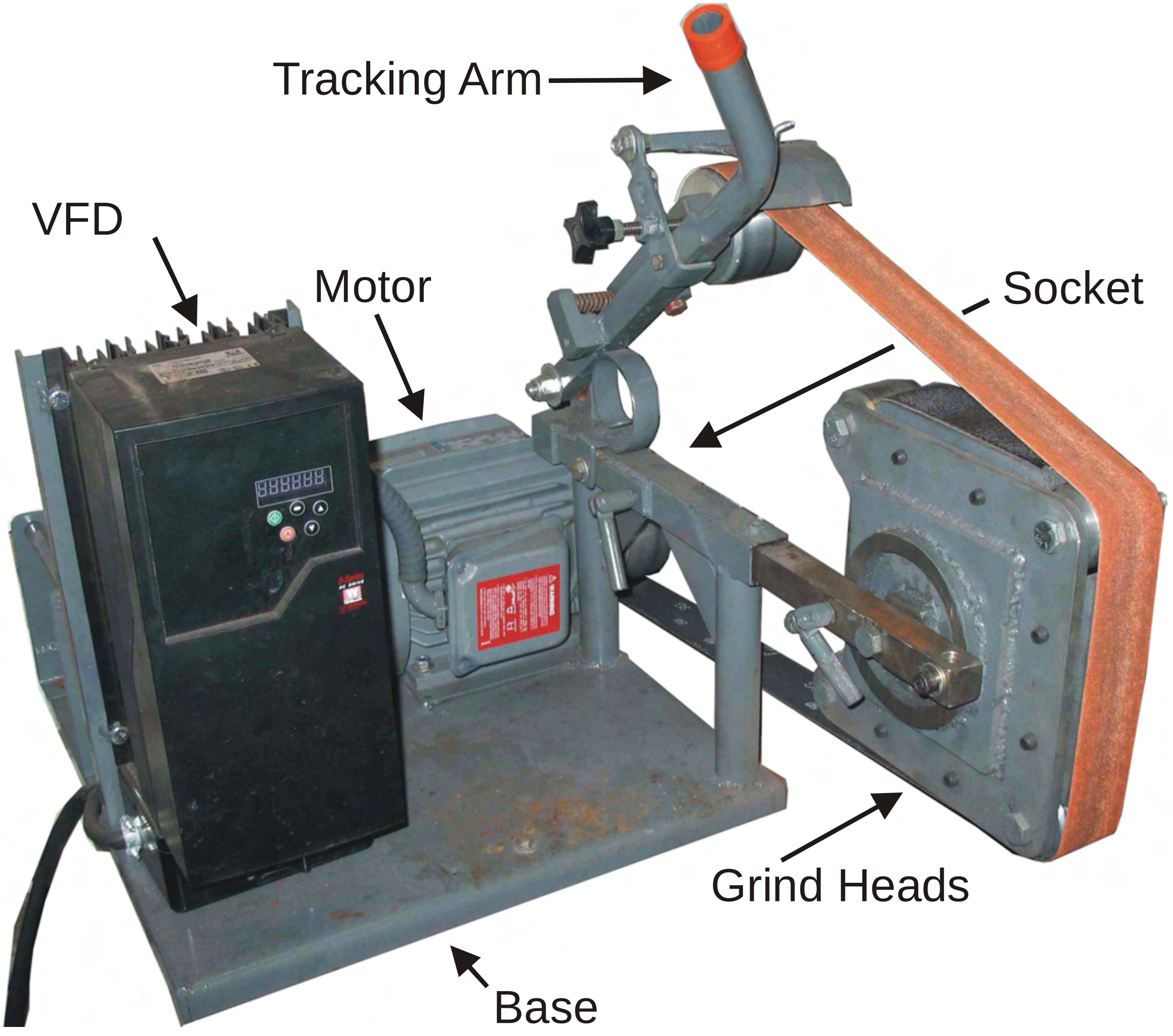
The IronFlower Knife Grinder
(DIY Variable Speed 2” x 72”)

Steve Bloom, Ironflower Forge



I. Overview

If you are reading this, then (almost by definition) you are a smith and you are interested in saving money - no - wait, that's redundant, isn't it. If you are selling knives as fast as you can make them and for good money, you will probably be better off just buying a commercial grinder and use the time to make more knives. If you are like me and most of the smiths I know, then there is something attractive about doing it yourself and saving significant bucks along the way. If that is true for you, then continue reading.

