main oil rifle feeds the mainshaft and output shaft directly. Although the output shaft rides its own bearings, the passage in the case penetrating the output shaft hole provides a small flow of oil that will eventually find its way into the bearings.

Some of the oil in the mainshaft bearing is picked up by a wick which carries it down a secondary passage to the shift rail (countershaft) bearing. Personally, I don't like this kind of serial lubrication scheme, because I think it has a tendency to under-lubricate the shift rail bearing.

Figure 140 shows the input side of the gearbox labeled to show oil flow. Not visible is an oil hole at the top of the mainshaft bearing.

There are numerous wipers and wicks throughout the gear case, and I've replaced all of them. Originally, every hole had a wick in it, but I've followed a slightly different philosophy. The mainshaft and input shaft both have embedded felt wipers. My feeling is that these bearings don't need wicks in the oil passages that feed them, since oil will merely flow out from the main passage and into the shaft bearing, where it's picked up and stored by the shaft wiper.

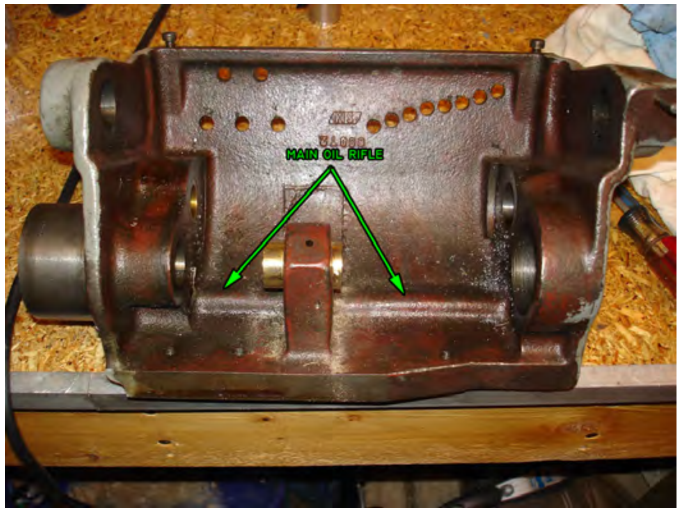


Figure 138: Inside of empty gearbox.

Figure 139: Side of gearbox showing lubrication points.

Furthermore, since the shift rail is lubricated using runoff from the mainshaft, having no wick impeding flow through the mainshaft bearings should improve the lubrication rate to the shift rail.

The felt used here is from a sheet of 1/8" thick F10. The F10 works well here, because you need something that's easily compressible.

You may not agree with these changes to the lubrication scheme, and I encourge others to follow their own logic in the matter.

Since I've begun operating the lathe gear box, I've found that oil poured into

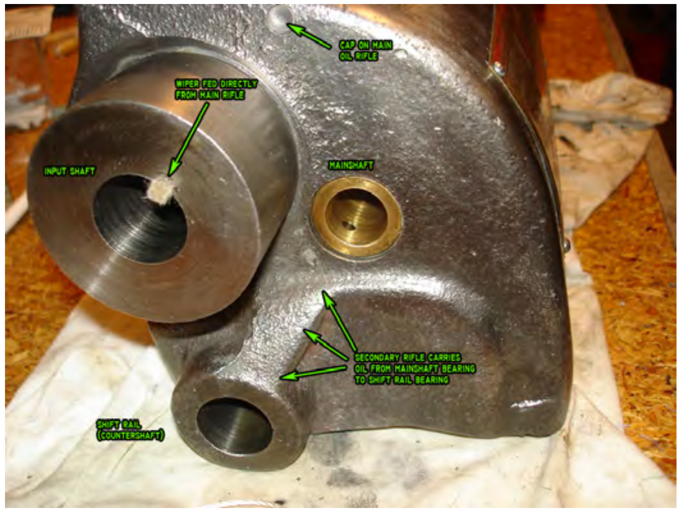


Figure 140: Input side of gearbox showing lubrication points.

the main rifle runs out rather quickly. As a result, I find myself adding oil to the gearbox frequently - once before first use, then again roughly every 30 minutes of use. However, everything in the box is well-soaked with oil (and makes a nice puddle beneath it). I bought a small aluminum baking tin at the grocery store which I've stuck beneath the gearbox using a couple strong magnets to secure it to the underdrive housing. This catches all the oil that drips off, leaving the floor clean.

In addition to the main oiler port, I've also been adding oil directly to the visible felts in the gear case on either side. This makes absolutely certain that all the bearings are well-oiled.

Nevertheless, I've considered whether I should've reinstalled the felts in the main oil galleries rather than letting the shaft wipers hold all the oil. The reason is, the main shaft is unable to store any oil - it all runs out. Yes, the shafts are all being very well lubricated (it's clearly visible when I fill the gearbox), but it's annoying that all this oil tends to flow right out of the gearbox over a fairly short period of time. Consider this carefully when choosing which parts of this rebuild to follow, and which to dismiss as "foolhearty".

11.4 Reassembly

The first step in reassembly is to insert the output shaft inner bearing. This is lightly pressed into the casting. It must be installed before the mainshaft is installed because the mainshaft gears will be in the way. This is clearly visible in figure 142.

The next step is the mainshaft. This can be a little tricky, because you must have the entire main gearset in position before inserting the mainshaft. That's because the length of the gearset is the same as the inner width of the casting - there's no room to slide gears onto the shaft one at a time. The problem is compounded by the need to align the keyways on the right side gearset.

I marked all the gear teeth over the keyway on each gear with a Sharpie to aid in alignment. I used the input shaft as a temporary hold for the left side mainshaft gears - the input shaft OD (on the smaller end) is the same as the mainshaft OD. Insert the input shaft from outside the case into the mainshaft bearing on the left side, and into the 3 gears that make up the left side main gears. This holds them in position while you slide the right side mainshaft gear stack. When the mainshaft is driven through, it will push out the input shaft.

I understand this isn't a very good way of describing reassembly of the mainshaft. It's a tricky - but not difficult - process. The best advice I can give is to try it a few different ways and come up with your own method.

Before any of that happens, however, you must replace the felt wiper. Figure 141 shows the new felt I installed. I experimented with a number of different options, and decided that 1/8"-thick, 1/2"-wide F1 felt works best. To make the wiper, cut a strip of the F1 to the proper length. Notice I left about 1/2" sticking off the end of the shaft. I did this because I figure I can add a drop of oil to it before each use to help augment the factory lubrication system.

The F1 is almost incompressible, and the groove for the wiper is slightly less than 1/8" (it measures at about 0.120"), so I had to carefully shove the felt into the groove. Once it's in there, use a sharp razor blade to trim the felt flush with the surface of the shaft. This may take some practice - I had to make several before I was happy with the technique. Since F1 is basically incompressible, it's important that it not be too proud of the shaft surface. You want it to stick out just slightly so it gently contacts the inside of the case bearing surface.

I did try using F10 here, but installing the shaft can be a rough process. When I inserted the shaft in the gears, the sharp edges caught on the F10 and tore it out. F1 is far more resilient, and there were no problems getting the shaft through the gears.

Figure 141: Mainshaft showing new felt.

Figure 142 shows the mainshaft finished. Notice the gears have all been cleaned and that the output shaft inner bearing has been reinstalled prior to installing the mainshaft.

Figure 142: Completed mainshaft installation.

The input shaft is installed next. I've noted the inner bearing in figure 143 (the one that is severely damaged on my gearbox), as well as the collar used to retain the input shaft. This goes together much easier than the mainshaft.

Originally that inner bearing required a substantial beating with a hammer to remove - so much so that I deformed it trying to remove it. So I chucked it up in the lathe (since the headstock and electrical work was finished at this point) and filed down the OD a few thousandths. Now it can be pressed in by hand, and is retained securely by the original retention pin (not visible in figure 143).

Next is the shift rail (or perhaps countershaft, depending on how you prefer to name your gearbox shafts). This was the easiest item to reinstall, because the shifters can be positioned to hold themselves pretty close to the correct position.

In figure 144 I'm showing my method for putting new felts in the keyway. That's a piece of 1/8"-thick F1 trimmed narrow enough to be forced into the groove. In the photo I'm using a fresh razor blade to trim away the protruding felt so it's flush with the surface of the shaft. As I've noted in the photo, be sure to press down firmly with your finger the area just ahead of the blade. If you don't do this along the whole length as you cut, the blade has a tendency to pull the felt up out of the groove as it cuts, which leaves the felt too far below the surface of the shaft to do any good.

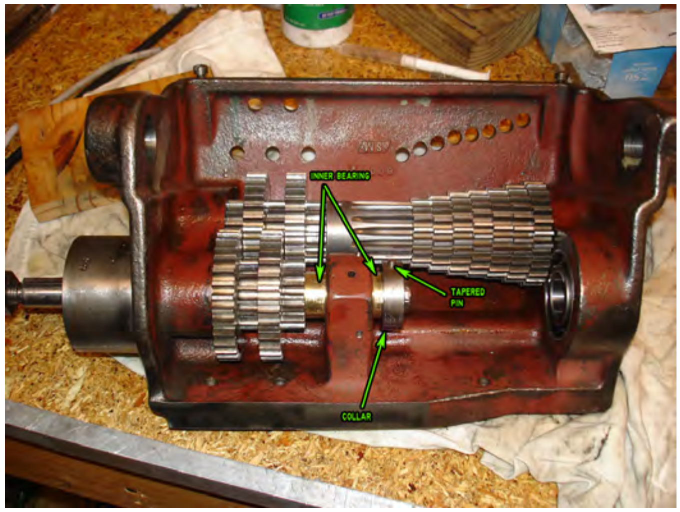


Figure 143: Input shaft reinstalled.

Figure 144: Method of installing new felt in gearbox shafts. The input shaft is shown, but other shafts are done the same way.

In figure 145 the gearbox is fully reassembled except for the leadscrew, which won't be reinstalled until the box is ready to go back on the bed. Remember how dirty this was?

The 2 gears that slide along the shift rail have 2 keys in them, corresponding to the 2 keyways in the shift rail (only one keyway is visible in this photo). The felts for the shift rail mount only on the left end, and I've noted one sticking out slightly in figure 145. I cut these felts slightly too long so they can be manually lubricated and their condition judged without dismantling the box.

Figure 145: Gearbox showing felt protruding from shift rail.

11.5 Gearbox Lubricant

South Bend specifies a gearbox oil of type "B", which has a saybolt universal viscosity rating of 150-240 seconds at 100°F. According to Machinery's Handbook, the conversion from saybolt viscosity to centistokes is:

$$\mu_{C,40^\circ C} = (0.22)\,\mu_s - \frac{180}{\mu_s}$$

in which the subscript "C" denotes centistokes and "S" denotes saybolt. This suggests an oil between 31.8 cst and 52.05 cst would be appropriate. It turns out the manual transmission fluid I use for my truck, Pennzoil Synchromesh, has a viscosity of 41.6 cst. I trust this oil in my truck transmission, and have no reason not to trust it here.

11.6 Reinstalling the Gearbox

I left the gearbox off the lathe and separated from the leadscrew for several months while I readied other parts of the lathe. I stored the leadscrew vertically (or very nearly so) in order to prevent putting any kind of curve in it.

When it comes time to reinstall the gearbox, you must attach the leadscrew before mounting the gearbox back on the lathe. This is because there's not enough clearance to get wrenches under the gearbox for attaching the leadscrew nuts.

As I mentioned earlier on this page there are two nuts that secure the leadscrew. One sets the preload on the inner and outer bearings, and the other is merely a jam nut. You don't need much torque on the inner nut! There's no need to put a lot of preload on those bearings. The way I did it was to tighten the inner nut until I just couldn't rotate the outer race of the outer bearing by hand. Unscientific, at best, but I think this should work.

