Reliability and the Chinese Scales “Experience”

Introduction:

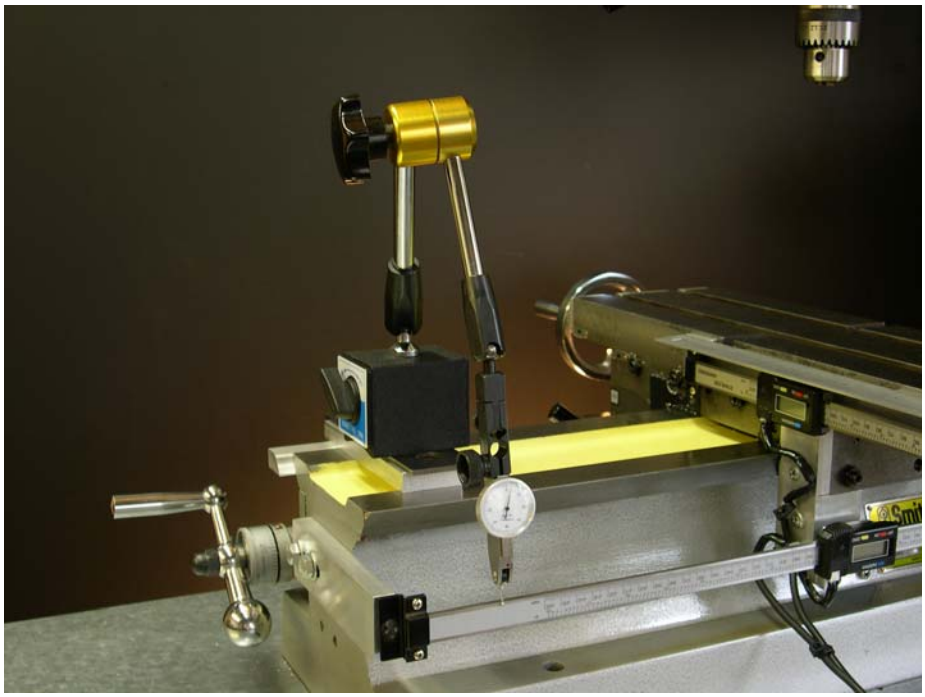
Some weeks ago I completed assembly of one of Scott Shumate’s DRO-350's. It seemed to me that his design was far superior to anything that I might buy without spending as much as $1800. And Scott’s continued support of his design has been tremendous. I had concerns, though, that the “weak link” in this hobbyist-priced system would prove to be the Chinese-made scales used to transmit measurement data to the DRO-350. Driven (compelled?) by this concern, I began to research the scales, their basic measurement technology, alternatives to them, and the whole Chinese scales “experience.” I have now changed my opinion about these scales and believe that the whole Chinese scales “experience” can be made “reliable.” Those who have been in the Yahoo! ShumaTech Group for a while, and those who have more experience with machining, may find a lot of what appears below to be “old news.” However, members who are new to the ShumaTech Group or who have less experience with machining may find some of this helpful.

Please note that a lot of my thoughts are “distilled” (plagiarized?) from posts that have appeared on the Yahoo! ShumaTech Group, and information I have gathered elsewhere. This information has led to my opinion on this topic, presented below. Take this with a grain of salt and make your own decisions. Here we go.

Contents:

Some Quick Definitions:

As you read this article, you may encounter a number of terms that seem confusing. Here are some very brief definitions of these terms that explain how they are used in this discussion.



Scale – an electromechanical device used to measure movement or distance. The scale has two major components, an encoder and a beam.

Encoder – the plastic box on a scale (usually black in color) that houses the major electronic components, including a digital readout.

Beam – the hardened stainless steel bar of the scale. It looks like a thick metal ruler. The encoder slides along the beam to measure movement or distance.

In the picture above you can see two of the scales mounted on my Smithy. The encoders and beams are easily identified in the lower and middle right part of the picture. (Ignore the dial test indicator and indicator holder in the middle of the picture. We'll get to that later.)

When Considering Purchasing Scales:

One of the first questions that people have about these Chinese-made scales is, "Where do I buy them?" There are at least three general sources – brick-and-mortar stores that do a lot of import tool business (Harbor Freight Tools, for example), internet vendors who sell machine tools and accessories to the home and hobby machinist (like Little Machine Shop), and eBay.

When you think you've found the scales you want to buy, consider who the vendor is and try to find out what kind of reputation they have. Be aware that sources for scales on eBay may give you the cheapest price, but they may not communicate well after the sale. You may wait as long as two or more weeks before your scales arrive, and you may not receive any emails from the vendor in the interim. This is not what we are used to with internet purchases; we are used to confirmation emails, notices of shipment, and quick answers to questions. A lack of communication from an eBay vendor after a $160 purchase (e.g., three scales) may be unnerving. If you need reliable communication from the vendor, consider purchasing your scales from a "regular" internet vendor like Little Machine Shop or Harbor Freight Tools' internet

site. Or, if you know of a “brick-and-mortar” store that sells Chinese scales, consider buying them there if you need “instant answers.”

Second, consider the support you will likely receive from your vendor. eBay vendors may not allow you to return a defective scale. Review the vendor’s return policy carefully; they likely will not do anything more than their return policy states. If they don’t have a “published” return policy, don’t buy anything from them, not even a set of drill bits!

Third, if you are considering purchasing more than one scale (i.e., three scales for a 3-in-1 machine like a ShopTask) try to buy three of the same type (i.e., three horizontal scales or three vertical scales). Vertical scales can easily be mounted horizontally, and vice versa; they don’t “care” how they are mounted (two of mine are mounted with the encoders upside-down to make the wiring easier). By purchasing three scales of the same type you can easily swap one encoder for another in the case of a malfunction. For example, if you lose your X axis encoder while doing a series of turnings on the lathe, you can always “borrow” the encoder off of the mill quill until you get a replacement. If all three of your scales are the same, they will mount and wire the same way; you should be able to swap an encoder and be up and running again in fifteen minutes.

Fourth, decide if you want to have a spare encoder on the shelf, just in case one on your machine should malfunction. If you want a spare, order the shortest scale you can find that is of the same type that you have put on your machine. You can’t buy encoders separately; you have to buy complete scales. Shorter scales are cheaper. So, buy the shortest one you can that is like your others, and take the encoder off of it when, and if, you need it.

Here’s an exception to the above. Lester Caine in the U.K. reminded me that scale beams are larger for horizontal scales longer than 18". It may be true for some of the vertical scales, too. And there are some monster width beams on some of the large head calipers available from Grizzly and other vendors; these all have data ports and should work with the DRO-350. If you need one really long scale and two short ones, the “same scale type” suggestion may be of little benefit. But give it some thought. If you lose an encoder, you’ll have to do something.