To build this grinder, you will need to have available a drill press, a welder (110 V MIG or a buzz box), some way to cut steel (chop saw, band saw, torch, etc.), some taps and associated drill bits, a square, some vise-grips, and other normal hand tools found in almost all shops. In building the prototype, I also used a Bridgeport mill, a lathe, and a surface grinder. These are not really needed but I have them, so I used them. If you don't know how to weld - learn. We are not talking Alaska pipeline level of welds here - the usual blacksmith's slobber welds will be more than enough.

A knife grinder basically consists of some means to move an abrasive surface past a piece of metal that may turn into a knife. The most common and convenient surface available today is the 2" x 72" belt - of which there are a bewildering choice of grits (NO! not that *type* of grits -- I've been in the South too long, I guess) and compositions. The typical grinder consists of a motor that turns a drive wheel, some type of surface to support the belt when it contacts the knife, and some sort of mechanism to keep the belt rotating in place without excessive slippage.

The major areas of concern are power generation and power delivery. Generation is everything from the electrical plug on the wall to the drive wheel. Delivery is everything else. The power that turns the drive wheel is almost always electrical and is converted to rotational energy in one of two modes - constant or variable speed. If you are interested only in a single speed unit or if you've already got a variable speed power generation unit to turn the drive wheel then skip over the rest of this discussion. The way to translate that rotation to the blade is the same in either case, so jump ahead to the build instructions.

If you are interested in a variable speed unit (and you should be), there are generally (yes, I know there are exceptions, just bear with me) three means of creating variable speeds but we first have to talk about power. Electrical power comes in two main flavors - single-phase (which is the usual power in most homes and shops) and three-phase (usually available only in industrial area - at least in the USA). For the remaining of us plebes, we have to deal with single-phase power (typically 220 to 240 V). The usual multiple horsepower electric motor (split phase or a capacitor start - like your compressor motors or your machine motors) that provide a constant torque application and usually start under a heavy load, cannot be speed controlled. They are not like routers or hand grinders with brushes. Hook a dimmer switch up and the magic smoke will soon appear. This means your motor choices are either single-speed, single phase motors , single speed three-phase motors with a phase converter (typically a PHASE-A-MATIC or perhaps another three-phase unit) , a DC motor with a motor controller, or a three-phase motor with a variable-frequency drive (=VFD), the last two being variable speed systems.

The first question is how powerful does the motor need to be. While it is easy to channel Tim Allen (MORE POWER!), you also have to be realistic. As power goes up, so does the cost and the increase is usually exponential. As an example, a 5 HP reversible single-phase 3450 RPM 220 V motor eats 15 amps while a comparable 1 HP unit uses 6.3 amps (www.surpluscenter.com catalog numbers 10-2530 & 10-1903 respectively). As the amps go up, so does the diameter of the wire needed to carry the power. For this example, 10 gauge is needed for the 5 HP motor while 14 gauge will do for the 1 HP unit (dependent on run distance and local building codes, of course). So more power means more expense - in terms of initial outlay for wiring and in terns of continued expense for electricity.

So how much power do you need? It's been my experience of over 20 years of grinding that under extreme pressure, the belt will slip before the motor bogs, so the bottleneck is slippage, not power. The usual top-of-the-line commercial units max out at 2 HP, so that's a reasonable target.