Getting the leadscrew properly installed in the gearbox while sitting on a workbench isn't trivial. It took me awhile to get it installed and the nuts tightened with the leadscrew in proper alignment to the case. Take your time, and try to minimize any torque you're putting on the gearbox with the leadscrew.

My method was to stack some scrap wood beneath the far end of the leadscrew so that when it sat horizontally it was at nearly the correct height for the gearbox hole. Figure 146 is showing that I had the gearbox positioned upside down, since that places the leadscrew closer to the bench surface. Not to mention it's easiest to get wrenches on the nuts with the gearbox in this position.

Figure 146: Reinstalling the leadscrew in the gearbox.

You'll want somewhere around 1-inch of wood stacked at the far end of the leadscrew to minimize the binding where it enters the gearbox. My method was:

1. Stack a 1" block at the far end of the leadscrew.
2. Slide the leadscrew into the gearbox and install the output gear and the two nuts (finger tight).
3. Torque the inner nut until you can't move the outer bearing race by hand anymore.
4. Rotate the gearbox assembly so it's right-side-up, being careful not to put too much stress on the leadscrew.
5. Stack a block several inches high at the far end of the leadscrew. Use enough height to take all the stress off the leadscrew where it enters the gearbox, so that the whole thing is balanced.
6. Check the tension on the leadscrew outer bearing by trying to rotate the outer bearing race by hand.

7. Use a wrench to make minor adjustments to the inner nut as necessary so the bearings are just tight enough so the outer bearing race can't be rotated by hand.

I went through this procedure several times until I was happy.

When you're ready to reinstall the gearbox and leadscrew, you'll need an assistant to hold and steady the far end of the leadscrew. If the apron is installed, rotate the leadscrew so the keyway is pointing down, and rotate the worm drive in the apron so the key is on the bottom. Position the apron about 1/3 of the way down the bed from the headstock-end. This will put it in a good position to provide support to the leadscrew close to the gearbox during the install.

Be careful to never let the gearbox hang from the end of the leadscrew! Slide the leadscrew into position and screw down the gearbox before your assistant leaves. Once the leadscrew is installed it's best to have the assistant help you hold up the gearbox (it's heavy).

12 Apron

The apron is attached to the carriage and contains the gearing necessary to bring power from the leadscrew to the power feed on the carriage and cross slide. Figure 147 shows an overview before removal.

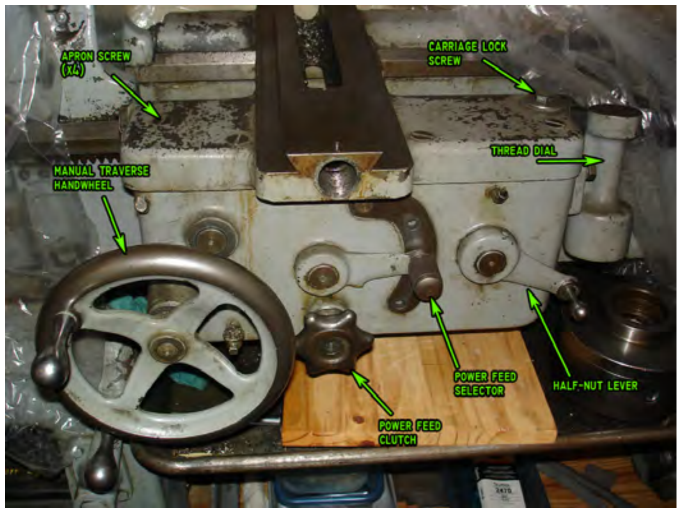


Figure 147: Apron before removal showing important parts.

Half nuts (which ride the leadscrew for threading operations) are engaged by pulling up on the half nut lever. Cross feed is selected by moving the power feed selector to the upper position. The lower position engages power longitudinal feed.

To remove the apron, the four slotted screws which secure it to the carriage must be removed. This can be done after the leadscrew has been removed, or the entire carriage assembly (with apron attached) can be slid off the end of the lathe if the leadscrew and gearbox are not going to be removed. I found the screws very tight, and you need a minimum 3/8" flat head screwdriver to avoid stripping the slots. A large "drag link" socket might be even better. I had to use a wrench on the handle of my screwdriver in order to get sufficient torque.

There is an oil sump in the bottom of the apron which is drained via a plug at the bottom. It's probably best to drain the sump before removing the apron (I didn't and ended up with a minor oil spill). If the sump is completely full (as it should be), there's quite a lot of oil.

12.1 Threading Dial

Begin by removing the threading dial, if equipped, by removing the single hex head cap screw that retains it in the apron. This device has a small gear that rides the leadscrew and is used to position the carriage properly when making a thread in multiple passes.

Shown in figure 148 is the thread dial cleaned up and disassembled. A small oil port is provided in the top of the shaft for oiling (not shown).

Figure 148: Thread dial parts.

12.2 Disassembly

With the apron off, remove the oil sump cover from the back (figure 149) to get at the innards. There's a gasket at the bottom to prevent leakage, so you might need to strike it to remove. Be ready to catch oil coming out. In fact, it's best to do this in some sort of drain pan.

To remove the sump cover, remove the 5 screws as shown in figure 149. The one in the center is longer than the others.

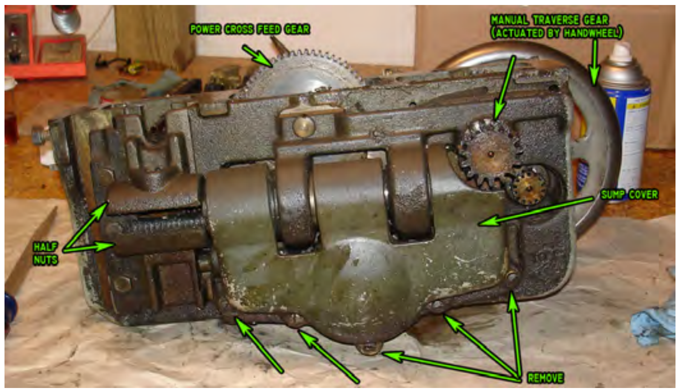


Figure 149: Back of apron before disassembly.

Figure 150 shows what's behind the sump cover. Power enters the apron through the leadscrew, which passes through the worm drive as shown. There's a key in the worm drive that engages the keyway on the leadscrew. The power feed clutch acts on the worm drive gear to transmit power into the rest of the apron.

12.2.1 Half Nuts

In order to remove the worm drive assembly, the half nuts must be removed so the worm drive cylinder has room to slide out. To do so, remove the gib on the left side secured by 3 hex-head cap screws and located by 2 dowel pins as shown in figure 151.

The dowel pins are probably too tight to permit removal of the gib by hand. I found it necessary to drive the pins *into* figure 151, which causes them to drop into the apron lower cavity where they're easily retrieved.

In figure 152 is shown the cam which actuates the half nuts vertically through a rotary motion of the control lever at the front of the apron. Pins in the back of the half nuts engage the cam slots. To remove the cam, first remove the handle on the front side of the apron by driving out the taper pin that retains it. Once the handle is removed, the cam will slide out.

Figure 153 shows the inside of the half nuts. It may be difficult to tell from this photo, but the thread forms are heavily worn. I suspect the half nuts were used often for power longitudinal feed instead of the power feed itself.

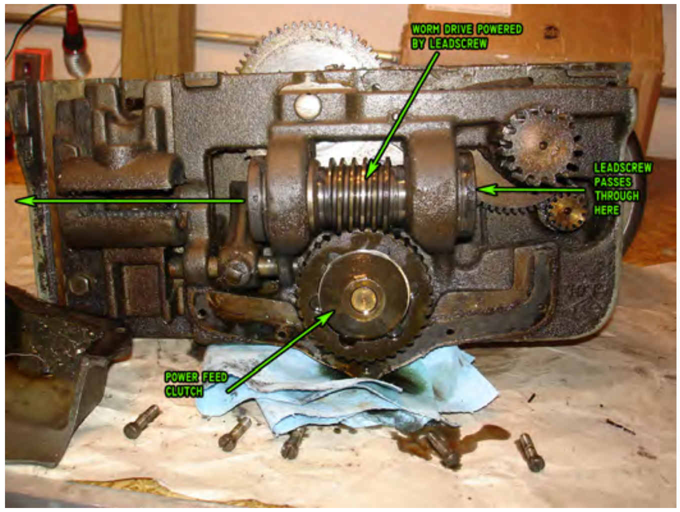


Figure 150: Apron with sump cover removed.

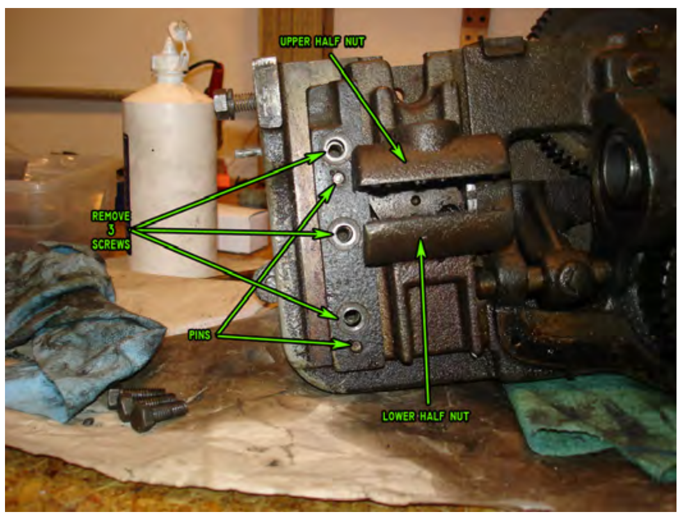


Figure 151: Removing the half nuts.

Since originally writing this section I have cut some threads. I found, quite surprisingly, that resulting thread form is very good, in spite of heavily worn half nuts and leadscrew. I was cutting some 7/8-9 threads to fit a nut for a spindle arbor on a grinder. A 7/8-9 nut is not a precision thread form, but it was critical that I get the threads on the arbor just right to avoid scrapping the part. I had no significant difficulty doing this.

I've heard it said (and seen it done) that to help compensate for slop throughout the drivetrain, leadscrew, and half nuts, one should hold a light pressure on

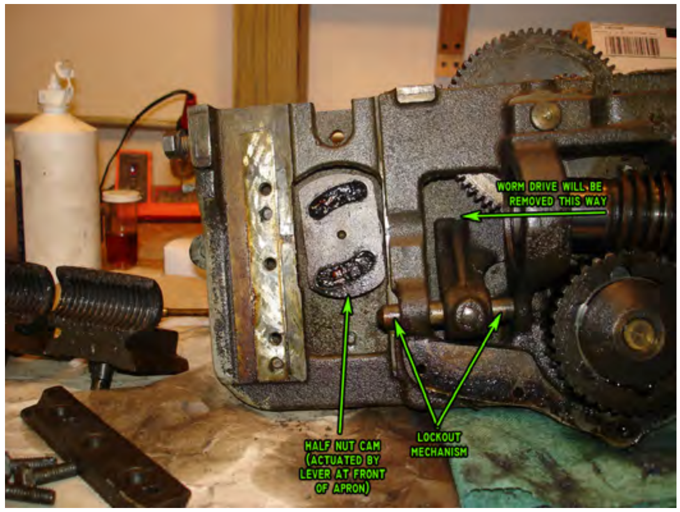


Figure 152: Half nut cam assembly.