Finally, test your scales immediately after you get them from the vendor. This includes the data port. If you don’t have an oscilloscope (and few of us do) the best way to test the data port is to hook the scale to your DRO-350 using one of the custom fit cables available from www.littlemachineshop.com, Lester Caine in the U.K., or elsewhere. (The Little Machine Shop part number is 1990.) You may have to attach a mini-DIN plug to the DRO end of the cable to plug it into your DRO-350. By using this cable you can test each scale without having to modify them in any way. You probably won’t be able to return a scale if you’ve modified it. The $6.95 (plus shipping) for the cable from LMS is well worth it if you discover you need to return a scale that won’t communicate with your DRO-350.

Back to Contents **Back to Summary**

Wiring Your Scales:

The type of wire that you use to connect your scales to the DRO-350 is not that critical. It needs to have four separate conductors; some people believe that it helps if the cable is shielded. The

DRO-350 appears to work well with cables as long as fifty feet, so length is not critical. You will need to attach a four pin mini-DIN plug to the DRO-350 end of each cable (assuming you put mini-DIN jacks on the back of your DRO-350).

Scott reminded me that, if you use a cable that has four separate conductors and a shield, you need to connect the shield to ground at the DRO-350 end of the cable. **Do not** connect the shield to ground at both ends; this will likely lead to what is called a "ground loop" that can wreak havoc on data signals. If you don't connect the shield to ground at all, it doesn't do you any good to have it in the cable.

As is noted above, you can buy cables that are custom made to fit the data ports on Chinese scales. These are often available from the Little Machine Shop; other vendors sometimes have them, too. You may have to put a mini-DIN plug on the DRO-350 end of these cables. However, a word of caution is in order. The tolerances on the plastic covers for the encoders on Chinese scales have been variable. Some people have found that the "made to fit" cables fit snugly on one of their scales, but are too loose to be reliable on another. Despite the fact that these cables are "made to fit," you still may have to find a way to help them stay in place, and connected. If you have a "loose tolerance" encoder cover, you may get intermittent contact with the data port unless you secure the "made to fit" cable with a touch of epoxy or by some other means.

Another concern about the "made to fit" cables is their length. Check the length before you order to be sure they are long enough for your needs, and to be sure they will provide enough slack for encoder movement as you use your machine. If you still want to use them but are concerned that they will be too short, consider buying an S-video (S-VHS) extension cable. This will have a female mini-DIN receptacle on one end and a male mini-DIN plug on the other. But, before you install the cable on your machine, check the pins on the male plug for continuity (see the caution about shorted shield wires in the discussion of S-video cables, below). If two of the pins appear to be shorted together, take the cable back to where you bought it and consider building your own extension cable.

Some people have successfully used S-video cables to connect to their scales. These cables come pre-wired with mini-DIN plugs on each end; a 25 foot S-video cable can be cut in half to make two 12.5 foot cables! These are shielded cables, but the shields don't end up being used as shield wires (see below).

Two words of caution about S-video cables. Some of these cables have two conductors and two shields. You will have to use the shields for two of the four conductors you need. It has been posted on the ShumaTech Group that some high-end S-video cables have the shields shorted together; the cheaper ones don't. Before you cut up a new S-video cable, check all the pins on one plug for continuity; if you find that two of the pins are shorted together, it's likely they are the shields. Take the cable back to where you bought it and get a cheaper one, or consider some other cable option.

The second caution about S-video cables is this. The insulated conductors may be of a very small gauge and are stranded wire. They may break as you try to connect them to your scales' data ports. The shields may include a large mass of stranded wire equivalent to 18 gauge or so (that's huge by comparison). It is a good idea to solder three-inch-long pigtails of approximate 24 gauge solid wire to the end of each insulated conductor. Do the same for each shield.

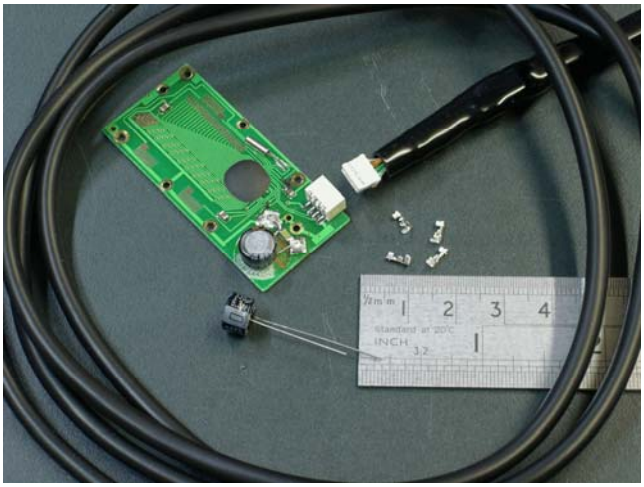
Then, insulate each of these connections with appropriate-sized heatshrink tubing. This will provide tougher and more convenient-sized wires to attach to your scales using either plugs or directly-soldered connections (see below).

Consider using the shield wires of S-video cables for DC voltage ("+" and "-"). The insulated conductors can then be assigned to "data" and "clock" signals. (This is what I did on my cables and I have not seen any evidence of interference in the signals, even with the fluorescent lights and other RFI/EMI sources that are near my DRO-350 setup.)

A final issue about wiring includes connecting the cable to the scale data port. If you use a "made to fit" cable, it's a snap. But if the cable plug does not fit well and you've secured it with a dab of epoxy, if you ever need to change the encoder or the cable, you'll have to find a way to work the plug loose, or order another cable, to replace it or a malfunctioning encoder.

Some people have chosen to solder their cable conductors directly to the data port pads on the encoder circuit board. This provides a reliable connection, but requires cutting the cable loose from the circuit board if the encoder needs to be replaced. Having to strip the wires and solder the conductors to a replacement encoder takes a bit of time. This is one downside to this technique of connecting cables to encoders. The other downside is this. The circuit boards in the Chinese scales encoders are not the most substantial in the world. If you apply too much heat to them, or leave the soldering iron on a trace for too long, the trace may de-bond from the circuit board, or may be damaged in other ways. (See the more complete discussion of this issue, below.) If you are careful, this technique of attaching cables to scales is very reliable.

If you choose not to use "made to fit" cables but still want "plug and play" connections, perhaps the best alternative is to use Molex "headers" available from Mouser, Digi-Key, or other electronics suppliers. The spacing of the contacts on the headers is not perfect for the pads on the encoder circuit boards, but it is good enough to make secure solder connections. Plus, with just a little Dremel Tool or Exacto Knife work, you can modify the data port cover so it will fit over the installed header/socket. Installed on the end of the cable, the Molex plug assembly will connect to the header securely. If you ever need to swap an encoder or a cable and the replacement has the same header/plug, it is a simple matter of unplugging the cable, removing the encoder or cable, mounting the replacement, and "plug and play."