The bottom line is - well - the bottom line. You probably don't want to pay (and pay and pay) for more power than you can use, so buy what you need but not more. For me, this means a 1.5 to 2 HP motor. In my shop, the run from the power panel to the grinding station is about 80', so I used 10-2 Romex to carry 220 V at up to 20 amps to accommodate the three grinders at the station. Even with two hands, I rarely run two units simultaneously but I do have guests occasionally.

Another aspect is the motor enclosure. A grind area is BAD NEWS on electricals. The magic smoke is easily released by metallic grinding dust that gets into the motor. You want a TEFC (totally-enclosed, fan-cooled) motor. Costs can range from $120 to $250 (used versus new; Surplus Center website; June 2010). I have had a TEFC Baldor motor operational for close to 20 years without a problem, so the extra cost of a TEFC motor is well worth it over the long run.

The last major consideration is the question of single versus variable speed. I have used a single-speed Bader BII for over 20 years and have built many blades with it over the years. Multiple speeds were achieved by interchanging 6", 4" and 1.75" diameter drive wheels (5419, 3613, & 1580 sfm respectively*). The last is needed so as not to burn out the bearings in very small contact wheels. Doing the swap is a major PITA - which is why I built a Bader clone to run the 1.75" wheel while the main machine ran the 4" wheel. So, in essence, I had a two-speed capacity. I have also had a variable speed DC unit. Variable speed is NICE - not critical, but nice. If you can possibly afford it, get it. So that's what next - three schemes to get variable speed.

Variable Speed Methods

Speed usually ranges from a maximum around 5400 sfm (~61 mph) down to some minimum speed which is dependant on your level of patience (hand sanding is probably as slow as it gets). Fast speeds remove metal quickly but with increased heat and belt wear and decreased control. Slow speeds are the converse. Metal hogging is done fast, handle work (especially for ivory, mother-of-pearl, etc.) are done slowly. Talk to two bladesmiths and you'll get at least three opinions of the optimal speeds needed. The three most common ways to get variable speeds will be discussed here.

Mechanical (Pulley) System:

If you have played with a drill press, a lathe, a mill, or even a metal-cutting bandsaw, you are already familiar with pulley systems. The motor turns over at the designed speed and you manually move a belt between pairs of pulleys to change speeds (see the section later in this manual for a detailed look at how to design such a system). The advantages are (typically) low cost and obvious repair / maintenance procedures. The downsides are a limited number of speeds and the complexity of building a multi-shaft system. For the 4-speed system described in this manual, the costs (as of June 2010) for 2 shafts, 4 pillow blocks, and 10 pulleys run approximately $120. Add a 1.5 to 2 HP TEFC single-phase motor and you will be pushing $300.

Direct Current (DC) Systems:

One of the nice features of a DC motor is that the speed is a direct function of the current supplied. The downside is DC power doesn't come out of the wall. The solution is a DC motor controller.

Motors: Let's start with a motor - something like the Surplus Center's # 10-2430 ($210; 1 HP; 90 V DC, 1750 rpm, 5/8" shaft, TEFC). 1 HP is a bit on the low side. A quick web search turned up some 1.5 HP, 4800 rpm motors in the same price range but the enclosures were not specified as TEFC - might be, just not stated to be so.

Some of the specifications need to be discussed. The max speed is 1750 rpm. To get the maximum desired speed of ~ 5400 sfm, we would need an 11.8" diameter drive wheel since:

$$\text{Diameter (in inches)} = SFM * 12 / (RPM * \pi)$$

Even if we dropped back to a 4" equivalent (3613 sfm), we would still need 7.9" wheel. Finding a 12" or 8" drive wheel for a 5/8" shaft is not likely. Typical drive wheels are 7/8 to 3/4" diameters with keyways, so we may need to keep looking for another motor.

When I put my DC system together, the Surplus Center had surplus (what else?) Pacific Scientific 2 HP, 3200 RPM, 180 VDC, 7/8" drive units that were decidedly NOT TEFC. The cost was something like $150. It has run well for something like 5 years but occasionally tells me it isn't totally happy (then it's time to blow the dust out again). There are units that are TEFC and even waterproof on the market - just not surplus at this time.