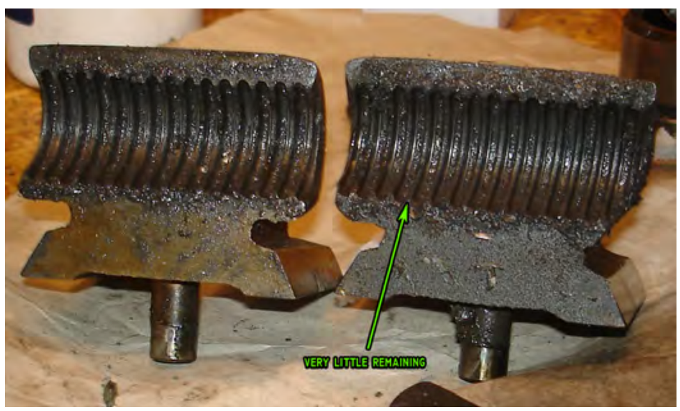


Figure 153: Half nuts removed

the apron handwheel when making a thread. This takes up the slack and runs the half nuts tight up against the leadscrew threads. I want to point out in the above example with the 7/8-9 threads that I did not do this, but I still got a good thread.

My point in saying all this is, even if your leadscrew and half nuts are almost worn away to nothing, don't assume you can't make good threads.

12.2.2 Worm Drive

Removing the worm drive can now be accomplished. Figure 154 shows the collars which secure the worm drive to the apron casting. Each collar has a straight pin, which is removed by driving into the picture. The collars are threaded onto the end of the worm drive cylinder, which runs in bushings as shown.

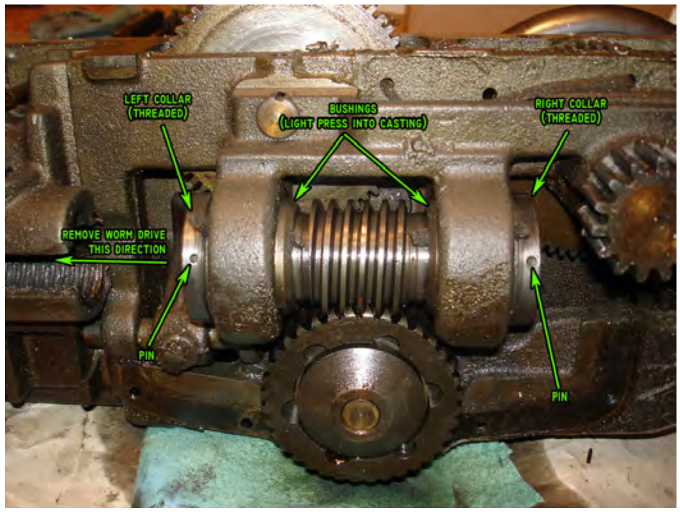


Figure 154: Worm drive removal direction.

Once the collars are removed, the bushings are clearly visible in figure 155. The locating pin is longitudinal, and can't be removed with the bushing in place. To remove the bushings, drive them out (they're lightly pressed into the case) as shown in figure 156 .

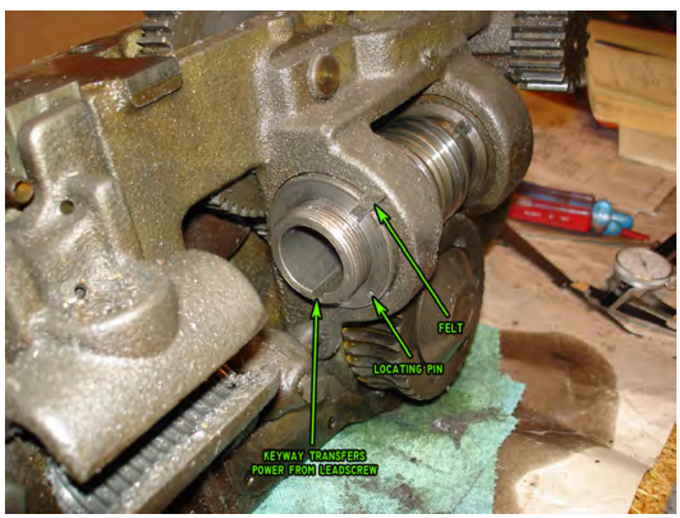


Figure 155: Worm drive end bushings.

Figure 156: Driving out the worm drive end caps.

12.2.3 Clutch

The clutch assembly is removed next. To do so, begin by removing the star knob (or lever on later model lathes). There's a hex cap screw that retains the knob, which was missing on this lathe (figure 157). I suspect the screw is #10-32 left hand thread. The star knob is also threaded on to the shaft behind it.

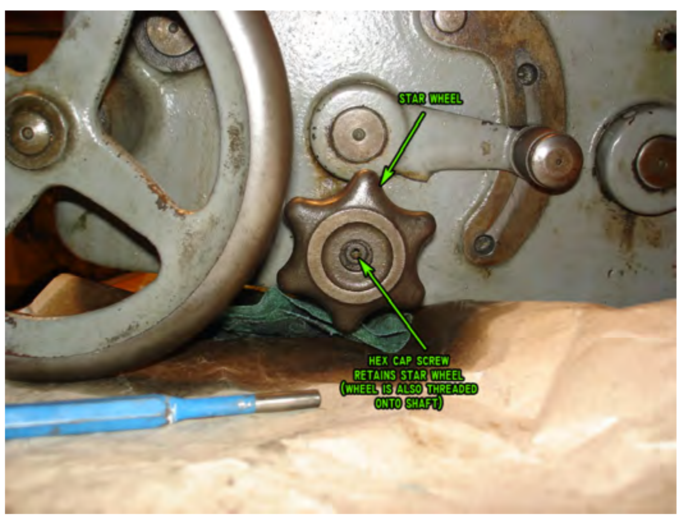


Figure 157: Star wheel before removal.

Figure 158 shows how the clutch shaft is retained in the case. There are two shafts - an outer and inner. The outer shaft provides a bearing surface for the worm gear while the inner shaft actuates the clutch pack. A straight pin retains the inner shaft to the outer shaft, which in turn is retained by the hex nut. *When the pin is removed, the clutch return spring may release the clutch pack on the back of the apron!*

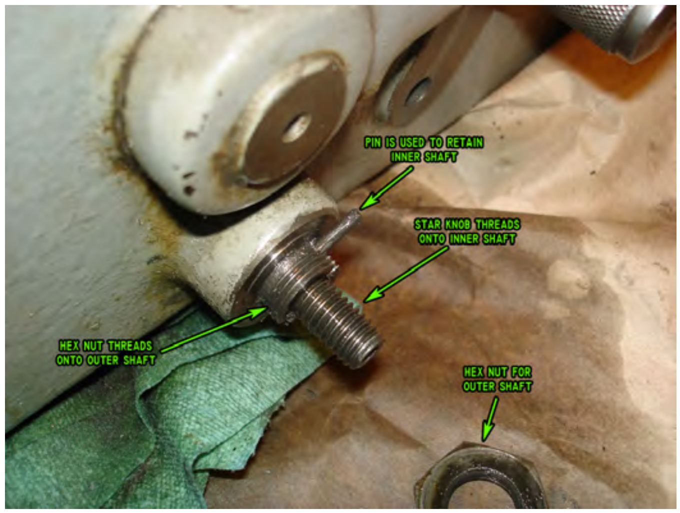


Figure 158: Star wheel removed.

Figure 159 shows the clutch being removed. With the star knob loose, the clutch pack is decompressed by the return spring, which permits the main drive gear to rotate independently of the outer shaft. When the knob is tightened, it squeezes the clutch pack together, which forces the outer shaft to rotate with the main drive.

Figure 160 shows a partial breakdown of the clutch assembly. The outer shaft is retained in the main drive by the external retaining ring as shown.

Figure 161 shows a partial mockup of the clutch assembly. The inner shaft is positioned concentric with the outer, and the clutch spring is in place, as well as the end bell. There are two types of clutch disks: one whose inner diameter is splined to match the outer shaft, and the other whose outer diameter is splined (the semi-circular protrusions that can be seen in the pack as shown) to the main drive.

Figure 162 shows what I thought was an anomaly. According to form 910D the part labeled "Oil Washer?" should be an oil washer, but on this lathe it's a thin gear. The inner diameter of the gear is larger than diameter "A", and "C", but smaller than diameter "B", which means when it's mounted on the shaft in the position shown in 910D it just flops around on the outer shaft. It turns out it was designed this way. This washer, with it's gear teeth, is actually an oil slinger, used to throw oil on all the gears in the vicinity. It doesn't rotate at the same speed as the outer shaft; instead it will rotate at some slower speed, but is apparently effective nonetheless.

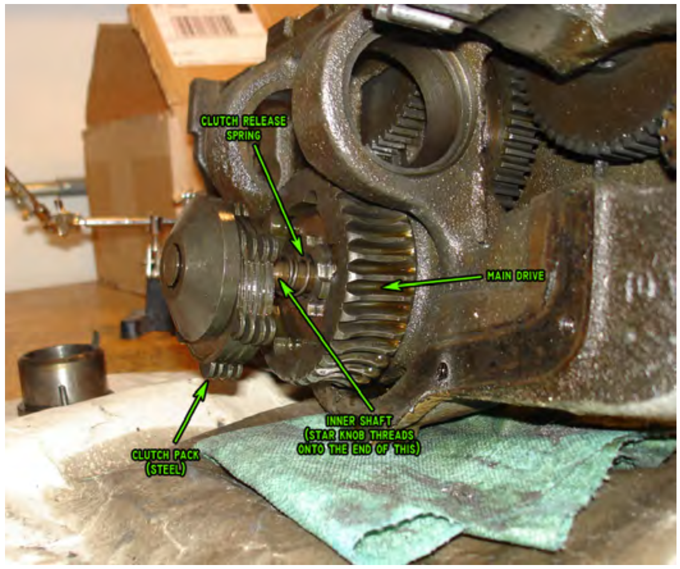


Figure 159: Clutch pack being removed.

12.2.4 Cross Slide Drive Gear

Next remove the cross feed drive gear (figure 163). This is the only gear that protrudes above the apron casting, and in so doing engages the cross feed lead-screw. To remove, punch out the pin as shown, and loosen the set screw. The shaft can then be driven out in either direction and the gear removed.

Figure 160: Clutch parts breakdown.

Figure 161: Mockup of clutch assembly.

Figure 162: Clutch parts showing unusual gear.

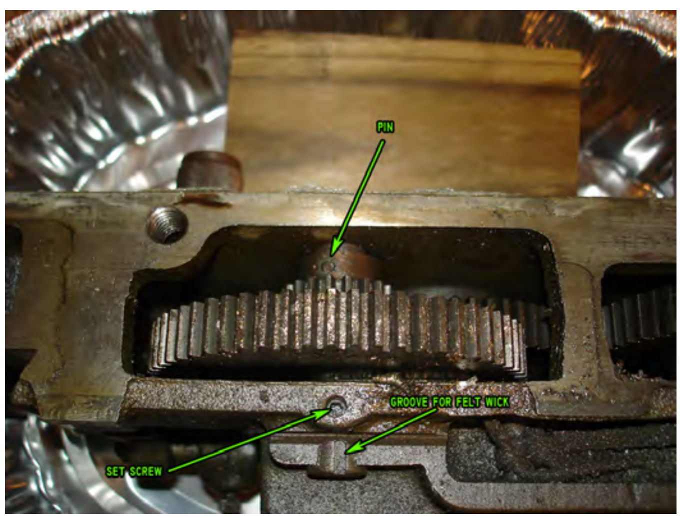


Figure 163: Position of cross slide drive gear.

12.2.5 Traverse Gear

Next remove the traverse gear assembly (figure 164). This is what engages the rack on the lathe bed to move the cross slide assembly when you rotate the handwheel. Note the taper pin - it's easy to tell the big end from the small end.

The gear that engages the rack is permanently affixed to the shaft, so the shaft must be removed by driving it out toward the bottom of figure 164.