MOLEX PARTS NUMBERS:
Header - Vertical, Molex Part Number 87437-0433; you'll need one per scale.
Housing, Molex Part Number 87439-0400; you'll need one per cable.
Crimp Terminal 24-28 AWG, Molex Part No. 87421-0000; you'll need four per cable.

Back to Contents **Back to Summary**

To Battery or Not to Battery:

(**NOTE:** If you choose to take a scale encoder apart, the first time you do, do it very carefully while seated at a table. Pay attention to how the parts are arranged, and make notes as necessary to aid with reassembly. You might think about first covering the table with an old towel to "catch" any parts that might otherwise get away. Once you've successfully taken one apart and successfully reassembled it, you'll find they are not that intimidating. But be careful the first time. There are no replacement parts available; if you damage or lose a part you may have to buy a new scale!)

Out of the box, the encoders on Chinese scales are powered by a single 1.5 volt battery. And, as you have read on the ShumaTech website, the battery really isn't necessary when these scales are connected to the DRO-350 because it provides DC voltage to the scales. As Scott has explained, when the DRO-350 is plugged in to the wall (even if the display is off) the batteries in the scales end up functioning like capacitors, and "filter out" any "noise" that may be getting into the DC supply as it travels through the cables to and from the DRO-350.

Although it doesn't "hurt" anything to leave the battery in the encoder, it can pose a number of problems. Soon after the first DRO-350's had been completed by users, posts began to appear on the ShumaTech Group that members' Chinese scales had begun to do strange things (sounds like the plot for a low budget science fiction movie, huh?). Anyway, among other things, it was discovered that, if the scales were left connected to the DRO-350 when its power supply was unplugged, the DRO-350 would drain the batteries in the scales. There was then a procedure that had to be followed to get the scales to work correctly again (remove the battery, leave it out for a minute, put in a new battery, bury a dead cat under the big oak tree...). And on it went.

To make a long story short, if you want to protect your setup from absent-minded mistakes, it is probably better to remove the battery from the encoder and leave it out. But at least one capacitor has to be soldered onto the encoder circuit board to perform the filtering function that the battery had been performing. Otherwise, noise may enter the DC supply and affect the stability and reliability of measurement readings.

On the ShumaTech site, Scott has noted that replacing the battery with a single 100uF capacitor appears to provide adequate filtering. Once the battery has been removed, the capacitor can be installed in the space where the battery had been. The battery contacts may have to be removed from the circuit board by heating their solder joints and pulling them loose. Once the capacitor is installed, the battery cover slips into place over it, making this a very clean modification.

NOTE: Scott has posted concern on the ShumaTech Group about the potential to cause damage to a Chinese scale circuit board by soldering components to it. These circuit boards are certainly not of the quality that Scott supplies for the DRO-350, and the traces on the boards may "de-bond" if heated for any length of time. (One of my data port pads did just that when I was trying to solder a S-video cable shield to it. I quickly changed to the Molex header and pigtail technique, above). So before you heat up the soldering iron and "go at it," be prepared to do some repairs if you leave the iron on the circuit board for "a second too long."

Another workable capacitor combination was suggested by David of the ShumaTech Group (message #1457). His combination includes a .1uF capacitor (for high frequency noise) and a 330uF capacitor (to catch lower frequencies). He noted that his scale readings were intermittently "jumping" by .20". Ouch! The "jumping" quit after he made this capacitors modification. David posted photos of how these capacitors can be connected. To see the photos go to Photos > DMS > HF Caliper Capacitor on the Yahoo! ShumaTech Group site. There are three photos in the folder that provide plenty of visual detail.

The nice thing about this installation is it, too, fits neatly into the encoder case. The larger capacitor is soldered in where the battery had been; the battery contacts have to be removed from the circuit board by heating their solder joints and pulling them loose. As above, once the capacitors are installed, the battery cover slips into place over it, making this a very clean modification. No more low budget science fiction movie!

Back to Contents **Back to Summary**

Time for Some Cleaning:

While I was researching this whole Chinese scales thing, I came across a post with a university email address. This post was from a physics department member at a major university who commented, "[These scales] must be assembled in a sand box." He went on to state how cleaning his scale had improved its reliability. I pulled one of mine apart and went at the beam, gib, and spacers with a dry paper towel. What I got was gray-to-black particulate matter that seemed rather oily. And a lot of it, too.

On the Long Island Indicator website (Longislandindicator.com) it was noted that it is best to clean electronic digital calipers with a clean cloth (these scales are like electronic digital calipers, aren't they?). They noted, too, that alcohol can be used to clean the beam. But I would certainly use denatured alcohol; you just don't know what is in isopropyl alcohol. Starrett's website echoes the dry cloth recommendation, but they also recommend using their special instrument oil on their electronic digital calipers. Hmmm...

I cleaned all of the metal parts of my scales with denatured alcohol, quickly wiping it off of the decal on the beam. They were incredibly dirty for an item that is said to be "precision equipment." I also polished their gibs starting with 400 grit wet-or-dry sandpaper, and polished the edges of the scale beams starting with 320 grit wet-or-dry sandpaper. (This polishing technique is presented in the next section.)

NOTE: I was willing to polish the edges of my scale beams; to me they seemed very rough. This technique is one that I use all the time with woodcarving tools and bench chisels. I feel very comfortable with it and feel I have good control while doing it. And yes, I used water as a lubricant for the sandpaper; I avoided getting water on the decal of the scale beams and immediately wiped them dry. I then cleaned them with denatured alcohol to displace any residual water. I just don't know how advisable this is. I plan to clean my Chinese scales periodically now that they are on my Smithy. My scale covers are of a two piece design, and the outer cover can easily be removed to access the scales for cleaning and adjustment. I believe that this will continue to be important.

Back to Contents **Back to Summary**

Prior to Mounting Scales:

(**NOTE:** the comments in this section may apply only to individuals who are using machines meant for the home machinist or hobbyist. Machines built for industry are generally better designed and built, and typically require little “finishing” before they can be set up and run. Of course, the price for such quality is thousands of dollars more than the home machinist might justify spending for equipment. To get closer to industrial machine quality, then, the home or hobby machinist may have to do a little “finishing” as described below.)