Controllers: The Surplus Center still sells the controller I have on my system (#11-2102 @ $170). Their description is: *Multi-drive solid state DC speed control. For operating permanent magnet or shunt wound motors. Complete with dual voltage switch for input voltages of 120 volt AC or 240 volt AC, line fuse, ON/OFF switch, and variable speed dial. Runs up to 3/4 HP, 90-130 volt DC motor with 120 volt AC input or 1-1/2 HP, 180 volt DC motor with 240 volt AC input. With auxiliary heatsink (Item 11-2101-H, $46) HP rating increases to 1 HP at 120 volt AC input or 2 HP at 240 volt AC.*

So for something like $366 (motor, controller and heat sink, since I have a 2 HP motor), I got a direct drive, variable speed power system that was compatible with the 6" drive wheel (7/8" shaft) I already had. Pretty sweet. The sticking point is finding the right motor at a reasonable price. A quick web search for "2 HP DC TEFC 180V" units turned up several motors with low rpm specs (1800) and high prices ($700-$1200). Like so many other things, if you are in the right place at the right time with money in hand, you may luck out. Otherwise, let's move on to the next option.

Three-Phase Motors and VFDs:

The two reasons I embarked on building a new grinder was the occasional hiccup in the DC unit and a gift of two 5 HP motors, one single-phase, the other three-phase. After all, free motor, more power - can it get any better? Well...yes it can, but only after doing some homework.

The single-phase 5 HP monster was the inspiration for the design of the pulley system described later in this manual. Over the years, I have heard of variable frequency drives (VFDs) that had some application to 3-phase motors, but that was pretty much all I really knew. Having a free 3-

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** sfm = surface feet per minute = rpm * circumference in feet*
*= rpm*π*diameter (inches)/12 = 3450*π*[6 or 4 or 1.75]/12*

phase 5 HP motor and a high-speed connection to the Internet as well as some free time late at night induced me to do some research.

It turned out that a VFD can be thought of as a high-tech equivalent of the dimmer switch or a relative to the DC motor controller. If the correct VFD and motor are combined, you can just dial up the speed you want (and maybe run even faster than the rated speed on the motor, i.e., overclocking is possible). The trick, of course, is “correct” in the previous sentence.

Many VFDs want 3-phase input to generate controlled 3-phase output. Not very useful if all you’ve got is single-phase. Some VFDs will take single-phase input but have to be downrated, i.e., to run a 1 HP motor, the VFD must be rated at 2 HP or more. In my case, a 5 HP motor meant a 10 HP VFD - and those are not cheap. Moreover, VFDs in that size range seemed to require a special enclosure to combat the grind dust in a knife shop. Bottom line - $700 to $800 to use that free motor which had way more power (and power consumption) than required.

The solution was a new 3-phase motor from the Surplus Center: #10-2131 (3600 rpm, $90; 1.5 HP, TEFC, 7/8” shaft). I found a new, discontinued VFD (3 HP, TB Woods -Model SE1C2S030D01, 230 Volt 1 Phase Input, DUST TIGHT) for $275.00 (dealerselectric.com). So for a grand total of $365 (and shipping, always shipping), I got a power system equivalent to the DC system for about the same price without the hassles of searching for the right surplus motor and/or putting up with a porous enclosure.

Conclusions:

Assuming you have to buy the single-phase motor for the pulley system, you can expect to pay $200-$250 to get one with the correct speed and shaft diameter. Add the costs of the mechanical train and you’re in the same ball park as the DC and VFD systems with far fewer speeds available. The DC systems are viable and about the same cost **IF** you can find a TEFC motor with an acceptable rpm and shaft diameter for the right price. I concluded that the VFD made the best sense and went that route.

Be aware, however, that the power transmission system that is described in the bulk of this manual will work with any of these power generation systems (with some inspired improvisation, of course).