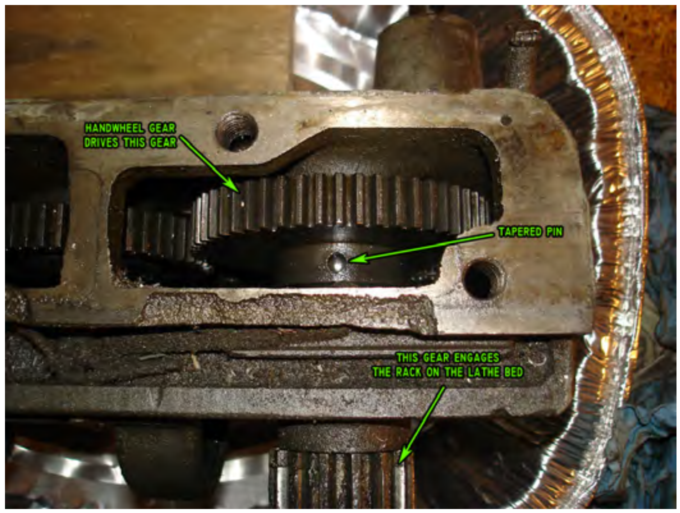


Figure 164: Rack drive gear (traverse gear).

12.2.6 Handwheel

To remove the handwheel, punch out the taper pin that retains it to the shaft as shown in figure 165. The shaft can then be pushed out in the direction shown.

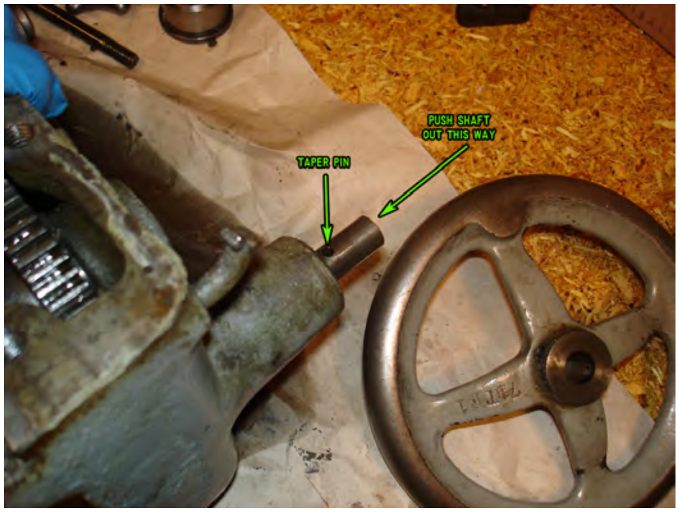


Figure 165: Handwheel shaft.

12.2.7 Drive Selector

Next remove the gear shift mechanism, which is simply a gear on an offset cam actuated by the gear selector lever. Remove the taper in as shown in figure 166 (note the apron has been flipped upside down to gain access to the pin).

Figure 166: Drive selector taper pin.

The clearest way to show the gear shift assembly is laid out in pieces, as in figure 167. All of the gears in the apron are shown here. It's difficult to tell from the photo, but the stub shaft on the gear selector cam is off-center, so when the drive selector lever is moved the central drive gear engages either the cross slide gear, nothing (neutral), or the rack drive intermediate gear.

Figure 167: Complete apron gearset layout.

12.3 Apron Lubrication System

The original lubrication scheme used a series of long felts running from the oil sump at the bottom of the apron casting up to the various shafts that require oil. I don't particularly like this system, especially after seeing the condition of the old felts. Nevertheless, the system worked pretty well, so I intend to use a similar arrangement, with a couple minor changes.

Of the 5 shafts, 3 of them are too far from the oil slinger to receive oil from it. These are the handwheel shaft, the rack drive gear and shaft, and the cross slide gear shaft. The gear selector lever shaft is splash-lubricated from the main sump, and the half-nut lever is lubricated automatically when oil is added to the half-nut sump via the oil cup on the right hand side of the apron.

The handwheel shaft, near as I can tell, had no way of obtaining fresh oil from either the lower sump or the upper reservoir. I suspect this apron was apart in the past, and not reassembled correctly (more evidence of that to come). To remedy the handwheel shaft, I drilled a small (7/64") hole in the casting directly over the felt keyway, as shown in figure 168. This hole penetrates directly to the felt keyway, and permits feeding oil directly to the felt. To test the idea, I assembled the handwheel shaft in the casting completely dry and pumped the recommended oil (Mobil Vactra No. 2) into the hole. As expected, the wick soaked up the oil and provided an abundance of lubrication. The wick I used here is a strip cut from a 12"x12"x1/8" F10. F5 would be equally good here (perhaps better, since it's more resilient). It's interesting to note it would be possible to remove the handwheel and shaft with the apron still on the lathe, so I can make quick inspections easily if necessary.

Internally, I modified the felt arrangement for the rack drive gear as shown in figures 169 and 170. Those photos show how the wick for the rack drive gear shaft (the wick that is farther away in both photos) runs up (toward the top of the photo), around the gear, and then through a hole in the casting to the upper oil reservoir. Originally, South Bend had that wick running straight down from the outer bearing (the right side of the photo) into the main oil sump. This resulted in one unused access hole to the upper oil reservoir.

A bit of research revealed why that extra hole in the upper reservoir existed: in prior years, South Bend routed these wicks exactly the way I've done here! Figure 171 is courtesy Mr. G. McLane, showing his South Bend Heavy 10 apron (very similar to the 13" apron) which is of an earlier vintage than my 13". Notice the unfinished cross brace, which doesn't contact the saddle when the apron is installed; contrast that with my 13" apron, which has a finely ground surface atop that cross brace which contacts the underside of the saddle when the apron is installed - a fact which precludes use of any sort of attachment (such as the wire shown in figure 171.)

To facilitate holding the wick away from the gears, I decided to grind a very small slot in the cross piece so that a small-diameter wire can be installed similar to the Heavy 10 arrangement shown in figure 171. Figure 172 shows the slot with a piece of 20-ga. wire installed to retain the felt. I used a piece of stranded copper wire (insulation removed), twisted and tinned with solder to make the

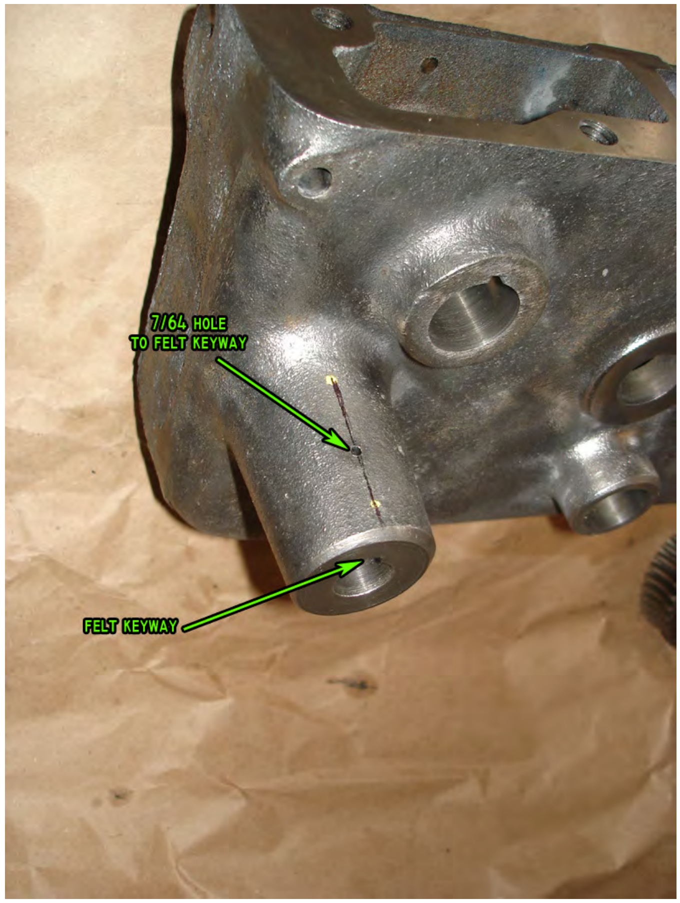


Figure 168: Apron casting with new hole for handwheel shaft.

retainer. The ends were then soldered together to make a ring without the need for twisting. The photo was taken just before snipping off the excess wire ends.

It's interesting to note that South Bend specifies two different types of oil for the apron: the upper reservoir gets Mobil "Vactra Heavy Medium" (since superceded by DTE Heavy Medium), while the main sump gets Mobil Velocite No. 10. The Velocite is substantially less viscous than the Vactra. If the outer rack gear drive bearing were run down to the main sump (as it came from the factory), it would receive the thinner Velocite.

I'm not clear on why South Bend changed the routing of that wick. It could be for economic reasons - it may have taken slightly less labor to install the wick down into the sump instead of across to the upper reservoir. Or perhaps there is some flaw in this routing that I don't see right now.

The wick I'm using here is from a 12"x12"x1/8" sheet of F5 from McMaster-Carr. I've simply cut strips of it long enough to reach from each bearing over to

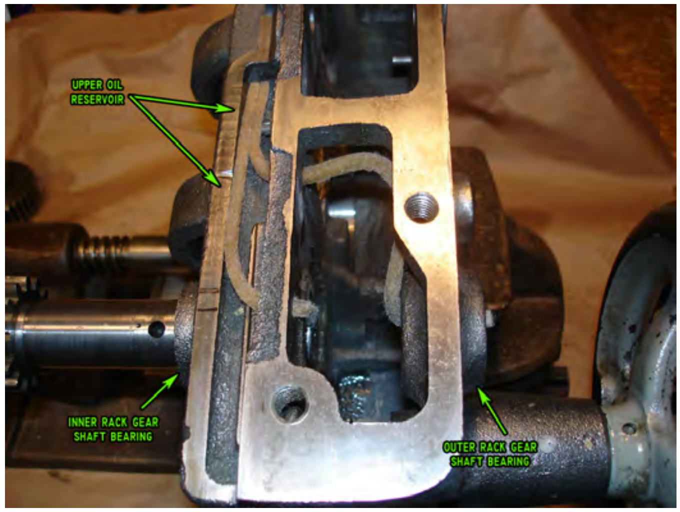


Figure 169: Felt routing for inner and outer rack gear bearings.

the upper reservoir. The 1/8" thickness is perfect for the depth of the keyways in the bearings. F5 or F10 would both work in this application, but I'm using F5 because it's more resilient than F10. F1 wouldn't work here because the felt needs to be compressed in service and F1 isn't compressible.

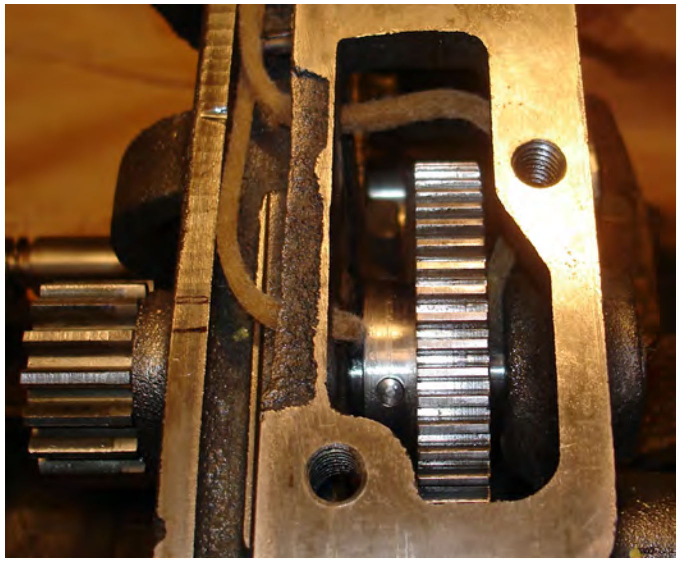


Figure 170: Felt routing for rack gear bearings with gears installed.