Before you begin to consider where you want to mount your scales on your machine there is a bit of preparatory work that needs to be done. First, if you haven’t polished the gibs on your machine, do it. When you add scales to the major axes of your machine, you are going to introduce a source of drag or friction to axial movement. This is true for any type of scale, not just Chinese scales. This friction makes your lathe or mill harder to use. It also increases the variability of the linear force required to move machine surfaces (e.g., the carriage, crossfeed table, compound tool post, and milling table). In a round about way, this friction will reduce the accuracy and reliability of data sent to your DRO-350 by the scales. By polishing the gibs of your machine, you will be doing what you can to limit the amount of friction that is produced where your machine’s moving surfaces contact their respective dovetails (their working axes).

Polishing gibs isn’t rocket science. It can be done easily with sheets of wet-or-dry sandpaper, a flat surface (a granite plate or piece of 3/8" thick plate glass), and a source of water.

Start with a sheet of 240 grit sandpaper, wet it thoroughly, and lay it out flat on the granite plate/plate glass. You only need to polish the gib face that rides on the dovetail of the machine; the other surfaces don’t need to be polished. Rub the surface of the gib on the sandpaper, trying to apply even pressure along the gib’s length. Use a variety of circular, straight, and figure eight motions, continuing to hold the gib very flat on the sandpaper. Inspect the surface of the gib frequently. You are finished with the 240 grit paper when the swirl pattern on the gib appears even. It won’t take long.

Wash off the 240 grit paper with water and lay it somewhere to dry. Wash the gib to remove particulate matter, and clean the surface of the granite plate/plate glass to remove sanding slurry that may have run off the edges of the sandpaper.

Next, take a piece of 320 grit wet-or-dry sandpaper and repeat the above procedure. Then, follow the same procedure using 400 grit, 600 grit, 1000 grit, 1200 grit, and 1500 grit sheets. When you are through you will have a gib that has a mirror surface. Clean it thoroughly with dish soap and warm water, rinse it very thoroughly, dry it thoroughly, and immediately wipe the gib with a rag dampened with mineral spirits. The mineral spirits will displace any remaining water, and will leave a light protective coating that will last until you get the gib back on the machine. If you are going to have the polished gib off of the machine for more than a day, coat it with oil, wrap it with a paper towel or lint free cloth, and put it in a dust free spot.

When you reinstall the gibs on your machine you will want to adjust them; this is the second bit of preparatory work that needs to be done. To adjust the gibs, follow the instructions in the manual that came with your machine. If you don’t have a manual, you can follow these simple steps with fair success.

(A typical lathe configuration is the example used in the following discussion. It should generalize to a typical mill configuration.)

First, reinstall both the carriage gib and the crossfeed table gib. (Don't worry about the compound tool post gib just yet. It can be done separately at a later time.) Tighten all of the gib screws just snug. They don't have to be tight. When they are all snug you should not be able to move either the carriage or the crossfeed table with their respective leadscrews.

Start with "the lowest gib in the stack." (That's the carriage gib on a lathe.) Loosen each carriage gib screw 1/16th of a turn. Check to see if the carriage can be easily moved with its leadscrew. If it won't move, loosen each screw another 1/16th of a turn. If it still doesn't move easily, loosen the screws another 1/16th turn. Once there is free movement, position yourself so that you can get a good grip on diagonal corners of the crossfeed table (e.g., the front-left and back-right corners). Remember, the crossfeed table gib screws should still be snug. Try to rotate the crossfeed table left and right on its horizontal axis (like you are trying to screw the lid on and off of a jar that is sitting on top of a counter). Any left-right movement that you perceive is evidence of "play" in the carriage gib adjustment. The goal of adjusting the gib is to allow free movement of the carriage with the leadscrew, while minimizing play in the gib adjustment. Too much play leads to poorly-machined parts. It will also cause the Chinese scales, or any other scales, to send inaccurate measurements to your DRO-350.

If you feel that there is too much play in the carriage gib adjustment, tighten each gib screw slightly, check for free travel and play, and continue the process until you feel you have reached an acceptable compromise. When you think you have, run the leadscrew back and forth through the extremes of its travel, checking for play in the carriage gib adjustment at random spots along the leadscrew's length. You may hit tight spots where free travel is limited, or spots where there is obviously too much play. Tighten/loosen the gib screws as you need to to achieve an acceptable compromise between free travel and play along the length of the leadscrew. There is no perfect machine, just acceptable compromise.

Once you are satisfied with the adjustment of the carriage gib, move the carriage to the middle of the lathe bed, and lock the carriage gib. (There should be an allen screw or some other fastener between the two carriage gib screws. Tighten this screw to lock the carriage gib.) Repeat the above procedure, only this time adjust the gib screws for the crossfeed table, and check for free travel of the crossfeed table with its leadscrew. Continue the process until you have achieved an acceptable compromise between free travel and play in the crossfeed table gib. Adjust the compound tool post gib following this same procedure.

Once gibs are polished and adjusted, you are ready to consider where to mount your scales.

Back to Contents **Back to Summary**

Deciding Where to Mount Scales on a Machine:

You have read on the ShumaTech site and elsewhere that the choice of where to mount scales on a lathe, mill, 3-in-1, or other machine is dictated, in part, by the design of the machine, and, in part, by personal preference. But there are at least four specific issues that must be considered. First, any scale will work more reliably, and indeed, will only survive for any length of time on a metalworking machine, if it is covered. This is true because metal chips can

damage scale beam surfaces and exposed encoder circuit board surfaces, eventually causing the scale to malfunction or fail altogether. Similarly, scale surfaces and electronic parts can be damaged by oil, coolant, and other fluids that are an integral part of metalworking and metalworking machines. Covers also serve to protect scales from damage from the inevitable dropped wrench, cutter, machined part, or milling accessory (a 60+ pound rotary table!). Covers must be made of a material that can survive in this metalworking environment, and must be made of a material that can be worked by the average home machinist. The choice of scale cover material may dictate the design or "shape" of the cover, so the material you choose to use will influence your decision about where to mount your scales.

Angle aluminum is one logical choice for making covers. It's not expensive, can be purchased at almost any hardware store or home center, and comes in a variety of widths and thicknesses. I chose to use 1.5" angle aluminum that is .065" thick. This material is easily cut and machined. I made my covers of a two piece design so the outer part of the cover could be removed to clean the scales when needed. And I chose to rip the lengths of the angles to the exact widths that I needed (you're not stuck with the 1.5" width). As an example, the vertical leg of the inner cover on my crossfeed table is 1.25". Its horizontal leg is 1" even. You can see photographs of my scale covers on the ShumaTech Group site; go to Photos > Bill's 2 Cents. Other Group members have posted photographs of how they have covered their scales, as well.

A second issue regarding where to mount scales is the need to position them (and their covers) so that they interfere as little as possible with the operation, adjustment, and maintenance of the metalworking machine. On a lathe, this issue requires consideration of gib screw access and gib lock access. It also requires thought about the need to move cutters close to the tailstock. (On my Smithy, for example, my crossfeed table scale cover presently sticks out 1.25" toward the tailstock; it limits my ability to get any closer to the tailstock with the edge of the crossfeed table and the toolpost mounted on it.) Limiting interference with normal machine operation, adjustment, and maintenance is a second issue that must be considered.