Power Transmission - The Grinder

The grinder described here is pictured on the front cover of the manual. It is composed of six elements of which the motor and VFD have already been discussed. The remaining elements are the base plate, the socket, the tracking arm and the grind heads (including various accessories for the heads). DO NOT start building until you’ve read through the manual and understand the basic principles. While I will be citing specific sizes of materials, bolt specifications, measurements, etc., they are all somewhat flexible - it all depends on what you have lying around and/or are willing to go out and buy. What is critical, however, is how the parts align with each other and their basic functions. The reality of designing a grinder is that you should start with the grinding head you anticipate using the most (here, the four-station flat platen head) and use the dimensions of that head to dictate how everything else is to be laid out. Unfortunately, jumping right into the fine details on building the head would obscure the overall picture which you need to understand how all of this goes together. So, we’ll start with the major components of the base plate, the socket and the tracking arm, then get into the heads and alignment. Once that is under your belt, you will be in a good position to alter the specifications of the various units to conform to whatever junk you have gathering dust in the corners of your shop.

We have to talk about orientation. You use a grinder standing in front of it. The grinder’s right side is on your left. When I say “right” ,“left”, “front” or “back”, I will be talking about the grinder’s orientation. Look at the front cover. The VFD is on the right front corner. Hopefully I will be consistent but if there is confusion, just look at the diagrams.

II. Base Plate

The base plate is an approximate 18” x 18” plate of steel. The exact measurements are not critical but if much smaller than those cited here, things may get a bit crowded. The plate should be thick enough to be rigid. In the unit pictured here, the plate was 18.5” square and was 10 gauge steel with the front and back edges rolled over approximately one inch. It was originally a component in a automobile alignment system, i.e., a rescue from a dumpster. The rigidity was enhanced by welding two strips of 1” x 3/16” steel onto the left and right sides. On other grinders, I have found that 1/4” plate works well and in some cases, a thinner plate with strategically welded angle iron reinforcements can also serve. It’s just a function of what you have and/or how much you want to spend.

The dashed lines in the base plate diagram are the “footprints” of the socket, VFD mount and motor mount assemblies. Only the first two will be welded to the plate initially. The motor mounts will be tack welded during the alignment process and will be fully welded once the alignment is completed.

The VFD mount is composed of two uprights (angle iron 1” x 1” x 1/8” or whatever) with a crossbar at the top connecting the sides. See the diagram above for the orientation of the angle iron pieces. The dimensions are set by the size of the VFD. Make the lengths of the sides equal to the length of the VFD plus room for connecting electrical cables. If you feel paranoid (and I did), you can add triangular gussets from the back of the uprights to the base plate to prevent flex. Typically, there are mounting holes on the rear of the VFD and you may find it convenient to predrill the uprights to match those holes before welding them to the base plate. Based on the VFD I used, the mount was composed of 2 pieces of 1” x 1” x 1/8” angle iron 14.5” long and 7.5” apart. The cross bar was 3/4” x 3/16” x 6.5”. I improvised a 220 V switch box under the VFD from a defunct fence charger box and a scavenged 220 V switch from a power supply. Why? I had the parts and wanted to isolate the VFD when not in use from spikes in the electrical supply - something fairly common out where I live. I could, of course, just unplug the unit.

Motor mounts can be virtually anything but small channel iron (2” wide) makes a convenient mount. Angle iron can also be used. Match dimensions to the foot length of motor, mark and drill bolt holes to match. Bolt the motor to the mounts. As mentioned above, don’t weld the mount to the base plate just yet. If your base is elevated above the bench on which you install the grinder (as it is in this case), you could just drill holes in the base plate and mount the motor directly. The downside to that approach is the obvious hassle involved with removing the motor down the road (especially if the unit is bolted down to a bench) and the fact that we don’t know where those holes ought to be.