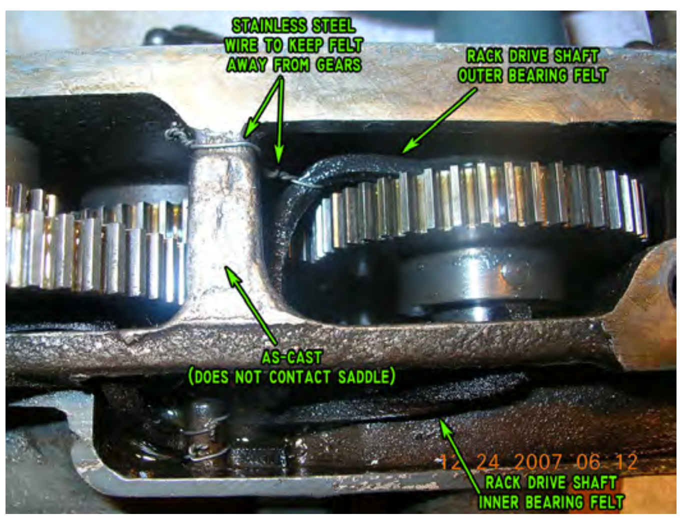


Figure 171: A heavy 10 apron showing different upper felt routing.

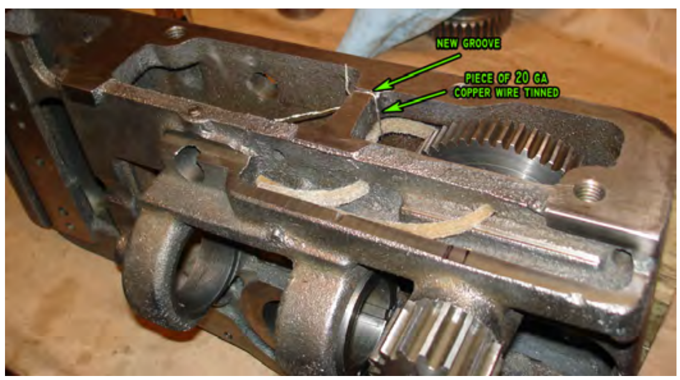


Figure 172: New upper reservoir felt routing.

12.4 Reassembly

12.4.1 Main Drive

With the rack drive arrangement reinstalled, we move over to the main drive assembly, which must be installed before the cross slide drive gear due to access considerations. This is where main power enters the apron from the leadscrew, and it has an interesting wick arrangement, difficult to explain and show adequately with photos. If you have questions, email me.

Figure 173 shows the routing of the wick before the worm gear itself is installed. Note the orientation of the wick keyway in the worm drive bushing! On this lathe, the assembly had been apart in the past and the bushings were swapped left/right when reassembled. This caused the keyway to be pointing 180 from where it is in the photo, which is bad. Fortunately, there was no damage (which leads me to believe the "repair" was relatively recent). Actually, the wick routing I'm showing was completely absent on this apron, and it took quite a bit of research with other lathe owners to figure out what the correct wick arrangement was.

The wick I'm using at this location is 1/8" diameter F1 corded felt, purchased from McMaster-Carr for a very reasonable cost. F1 is quite durable, and fits nicely into the keyways and around the clutch gear. It would also be possible to use F5 here, but in my opinion the sturdier F1 is a better choice.

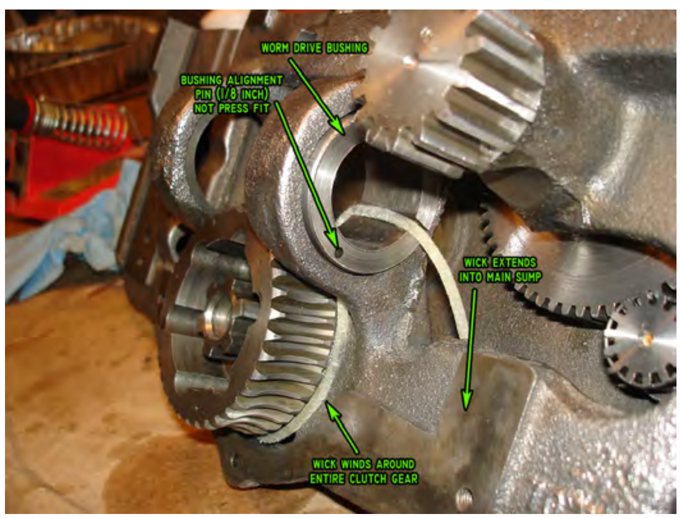


Figure 173: Clutch gear felt routing.

Figure 174 is showing the inside view of the felt routing from figure 173. *The loose end of the wick on the left side of the photo is just laying there temporarily for assembly.*

Figure 175 is showing the way the wick lays with the worm drive gear installed. The collar that retains the worm drive isn't shown here, but when

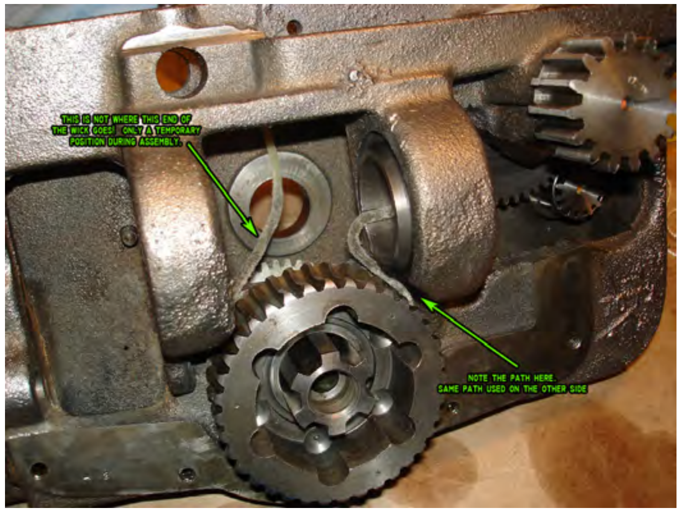


Figure 174: Clutch gear felt routing.

installed it keeps the worm bushing pin from falling out and holds the wick against the its keyway in the bushing. Since the bushing is stationary and the collar rotates with the worm drive gear, the felt provides lubricant to the interface.

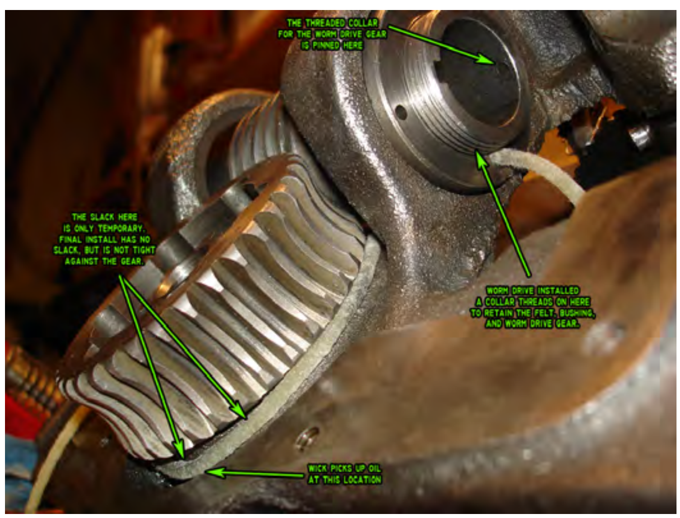


Figure 175: Felt routing around the main drive gear.

Figure 176 shows what I did with the ends of the wick that drop into the main sump. Originally, South Bend didn't extend the wicks into the sump, but I figure why not? In so doing, we make the felt triple-redundant, by which I mean it obtains oil from three sources. The two walls should keep the felt from engaging any of the mechanism. Figure 176 notes a few other items that are visible and important for the next section.

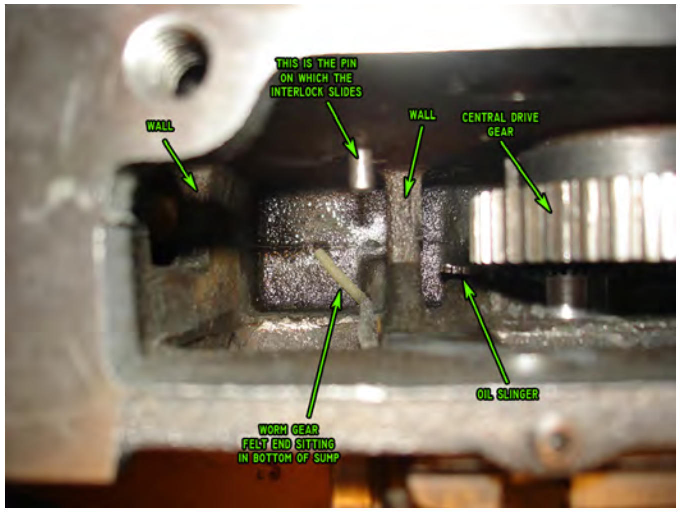


Figure 176: Felt routing for main drive gear shown from above.

12.4.2 Central Drive Assembly

Next the central drive gear must be installed. Figure 177 shows it installed (during disassmbly - I didn't take a picture at this point during reassembly). Although the worm drive is clearly absent in this photo, I installed the central gear after reinstalling the main drive assembly. This gear is mounted on an eccentric shaft that is rotated by the gear selector lever on the front of the apron. As the selector is rotated, the central gear engages either the rack drive gear or the cross slide drive gear (or neither for neutral).

This is a good opportunity to look at the interlock mechanism that prevents the operator from engaging both the half nuts (for threading) and the power feed simultaneously. Figure 178 shows the interlock with the main power feed engaged. Notice the interlock has been pushed from the notch in the gear selector and the end of the interlock shaft is engaging the lower half nut.

Figure 179 shows the interlock in the opposite configuration - the half nuts have been engaged, which has forced the interlock mechanism to engage the notch in the gear selector. In this position the operater is unable to move the gear selector lever out of neutral.

This is a very crude mechanism, and at first seems odd without some kind of spring to hold the interlock in one position. But it works, and is foolproof. It is a valuable safety feature, since engaging both the power feed and the half nuts simultaneously would be disasterous.

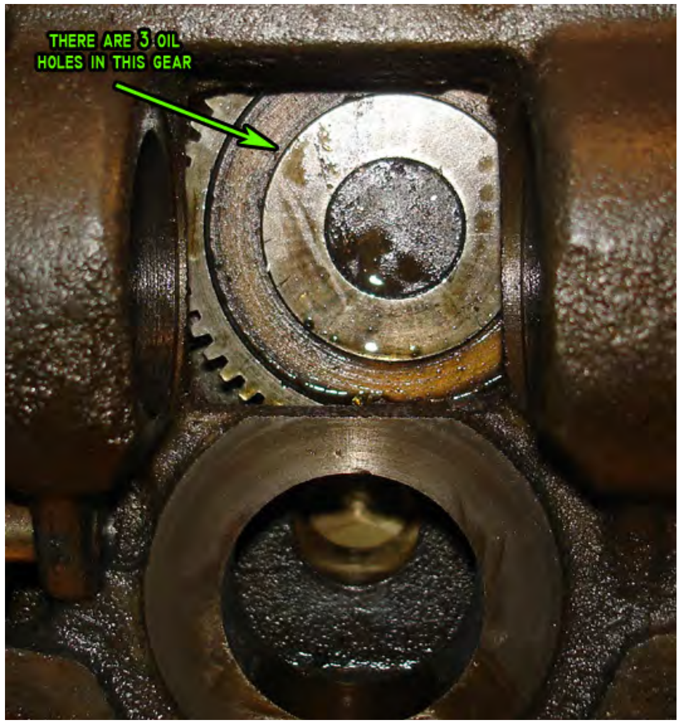


Figure 177: Central drive gear.