A third issue that is more applicable to lathes than mills is the need to choose a location that allows encoders to be mounted very rigidly in a manner that allows the entire scale to be covered on both sides and on top. The scale cover, then, might be configured similar to a "U" channel, with the open side of the "U" pointed down. The encoder might be mounted on a "U"-shaped or "Z"-type bracket, with one leg attached to a machine surface. This arrangement might allow the encoder leg to stick up and "float" inside the channel of the cover.

Here are two more words of caution, this time about the encoder mounting brackets that come with Chinese scales. Many of these brackets have a single vertical slot for mounting them to machine surfaces. If a single screw is used to mount them they will inevitably work loose. This will occur because of the movement of the scale beam through the encoder. This repetitive left/right movement occurs at a right angle to the bracket's vertical slot and, like pushing left and right on a fence post, will eventually work the bracket loose. You might choose to use two screws in this slot but, as above, there will still be a tendency for the right angle motion of the beam to work the bracket loose.

A second concern with these brackets is their rather light gauge. Even when mounted securely, these brackets will have the potential to flex with the repetitive right angle motion of the scale beam. This flexing will introduce error in measurement; it is analogous to backlash on a leadscrew.

Perhaps the better way to mount encoders is to fashion mounting brackets of .125" or thicker material that is attached to machine surfaces with two substantial fasteners located so they resist the tendency of beam movement to work the fasteners loose.

Finally, when considering where to mount scales, there is a need to identify a location where the scales and their covers will be free to move through the limits of their travel without encountering obstructions. This is a particular challenge when attempting to mount scales on a lathe that has an accessory mill column mounted near the middle of the lathe's rear dovetail.

Back to Contents **Back to Summary**

Consider the Humble Chinese Scale:

Scott has posted quite a scholarly discussion of the electronic theory, design, and operation of Chinese scales on his ShumaTech website. It is helpful to review, if for no other reason, to allow you to begin to consider the complex job that your DRO-350 is performing once it is built and connected to your Chinese scales.

When you get ready to mount your Chinese scales on your machine, there is a need to understand their physical characteristics, too. Failing to understand these characteristics can cause you to mount them in a manner that leads to inaccurate/unreliable data being transmitted to your DRO-350. It can also lead to malfunction or premature failure of your scales.

(**NOTE:** As is stated above, if you choose to take a scale encoder apart, the first time you do, do it very carefully while seated at a table. Pay attention to how the parts are arranged, and make notes as necessary to aid with reassembly. You might think about first covering the table with an old towel to "catch" any parts that might otherwise get away. Once you've successfully taken one apart and successfully reassembled it, you'll find they are not that intimidating. But be careful the first time. There are no replacement parts available; if you damage or lose a part you may have to buy a new scale!).

When you remove the four screws from the backplate of the encoder head of a scale, the scale will come apart in two "assemblies." One of these will include the metal backplate, the gib, and the scale beam. This assembly will come apart as a unit because the gib will exert enough pressure on the beam that it will likely stay put in the groove milled for it in the backplate. Look to see where the gib screws are located. They are tiny slot head screws installed in the gib side edge of the backplate. (We'll use them in the next section.)

The other assembly will include the encoder circuit board, the battery, the buttons, and the encoder case or shell. This assembly, too, will hang together because the circuit board is held to the encoder case with screws.

The tinkling sound that you heard when you pulled the scale apart was a pair of .004" thick wear strips/spacers that fell on the table top (look down, they're there!). You will notice that these strips each have two holes punched in them; these holes hold the strips in position when the backplate is screwed to the plastic encoder case (the backplate screws go through the holes in the wear strips/spacers).

The important "physical" parts of these scales are the beam, the encoder circuit board, and those "musical" wear strips/spacers. When you look at the printed side of the beam you are actually looking at what is referred to in the trade as a "decal." It is just there to offer some protection to what is underneath it; well, it also serves to "pretty things up" a bit. Under the decal, attached to the hardened stainless steel beam, is a circuit board. This circuit board has been etched in very fine divisions.

When you look at the exposed side of the circuit board in the encoder head assembly you will see many regularly spaced "traces." Each of these traces makes its way back to a pin of the electronic chip mounted on the surface of the circuit board. As the encoder circuit board passes along the beam it "reads" position by measuring the "capacitance" (i.e., the amount of electrical potential or "charge" that develops or can be "held") that exists between its traces and the divisions etched in the surface of the circuit board on the beam. The capacitance continues to vary as the encoder head moves. It constantly increases and decreases as the traces on the circuit board approach, pass directly over, and move past the divisions etched in the surface of the circuit board on the beam. This is a type of measurement technique developed by a Swiss company; it is generally referred to as the SYLVAC capacitance measurement system.

Oh yeah, the wear strips/spacers. For this measurement system to be reliable, the encoder circuit board must be held or fixed at a constant distance from the circuit board on the beam. Although this "gap" does not appear to have to be held absolutely constant, it is important to the reliable performance of this measurement system. If these wear strips/spacers should wear unevenly, or if they should wear down to, say, .002", it is reasonable to expect that the performance of the scale would change. (Sounds like the topic for at least a master's thesis to me!)

So, what does this have to do with mounting these Chinese scales on a metalworking machine? Well, here it is. It is my opinion, that for Chinese scales to work reliably, and for them to function in a reliable manner for an extended period (maybe even several years) it is necessary to mount them in a manner that limits imposition of forces that might distort the relationship of the encoder head to the scale beam. In the next section I will share some thoughts on how this might be done. But first, take a break, a long break, maybe that five day float trip you have been wanting to take down the Grand Canyon, or that extended ski trip in the Swiss Alps....

Back to Contents **Back to Summary**

Getting in the Same Plane (No Fear of Flying):

When you first thought about building Scott's DRO-350 and contemplated mounting scales to your machine, did you find yourself giving much thought to what mounting scales meant? When I first looked at Chinese scales on eBay (yep, me too!) I thought, "Well, there's a slot on either end and they include that little bracket for the encoder...Three holes to drill and I'm done!" Yeah, you can mount them that way, but you probably won't be happy with how the scales move (their "action") and you'll probably end up with at least a mechanical malfunction within thirty days (if not sooner).

Let's back up a minute and consider what we're doing. With Scott's DRO-350 and attached Chinese scales we are wanting to measure axial movement. Okay, that means movement in a straight line on a specific "axis." Great. And we all know that our machines have "axes," although the labels seem to change from one type of machine to another. On this machine it's an "X" axis, and on that machine it's a "Y" axis....