Once the socket is fabricated (see the next section), place it at the front and parallel to the left side of the base plate as shown. The standoffs must be perpendicular to the base plate. If the standoffs are cut with a pipe cutter (as suggested), they should be reasonably square, but don’t trust that. I have found that a 12” long piece of 4” x 4” x 1/4” angle iron (or equally good, a 12” piece of 4” or 6” channel iron) is a great aid. One leg can be clamped to the base plate and the other to one or both of the standoffs (see Figure II.2). Use a square to verify that the standoffs are perpendicular to the plate and then tack weld. Remove the clamp mechanism, recheck with the square, and finish the welding.

Typically, a grinder is bolted to a bench or table, so remember to drill some 1/4” or 3/8” holes in strategic locations for the bolts and/or lag screws. Between the front leg of the socket and the VFD mount is a good location as is the back right corner of the plate. You won’t be able to get access in front of the VFD mount or behind the motor, so the left rear and right front corners are out. There’s nothing wrong with the center of the plate but use your best judgement. You can paint the assembly at this point but remember, there will be some welding around the motor mounts eventually.

Base Plate Diagram

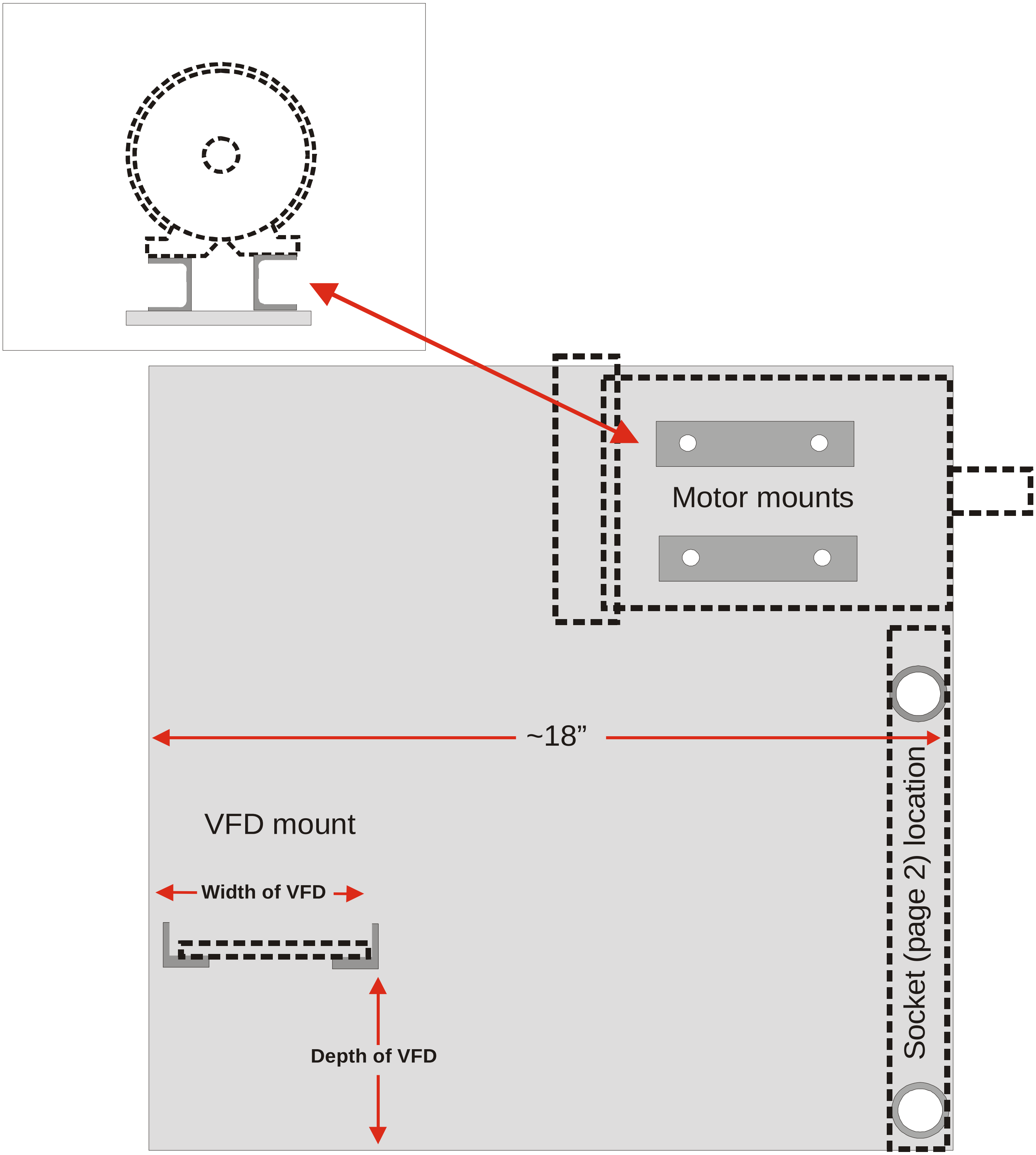


Figure II. 1. Base plate diagram

III. The Socket

The socket is the heart of the grinder. It is simply a mechanism to hold the grinding heads in the proper alignment to the drive wheel so that you can grind and not be chasing flying belts. The exact dimensions will be controlled by your choice of arm material and the size of the motor and base plate, so it is critical that those specifications are set in stone before you build the socket.