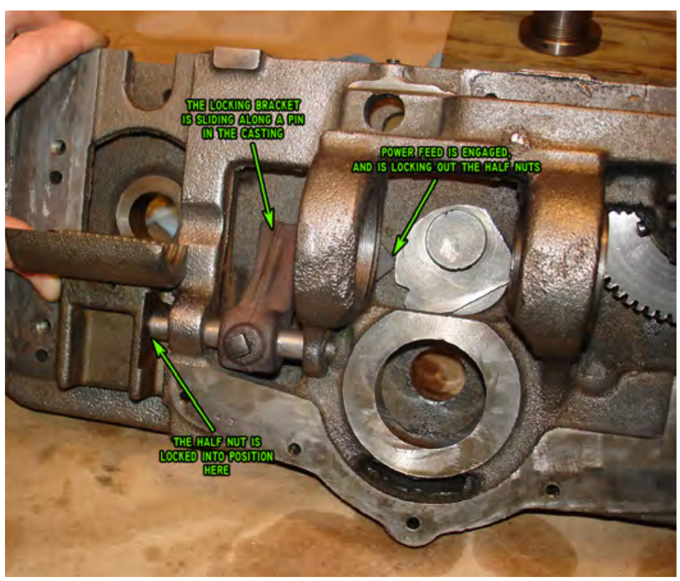


Figure 178: Drive interlock engaged.

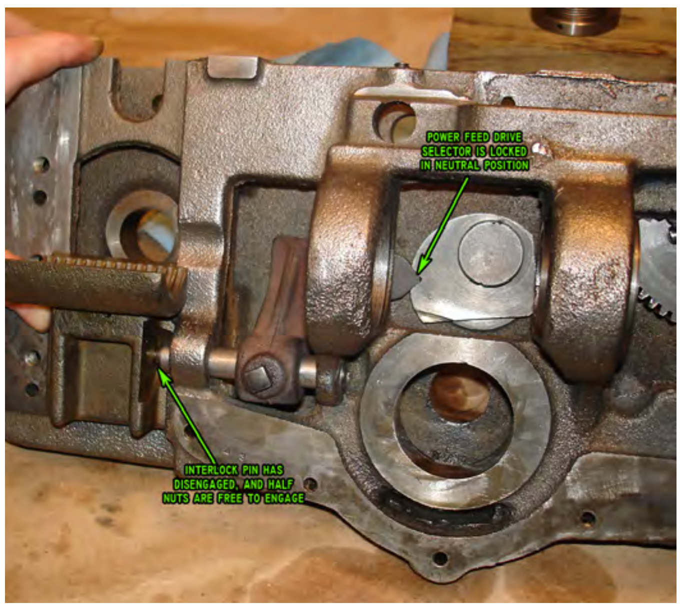


Figure 179: Drive interlock disengaged.

12.4.3 Worm Drive

Figure 180 shows the worm drive installed. There are two 1/8" pins that keep the end caps from backing off the worm gear (not visible in the photo). The clutch is also partially assembled here - the plates have been inserted but the pressure plate has not. Also visible are the half nuts on the left edge of the photo.

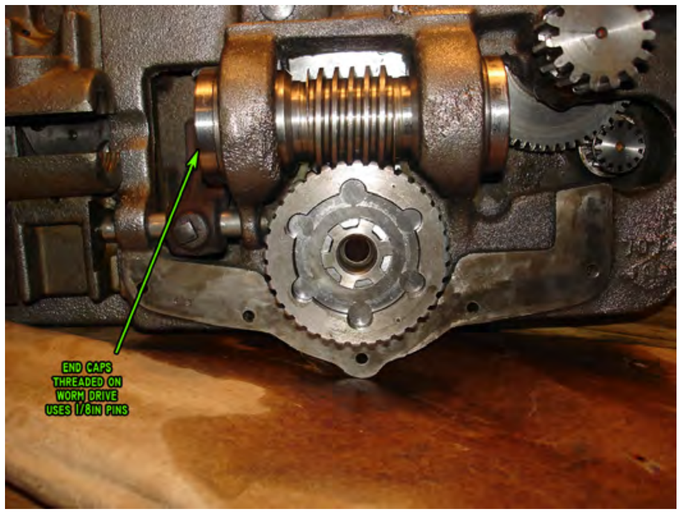


Figure 180: Worm drive installed.

12.4.4 Cross Slide Drive Gear

The last gear to be installed is the cross slide drive gear as shown in figure 181. This also happens to be the most difficult felt to run, due to the tight clearance. There's a groove for the felt in the gear shaft, but due to the way it's put together you have to install the gear shaft through the gear at the same time as the felt. What I mean is, you must position the felt in such a way as to drive it into the keyway as the shaft is being driven into the case!

If that's confusing, you've just about got it right. It took me awhile to plan out a method, and 3 or 4 tries to get it right. The felt has to be thin, as indicated, because the keyway is shallow and the clearance between the gear and the case is tight (around 0.075" or so).

The red arrows in figure 181 are attempting to show the path that the wick takes from the upper reservoir to its termination at the end of the keyway in the shaft.

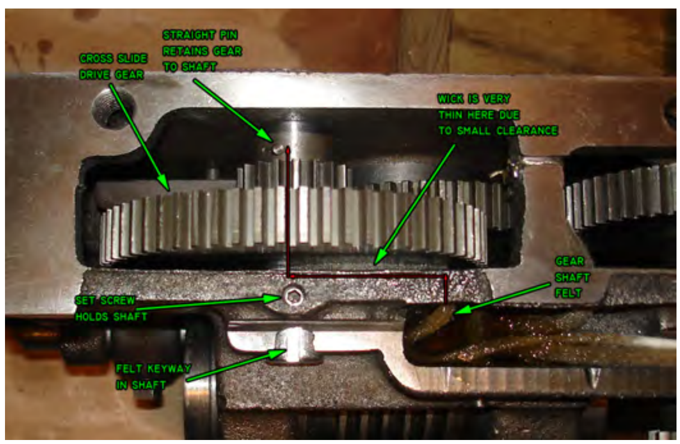


Figure 181: Cross slide drive gear felt routing. The red line follows the path of the felt from the upper reservoir.

12.4.5 Repaired Apron Oiler

One of my oilers - the one that feeds the half nuts - had a missing cover. Initially my intention was to replace it. But i discovered, rather by accident, that a 3/16" drive-in shouldered oil hole cover presses nicely into the end of the original. Doesn't look quite as "clean" as the original, but it's good enough (figure 182.)

If you would rather replace this altogether, a good part number from McMaster-Carr is 1239K15, "drive-in elbow-style oil-hole cover, 5/16" hole diameter". This is a Gits-brand oiler, so it's consistent with the original manufacturer, but it looks nothing at all like the one I've pictured here. The problem you'll encounter, however, is the metal used on the modern oiler won't accept solder. In fact, if you heat it up to solder it you may inadvertantly melt it. I know this because I tried it. So if you buy such a replacment be sure to consider the fact that you'll have to come up with another way of attaching a short piece of brass tube to it.

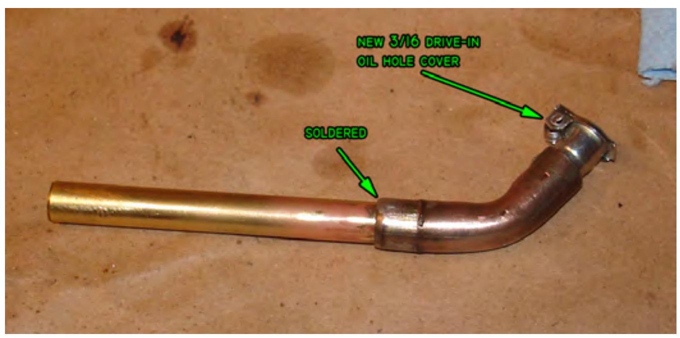


Figure 182: Repaired apron oiler.

12.4.6 Sump Cover

The last thing to do was cut a new gasket for the sump cover (figure fig:NewGasketPositionOnSumpCoverSmalle
I decided to use a rubber/cork blend, which I got at an auto parts store for about $5 (much cheaper than McMaster-Carr, for some reason). I applied a little Dykem blue to the gasket area on the cover, then transferred that to a piece of paper and made a template.

Figure 183: New sump gasket in position.

Of the 5 screws shown in figure 184, only the one in the center and the far right end (on the handwheel side of the apron) actually penetrate the casting into the oil sump. To those two I applied a little thread sealant. I applied no sealant to the gasket itself.

I also stuck a little neodymium magnet on the apron drain plug so I can collect any metals that find their way into the oil when I drain the apron for periodic maintenance. You could either put it as I've shown in figure 185, or you might want to insert the drain plug in the Apron casting, then attach a magnet (or two) to the outside of the plug if you're worried about possibly losing the magnet in the casting. Initially, I did it as pictured, but later changed my magnet to the outside of the plug because it was difficult to keep the magnet attached to the drain plug when reinserting it. Sticking the magnet to the outside of the plug should accomplish the same task, but in a more convenient way.

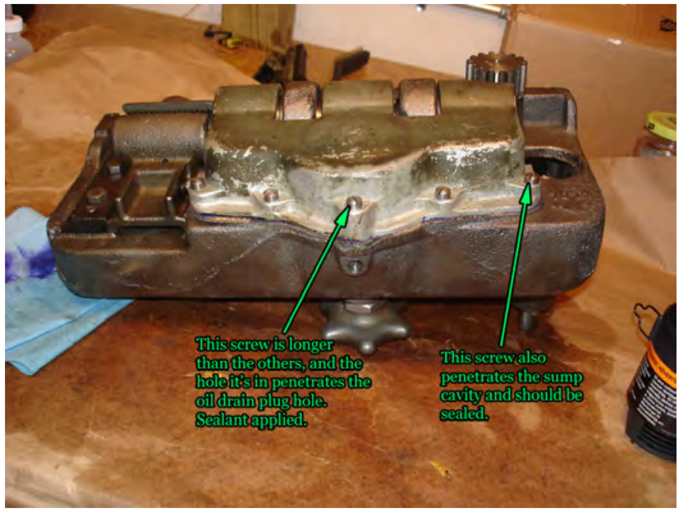


Figure 184: Reinstalled sump cover.

Figure 185: Magnet on apron oil drain plug.

13 Saddle

Once the compound, cross slide, and apron are removed, the only thing left is the saddle. To remove it, simply remove the gib at the back of the lathe as shown in figure 186. It is secured with three hex cap screws. The purpose of the gib is to retain the saddle and prevent it from rocking under load.

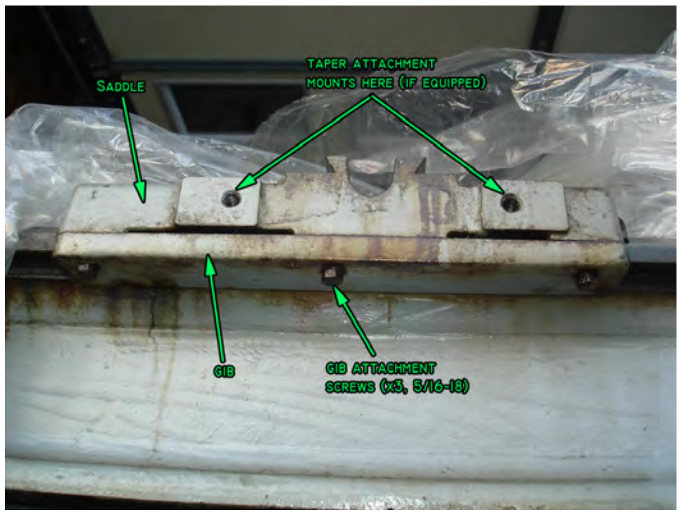


Figure 186: Saddle showing back side gib.