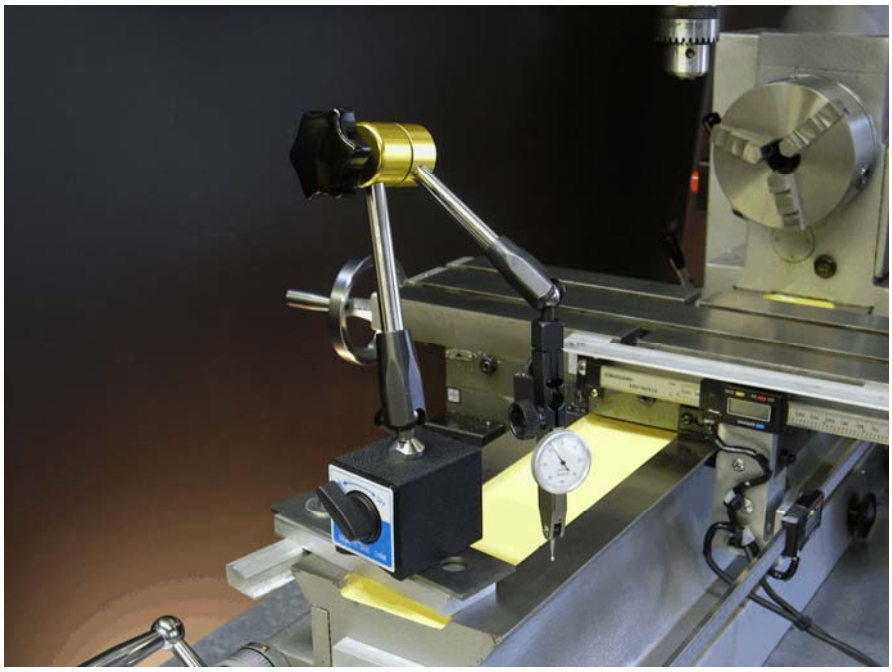
Let's consider the major axis on a lathe bed; for sake of simplicity I'll just call it "The" axis. Here's the big question, just "where" is that axis? Is it a hypothetical? Or is it supposed to be painted down the middle of the bed? Nope, "The" axis is the dovetail on the front or back of the lathe bed opposite the carriage gib. So if the carriage gib is on the back of the carriage, "The" axis is the front dovetail. That dovetail is the surface that the carriage "registers" to, and the gib screws simply snug the carriage up to that dovetail. So, functionally, that dovetail is "The" axis, and if we want to accurately measure carriage movement along "The" axis with a Chinese scale, we have to "register" the scale to that dovetail. Of course, we can't bolt the Chinese scale directly to the dovetail. What we can do is create a mounting for the scale that holds it exactly parallel to the vertical plane defined by "The" axis (i.e., that dovetail). At the same time, our mounting must allow the encoder on the scale to move with the carriage (to meter its movement along "The" axis) while the scale beam is held steady, or vice versa. Still with me?

Okay, so we just hang the encoder on the carriage (it "registers" to the dovetail), eyeball the beam to get it level, and we're good to go, right? No. Remember the musical spacers and their .004" gap in the section above? Somehow we have to "protect" that gap.

Here's an analogy. Suppose you decided to mount your carriage encoder on a piece of 1.5" wide X .125" thick angle aluminum at the back right corner of the carriage (that's what I did). So, that gives you a rigid 1.5" wide mounting surface. Super. Now, suppose your scale for your lathe bed axis is an "18 inch" scale. Its beam will actually be about 22.5" long. Imagine that you had two rigid metal rulers that were about that same length. Suppose you attached the middle of one of those rulers to the mounting surface for your encoder, and you "eyeballed" the ruler level (that's good enough for now). And suppose you mounted the other ruler to the lathe bed with equal length spacers which held it exactly parallel to the vertical plane of "The" axis. And as you were mounting it you watched to make sure it was level with the other ruler. Now, suppose you hoped to maintain a consistent gap between the rulers, say, a .125" gap, and the spacers you made to hold the second ruler were cut with this gap in mind. Having mounted the rulers in this manner, what do you suppose the gap would be like if you measured it from one end of the rulers to the other? With any luck, the gap would be pretty close to .125". However, the reality is that if the mounting surface for your encoder deviated from the vertical plane of "The" axis by as little as .008", the gap would totally disappear on one end of the rulers (the rulers would touch!) and the gap would be approximately twice what you wanted on the other

end. An 18" Chinese scale, or any scale for that matter, would behave much like these rulers if its encoder was mounted on this same out-of-parallel surface; the gap might be close to tolerable when the encoder was at the mid position on the beam, but it would disappear, and the scale would bind horribly, when it approached the fixed end of the beam! Under these conditions scale parts could gall or “fuse” to each other. If you escaped this “galling,” with repeated use you would soon cause enough wear to the backplate, gib, and wear strips/spacers that you would lose the .004" gap, the data transmitted from the scale would become unreliable, and in a worse case scenario the scale would fail. The way to prevent this is to, first, mount the encoder so that it is exactly parallel to the vertical plane of “The” axis, and parallel with the plane defined by the ways of the lathe bed. Then, attach the beam on one end so that it is exactly parallel to the vertical plane of “The” axis, centered in its slot in the encoder, and parallel with the plane defined by the ways of the lathe bed. Here are steps to follow that get this done.

You will need some “tools” to accomplish this setup task. They include a dial test indicator, an indicator holder of some sort, a flat aluminum bar approximately 1" to 1.5" wide and long enough to span the ways on the lathe bed plus 1.5", and a piece of scrap aluminum that is approximately .5" X 1" X 4". You will use the scrap of aluminum and the flat aluminum bar to construct a fixture similar to a “hook rule.” This works best if you can bevel one .5" edge of the aluminum scrap to complement the angle of the dovetails on your lathe bed. So, if the angle of the dovetails is 37 degrees, you will want to bevel one edge of the aluminum to the same angle. Then, when you flip the aluminum piece lengthwise, it will match up with the dovetail, and its top surface can be held flat and even with the horizontal surface of the way that adjoins the dovetail.

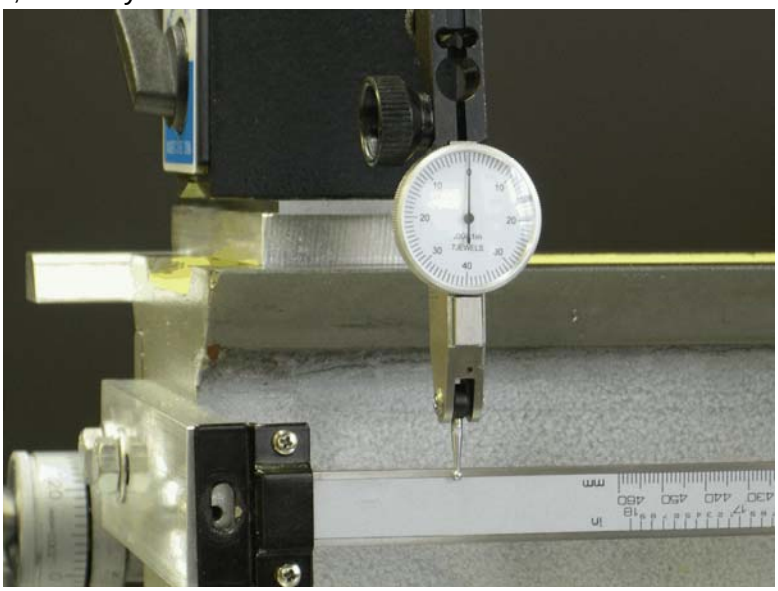


Drill a .25" hole in the width of the surface of the aluminum bar, approximately 1" from its end. Then drill a #7 hole through the top surface of the beveled aluminum piece (not the bevel!) and tap it with a .25" X 20 tap. Assemble the pieces with an approximate .25" X 1" bolt, with the bevel on the aluminum scrap up, and toward the long end of the aluminum bar. Square the two pieces so the bar meets the beveled piece at an approximate right angle. Tighten the bolt securely. You will end up with a fixture that can lay flat on the ways of the lathe bed, and the beveled piece will “register” the fixture to the dovetail (“The” axis of the lathe bed). (**NOTE:** In the pictures in this section I have used a shorter aluminum bar to reduce some of the “visual confusion.”)

Next, fashion a method to securely fasten your indicator holder to the aluminum bar of the “hook rule” fixture. If you are using an indicator holder that has a magnetic base, you might consider gluing a square of scrap steel to the bar with quick setting epoxy. However, if you are using a magnetic base indicator holder, try to mount it on the bar so the magnetic base is over the void between the two lathe bed ways. You will soon need to slide this fixture along the lathe bed while keeping it reliably “registered” to the dovetail. If the magnetic base ends up on top of one of the ways, its magnetic pull may be too strong to allow you to move the fixture easily and reliably.

Okay, it is now time to mount the scale for “The” axis of your lathe. Move the carriage to the mid position of the lathe bed. With the beam in the encoder, adjust the scale beam so it is centered (i.e., there is the same amount of the beam revealed on either side of the encoder). Snug the beam gib screws in the encoder head. Now, screw or bolt the encoder in position on its mounting surface.

Place the “hook rule” fixture on the lathe bed and slide it close to the tailstock edge of the carriage (don’t let it touch the carriage). If you haven’t already done it, attach the indicator holder to the fixture. Mount your dial test indicator vertically in your indicator holder. “Register” the bevel of the “hook rule” to the dovetail, and lower the dial test indicator so it just contacts the top metal strip on the face of the scale beam, as close to the encoder as is reasonable. Tighten the indicator holder adjustment(s) so the setup remains rigid. Then, without changing any adjustments on the indicator holder, carefully slide the fixture to the tailstock end of the lathe bed, keeping the fixture “registered” to the dovetail. If the scale beam is not approximately level, the contact tip of the indicator will either move up and off of the metal strip at the top of the face of the beam, or it will end up riding lower on the beam, on the decal covering the circuit board. Adjust the level of the encoder slightly; this will simultaneously adjust the level of the beam. Repeat the above steps until the contact point of the indicator stays on the metal strip at the top of the face of the beam as it moves from near the encoder to the tailstock end.

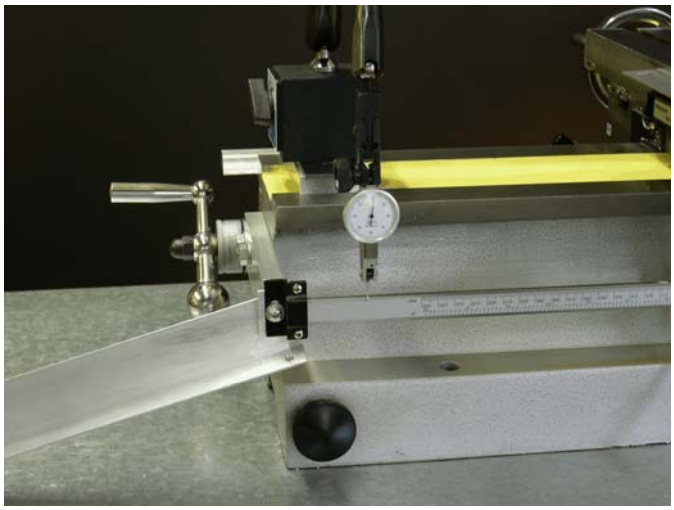


Once the encoder is leveled (and the beam will level with it) take indicator readings on the beam next to the encoder, and at the tailstock end of the beam. If there is a difference in the readings, then the encoder is not mounted parallel to the vertical plane of the dovetail (i.e., “The” axis). To correct this, fashion a small shim from shim stock and carefully slide the shim under the “low” end of the encoder or its mounting. After a shim is added, repeat the above procedure to determine if the shim was enough. Continue to add shims until the readings are approximately equal. (On my Smithy I had to shim the tailstock end of the encoder .008").

The next step is to fine tune the encoder so it is level to the horizontal plane of the lathe bed ways. Move the “hook rule” fixture and indicator holder back close to the carriage. Loosen the indicator holder setup, and mount the dial test indicator horizontally. Lower the indicator holder so the tip of the dial test indicator just touches the top edge of the scale beam. Note the reading on the indicator. Move the fixture to the tailstock end of the bed, keeping it registered to the dovetail. Note the reading on the indicator. Any difference between the two readings will identify that the encoder is not level to the horizontal plane of the lathe bed ways. Loosen the screws/bolts holding the encoder to its mounting and raise the “low” end slightly. (Don’t let the shims fall out of position!) Repeat the above steps until the indicator readings are approximately the same. Tighten the encoder mounting securely. Now, take a break and admire your progress.

It is time to attach the beam to the lathe bed. Hopefully you designed a mounting for the end of the beam that allows it to be adjusted horizontally, either closer to or farther from the lathe bed. If you didn’t, have a bunch of washers and shims handy. And hopefully you have already fashioned the inner half of the cover for this scale. If you plan to mount the cover at the tailstock end using the same screw that holds the end of the scale beam, you will have to have the inner cover available for the next step.