Figure 187 shows all the saddle parts from the top and figure 188 shows the bottom side. Note the felt wipers, which will need replacement. The two 3/8-16 tapped holes shown in the bottom side photo are for mounting a follow-rest.

There's really not much to tell here. The saddle is just a big iron casting that slides along the ways. It is worth noting that people say more wear occurs in the saddle ways than in the bed ways. This lathe has a great deal of wear in the bed ways, and the saddle ways (particularly the front one) are worn even worse.

It's also interesting to note the saddle gib doesn't appear to have any means of lubrication, as far as I can tell. Yet it's sliding surface contacts the underside of the bed way in the back, so it needs some lubricant.

When I say "heavily worn" figure 189 is what I mean. This is an extreme closeup of the front (operator side) way on the saddle. Notice there's a large ridge and so much of the saddle way surface has worn away that rough cast iron is emerging where there were voids and imperfections in the original casting.

I've heard that when these ways get really bad they begin digging into the flat portion of the bed ways. I'm not quite there yet.

This is one of those things that would be nice to inspect before purchase. But you can't, because the entire carriage has to come off to see it. But if the bed ways have a big ridge (like mine do), it's a pretty safe bet the saddle ways

Figure 187: Saddle removed showing parts.

Figure 188: Underside of saddle.

are in terrible condition (as mine are).

I made new felts for each corner of the saddle as shown in figure 190. These were made from 1/8-inch F1 sheet, with two of them stacked to make up the thickness I needed to fill the retainer. They can be pumped full of oil from the top at any time to help keep the ways lubricated. You want to trim the felt carefully here because you don't want the saddle riding the bed ways on the felts - it needs to ride on the iron itself.

Figure 191 shows the saddle finished and reinstalled on the lathe. Notice there is no longer any paint (the light areas in the photo are not visible in reailty - the camera flash reflected off some remnants of old paint). I prefer the look and resilency of bare cast iron to paint, so parts that are subject to lots of wear from flying pieces of metal will not be repainted.

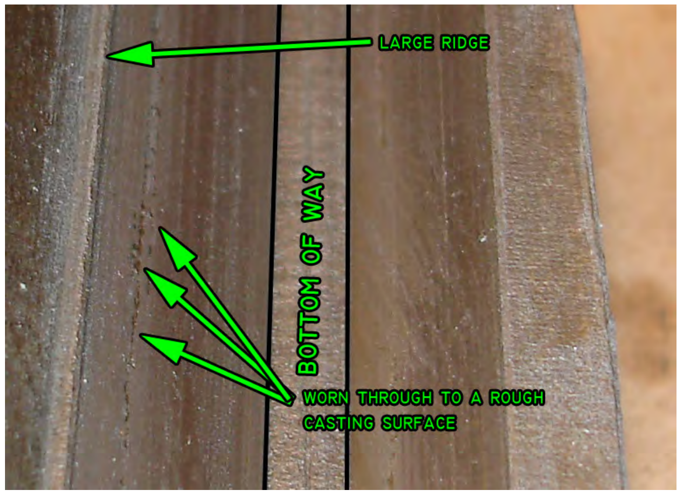


Figure 189: Saddle ways showing major wear.

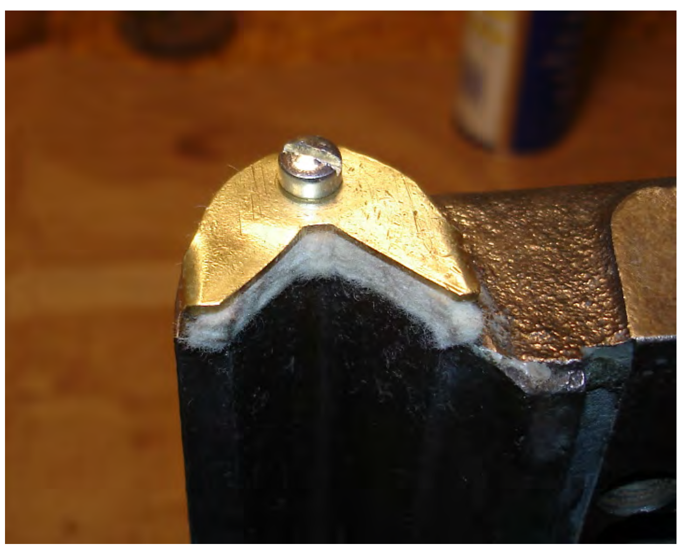


Figure 190: New saddle felt.

Figure 191: Saddle cleaned and reinstalled.

14 Tailstock

The tailstock is pretty simple. It's really just a cylindrical ram and a leadscrew. Figure 192 is what it looked like sitting on the lathe when I bought it.

The tailstock runs on its own ways, which you might assume aren't heavily worn since the tailstock isn't in use as often as the carriage. But you'd be wrong - the tailstock ways and base (to be seen) are both heavily worn on this particular machine.

The blind hole labeled in figure 192 is for something South Bend called a "dauber". Basically it's an oiler for lubricating a dead center. The following thread discusses the dauber: http://www.practicalmachinist.com/vb/south-bend-lathes/making-tailstock-dauber-130321/

Oilers are 3/16" drive-in type, readily available new.

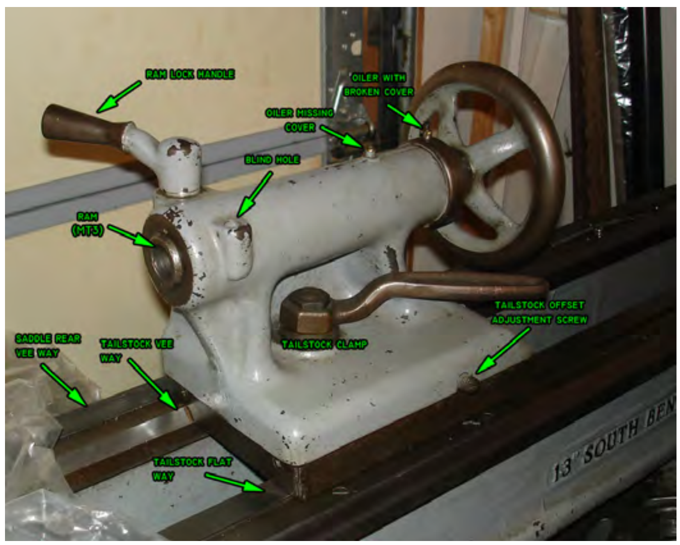


Figure 192: Tailstock before removal.

If you plan to completely dismantle the tailstock you'll want to remove the end cap while the tailstock body is clamped securely to the lathe bed. The end cap may be very tight, so having the tailstock on the bed and clamped into position makes it much easier to remove.

Remove the handwheel by removing the nut as shown in figure 193. Be careful not to lose the little pin that acts like a key to lock the handwheel to the tailstock ram leadscrew. The end cap has a hexagonal body that can be gripped with a 1-11/16" socket (figure 194.)

To remove the tailstock from the bed, simply unscrew the tailstock clamping nut completely, which will release the tailstock clamp shown in figure 196, beneath the bed. With the clamp removed, lift the tailstock off the ways. It weighs around 20 lb.

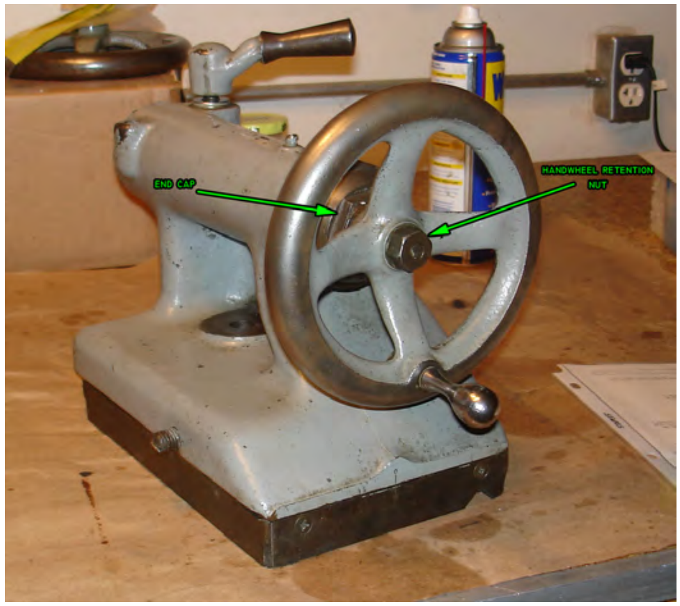


Figure 193: Tailstock showing handwheel parts.

Dismantling is straightforward. First remove the ram by turning the leadscrew clockwise until the ram runs right off the end of it. The parts manual indicates a rubber washer is normally present at the end of the leadscrew (mine was missing), but the ram should take care of pulling that off when it comes off the end of the screw.

Then remove the ram locking mechanism by unscrewing it counter clockwise. It uses two aluminum "grips" (which the South Bend parts diagram calls "plugs") that jamb against the ram when the lever is tightened. Figure 197 is showing the hole left after the lever and plugs have been removed. It may be necessary to punch the plugs out from the bottom as shown in the photo, but they're not a very tight fit.

Figure 198 shows two "mystery" items in the tailstock. The South Bend parts diagram refers to them as a "set screw and pin". It turns out the pin is there to prevent the aforementioned aluminum plugs from dropping out if you remove the locking lever. The set screw is holding the little key that sits in the bottom of the tailstock casting and prevents the ram from rotating when the leadscrew is rotated.

If you need to remove the oilers (like I did), just yank them out with a pair of pliers. The correct replacement is McMaster-Carr part number 1232K31, which is a 3/16" drive-in Gits-brand oil hole cover. Both of mine had felts in both oil holes. I replaced the one in the end cap with a piece of 1/8" diameter F1 (by slipping a piece into the oil hole cover after reassembly). The one in the main body of the tailstock I left off, since I figure it's better to just let the oil flow

Figure 194: Tailstock rear bushing removed.

Figure 195: Tailstock anchor in position under bed.

into the casting unimpeded by the presence of a felt. Why was there a felt there to begin with? To retain oil rather than letting it run out. Without the felt you must add oil before each use, whereas with a felt you can add oil only when the oil cover goes dry. I'd rather just add oil before each use.

Figure 199 shows all the tailstock parts cleaned and ready for reassembly. The new felts for the tailstock base are made from 1/8-inch F1 sheet.

There are large wiper felts on the front and rear of the tailstock. The old ones are shown in the photo above. I cut new ones from 1/8" thick F1 felt,

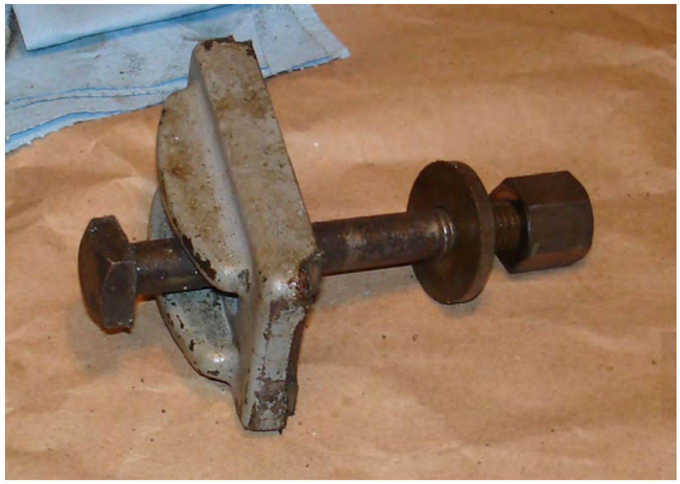


Figure 196: Tailstock anchor.

Figure 197: Tailstock ram locking mechanism removed.

which is the same stuff I used for the way wipers on the saddle.

To make the new felts, I simply used the metal shields that mount over top of the felts to make a paper template. From that template I cut a sheet of F1 using a sharp razor blade. Figure 200 shows one of the two tailstock wipers (the other one is identical) soaked in oil (Mobil Vactra No. 2) and ready for installation.

Figure 201 shows a felt reinstalled on the tailstock base. The felt must be trimmed flush with the ways of the tailstock (the area between the ways can be left alone). The tailstock base needs to slide on its ways, not on the felts, so it's

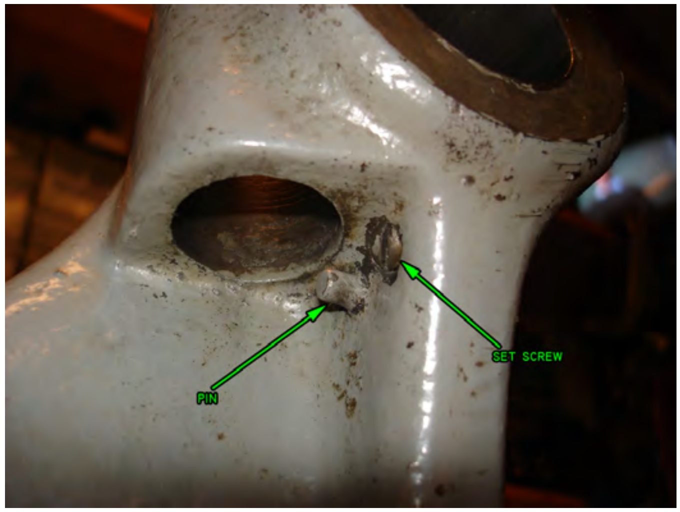


Figure 198: Tailstock pin and set screw for key.

Figure 199: Overview of tailstock parts.

important to ensure when you place the tailstock down on the bed ways it isn't sitting on the felt.

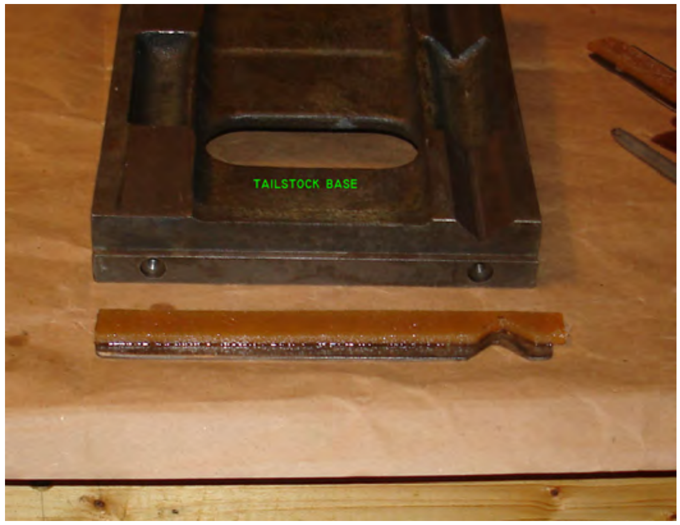


Figure 200: New tailstock base felt.

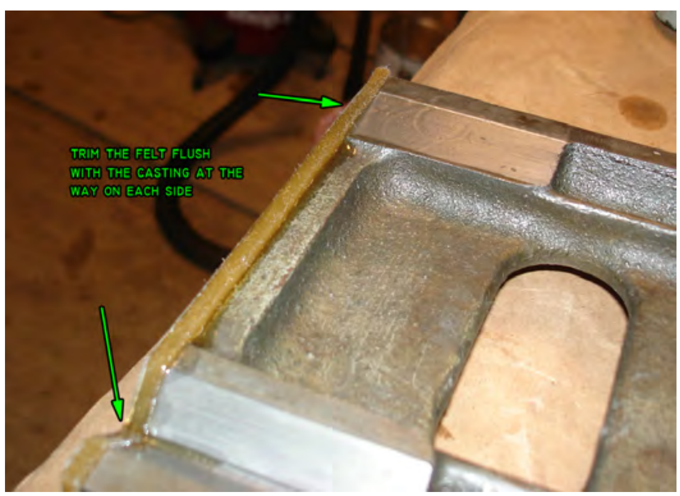


Figure 201: New tailstock base felt installed.

15 Lubricants

In this section you'll find my choices for lubricants and lubrication points, which may or may not correspond exactly to South Bend recommendations. The primary reference I used in making my table of lubricants is South Bend lubrication chart number 6503. You may notice that publication lists Vactra for oil "C", while I'm using mostly Mobil DTE Heavy Medium for "C". This is because, apparently, Mobil changed the formulation of Vactra some time ago and DTE is the recommended replacement. Vactra is now primarily a way oil.

Although Vactra is intended as a way oil, its tackifiers make it ideal for open gears, where it sticks like glue rather than running off. I'm also using it in a few other places where it's stickyness is useful, such as lead screws.

I'm using Vactra No. 4 for most of the sliding way surfaces on this lathe, in an attempt to partially compensate for the extensive wear. South Bend recommended No. 2 for the way surfaces.

The oils referenced on this page are:

- Mobil Vactra Numbered Series
- Mobil DTE Heavy Medium
- Mobil Velocite No. 10
- Pennzoil Synchromesh
- Magnalube-G (McMaster-Carr carries it)

You may ask yourself, "why Pennzoil Synchromesh"? Good question. Notice that the only item in the South Bend lubrication chart specified as requiring type "B" oil is the gearbox. That oil has a saybolt universal viscosity rating of 150-240 seconds at 100°F. According to Machinery's Handbook, the conversion from saybolt viscosity to centistokes is:

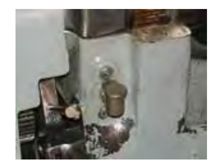
$$\mu_{C,40^\circ C} = (0.22)\,\mu_s - \frac{180}{\mu_s}$$

which suggests an oil between 31.8 cst and 52.05 cst would be appropriate. It turns out Pennzoil Synchromesh, has a viscosity of 41.6 cst. I trust this oil in my truck transmission, and have no reason not to trust it here. Since I keep a large stock on hand for the truck, it's convenient to use a bit for the lathe as well.

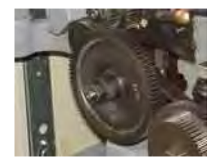
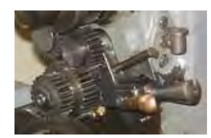
Please bear in mind the comments here are my personal philosophy in oiling. I'm a believer in the notion that "there's no such thing as too much lubrication". As a result, I tend to apply a lot of oil, frequently. I developed this table so that I could print out a lubrication checklist to keep beside the lathe which may be referenced before each operation.

For the most part, I'm using the oils recommended by South Bend. I deviate from the South Bend recommendations when it comes to open gears, for which I prefer to use Vactra No. 2. I do this because the way oil has tackifiers that make it stick like glue to the gears rather than being slung off when they spin. You'll notice I'm also using Vactra No. 2 in a couple other places where South Bend recommended type oil "C" (such as the belt tension lever). This was merely for convenience, and because I wanted something that would stay put rather than running off.

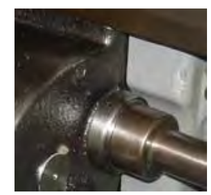
My frequency recommendations are generally more often than those proposed by South Bend.

Number	Description	Comments	Lubricant	Photo
1a	Headstock spindle bearings (Front)	Keep full. Change oil every 3 months, depending on use.	Mobil Velocite 10	
1b	Headstock spindle bearings (Rear)	Keep full. Change oil every 3 months, depending on use.	Mobil Velocite 10	
2	Back gears	Remove two covers to access the back gears for lubrication. Lubricate before each use.	Mobil Vactra No. 2	

Number	Description	Comments	Lubricant	Photo
3	Back gear shaft & pulley cone	Add Teflon-based grease annually. To do this, rotate the spindle and back gear until both oil holes are pointing straight up. Pack the oil openings with grease and leave overnight so gravity will draw the grease into the bearings.	Magnalube-G	
4	Spindle thrust bearings (2)	There's an inner and an outer bearing. To access the inner bearing remove the aft back gear cover (2 screws). Lubricate every hour of operation.	Mobil Vactra No. 2	

Number	Description	Comments	Lubricant	Photo
5	Reversing geartrain	Use sufficient oil to wet every gear. Keep the gears "wet" with oil at all times. Oiling once per session is usually sufficient.	Mobil Vactra No. 2	
6	Idler gear bushing	Oil daily when in use. Does not contain any felt or oil-retention features.	Mobil Vactra No. 2	
7	Reverser bracket	Keep full when in use. Usually filling at the start of operations is sufficient for a day's work.	Mobil DTE Heavy Medium	

Number	Description	Comments	Lubricant	Photo
8	Gearbox main reservoir	Fill before each use and periodically check during long operations.	Pennzoil Syn-chromesh	
9	Gearbox left side (2 shafts)	Add a small amount of oil to the felts for the shift rail (countershaft) and mainshaft before each use.	Pennzoil Syn-chromesh	

Number	Description	Comments	Lubricant	Photo
10	Gearbox right side (2 shafts)	Add a small amount of oil to the felts for the shift rail (countershaft) and mainshaft before each use.	Pennzoil Synchromesh	
11	Leadscrew outer bearing	Add a small amount of oil to the hole in the outer bearing race.	Mobil Vactra No. 2	

Number	Description	Comments	Lubricant	Photo
12	Belt tensioner lever	Add a few drops of oil monthly.	Mobil Vactra No. 2 or DTE Heavy Medium	
13	Belt tensioner	Add a few drops of oil monthly.	Mobil Vactra No. 2	
14	Leadscrew	Keep the threads clear of chips and debris. Oil before each use.	Mobil Vactra No. 2 or No. 4	

Number	Description	Comments	Lubricant	Photo
15	Apron upper reservoir	Keep full. Check before each use.	Mobil DTE Heavy Medium	
16	Half nuts	Oil before use.	Mobil DTE Heavy Medium	
17	Apron main reservoir	Keep full. Change oil periodically depending on use (there's a drain plug at the bottom).	Mobil Velocite 10	

Number	Description	Comments	Lubricant	Photo
18	Apron handwheel shaft	Oil as required. Refer to section 12.3 (page 144.)	Mobil DTE Heavy Medium	
19	Leadscrew support bracket	Oil before each use. There is no oil retention felt at this location, so it won't hold oil for long.	Mobil DTE Heavy Medium	
20	Tailstock lead-screw bushing	Oil before each use.	Mobil Vactra No. 2	

Number	Description	Comments	Lubricant	Photo
21	Tailstock ram	Oil before each use.	Mobil Vactra No. 2	
22	Bed ways	Oil before each use.	Mobil Vactra No. 2 or 4	
23	Saddle gib way	Oil w	Mobil Vactra No. 4	

Number	Description	Comments	Lubricant	Photo
24	Cross slide lead-screw bushing	Oil weekly	Mobil Vactra No. 2	
25	Cross slide lead-screw nut	Oil weekly	Mobil Vactra No. 2	
26	Compound lead-screw bushing	Oil weekly	Mobil Vactra No. 2	

Number	Description	Comments	Lubricant	Photo
27	Compound lead-screw nut	Oil weekly	Mobil Vactra No. 2	
28	Cross slide ways	Keep clean and well oiled along entire length (move the cross slide as necessary to gain access). Clean chips after each use.	Mobil Vactra No. 4	
29	Compound ways	Keep clean and well oiled along entire length (move the cross slide as necessary to gain access). Clean chips after each use.	Mobil Vactra No. 4	

Number	Description	Comments	Lubricant	Photo
30	Rack	Periodically apply oil to keep wet.	Mobil Vactra No. 2	
31	Motor	Add a small amount of grease annually. (Picture shows motor removed because plug is difficult to see when installed.)	Mobil Vactra No. 2