Gather the pieces that will be held by the screw that holds the end of the scale beam. Attach them in order to the mounting, but don’t tighten the screw completely. (You may have to loosen the gib screws on the encoder backplate to move the mounting bracket on the end of the beam into alignment with the screw/bolt hole on the mounting. Be sure to re-tighten the gib screws when you have the end of the beam aligned.) If the end of the inner cover is held in place by this same screw, go ahead and install it, but, after you have installed the screw, rotate the cover (like a windshield wiper) all the way over to the left so that it does not cover the scale. For now, you simply want the cover to act as a spacer in the stack of parts attached to the mounting by the screw. Now tighten the screw



Reinstall your “hook rule” fixture, indicator holder, and dial test indicator (vertically) in the same way that you had them when you adjusted the encoder parallel to “The” axis, above. Follow the same steps to determine if the beam is parallel to the vertical plane of “The” axis. To correct any deviation from parallel,

move the mounting in or out from the lathe bed (or add or remove shims under the mounting) until the indicator reading is the same when measured near the encoder and at the tailstock end of the beam. When the measurements are the same, tighten the fittings on the mounting securely.

Well, we've made it to the last two "major" steps. Loosen the screw holding the end of the scale beam to its mounting. Loosen the beam gib screws on the encoder backplate approximately 1/16th turn. Check the beam movement; if it does not move easily, loosen the screws a bit more, or if it is too loose (i.e., there is too much "play"), tighten the screws slightly. Keep checking the movement until you have reached a satisfactory compromise between free movement and play. When you think you have it right, put the scale cover into its final position and re-install the screw holding the end of the beam to its mounting. Tighten the screw.

Reinstall the "hook rule" fixture and the indicator holder. Mount the dial test indicator in a horizontal position, and adjust it to ride the top edge of the scale beam. Tighten the adjustment(s) on the indicator holder. Now, move the indicator near the encoder, keeping the "hook rule" fixture "registered" to the dovetail. Note the reading on the indicator. As you've done before, carefully move the fixture to the tailstock end of the lathe, and note the reading on the indicator. The difference between the two readings will identify if the tailstock end of the beam is high or low compared to its height at the encoder. Loosen the screw holding the end of the beam and adjust its height as necessary. Tighten the screw, and repeat the above procedure until the two readings are approximately equal. When you've got it, you're done. Go grab your drink of choice, find someone who might care, and show them what you've accomplished. (When their eyes glaze over, let go of their arm so they can go back to what they were doing - you don't want to push your luck!)

When you are ready, this same procedure, using the same "hook rule" fixture, can be used to align the scale on the crossfeed table of the lathe. But the fixture must be "rearranged" slightly. On the crossfeed table the dovetail opposite the gib is probably not exposed. So you end up having to "register" the "hook rule" fixture to the edge of the crossfeed table. This isn't the preferred method, but it is what can be done. To do this, loosen the .25" bolt that holds the beveled aluminum piece to the aluminum bar, and spin the beveled piece 180 degrees. You should end up with the square edge of the beveled piece toward the long end of the aluminum bar, ready to register to the square edge of the crossfeed table. Got the picture?

If your indicator holder has a magnetic base, it may really "get a grip" on the surface of the crossfeed table (depending on how strong the magnet is). Try spacing the "hook rule" fixture up off of the crossfeed table slightly. A pair of narrow .125" thick parallel bars, laid flat on the surface of the crossfeed table, might be the ticket!

Back to Contents

Summary:

Well, that's a lot of "stuff." But as I researched the issue of the reliability of Chinese scales and the whole Chinese scales "experience," the above issues seemed to surface over and over, and seemed to be the more important issues to consider. I believe that, by paying attention to these issues, you can help your scales achieve a level of reliability that will satisfy you, and allow

Scott's DRO-350 to meet the goals of his design. Here is a summary of the information you just read:

As you consider purchasing scales:
- Consider the type of vendor
- Consider the vendor's support
- Consider purchasing all scales of the same type
- Consider if you want a spare in reserve
- Test the scales as soon as they arrive

As you prepare to wire your scales:
- Length of cable is not a big issue
- Four conductors are required
- A shield may prove helpful
- "Made-to-fit" cables are available
- S-VHS or S-video cables are an alternative
- Direct soldered connections to the scales
- Molex headers allow "plug and play" connection

Considering deleting the battery:
- The battery can be left in to act as a "filter"
- A capacitor must be installed if the battery is deleted
- Be careful with that soldering iron!

Clean your scales:
- Give all metal parts a thorough cleaning
- Use a soft cloth
- Consider using denatured alcohol, but no other solvent

Prior to mounting:
- Polish gibs
- Adjust gibs

Deciding where to mount scales:
- Decide on cover material
- Avoid interference with machine operation, adjustment, and maintenance
- Mount scales rigidly, and covered on top and both sides
- Mount scales to avoid obstructions

Physical characteristics of Chinese scales:
- The scale beam
- The encoder
- Spacers/wear strips
- The gap

Mounting scales in the appropriate planes:
- Fashion a "hook rule" fixture
- Align the encoder parallel with the vertical plane of the dovetail
- Align the encoder parallel to the horizontal plane of the ways
- Align the scale beam parallel with the vertical plane of the dovetail
- Adjust the free movement and play of the scale beam
- Align the scale beam parallel to the horizontal plane of the ways

Back to Contents

Onward and Upward:

You have made it to the end. I thank you for being patient with me as I tried to explain my opinion of how Chinese scales, and the whole Chinese scales "experience," can be made as reliable as possible.

I think that those recommendations I have distilled from other sources, and those that I have developed on my own, may allow these scales to continue to provide reliable data to Scott's DRO-350. They are not nearly as sophisticated as his design. But they offer the hobby or home machinist a chance to have a first rate DRO without having to get a second mortgage on the house.

I first posted this article on the internet at the end of March 2004. Since then, Scott and the Yahoo! ShumaTech Group have embarked on another ambitious DRO project. This includes the development of a PC-based DRO. At the time I am revising this, the plan is to develop a scales interface that will plug into a computer's USB port. The scales interface will accept input from Chinese scales, quadrature encoders, and many other high-end commercial scales. The open source code computer software (freeware!) will be developed in the Java programming language, so it will run on Windows, Macintosh, Linux, and other platforms capable of running Java. The hope is that this project will allow the home and hobby machinist to approach the sophistication of CNC machining without a tremendous investment of both money and time.

Even with the PC-based DRO, users will still need to mount their scales so they function reliably. Whether you decide to build a DRO-350 or go with the PC-based DRO, I believe that the information presented above will continue to prove valuable.

If you feel my opinions/recommendations need adjustment, or if you have comments or questions, please post your concerns on the Yahoo! ShumaTech Group. Or you can email me direct at havins-w@sbcglobal.net.

Thanks again!

Bill Havins
March 29, 2004
Revised May 28, 2004

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