The prime component of the socket is a square tube just large enough to allow the arm material to slide through it. The fit should be loose enough not to require grease but tight enough so that the lock bolt only needs a quick turn to immobilize the arm. 1” x 1” stainless steel bar was used in the prototype primarily because it was on the shelf. Mild steel would have been okay and 1.25” to 1.5” square stock would have been fine too.

There are websites (www.onlinemetals.com for example) on which you can survey the dimensions of square tubing. To handle a 1” x 1” bar, $3 of 1.25” x 0.065” mild steel A36 hot rolled square tube with an internal dimensions of ~ 1.12” would do the trick.

The tube needs to be connected to the base plate and that is what the standoffs do. If the length of the standoffs is sufficiently long, an arm can be run over the front of the motor and next to the drive wheel. That makes alignment easier. If the length is too short, the belt will contact the rear bottom idler on the 4-station head (not a problem if you make a 3-station head or a 1-station head). Since the belt length is fixed at 72”, changing the standoff length will require moving the socket in or out and/or changing the overall arm lengths - it’s all related. Seven to eight inches appears to be the sweet spot.

The standoffs can be made of anything that you can weld but black pipe seems to be optimal. 1” Schedule 40 pipe has an exterior diameter of 1.32” and that is only 0.07” wider than the tube, so for less than $10 at the big-box store, you’ve got the standoffs. The lengths are controlled by the height of the motor when mounted plus 1/2”.

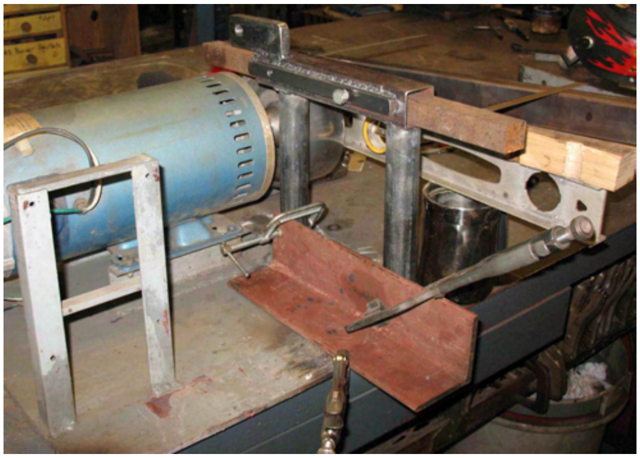


Figure II. 2. Welding jig

You want the tube to be as close to square to the base plate as it can be - basically zero lean left to right. That means the standoffs’ ends must be perpendicular to the sides. If you have a lathe, you can use a cutoff tool. Even easier is a pipe cutter. The cutter will, turn by turn, deepen a perpendicular groove until the pipe is cut. If you are careful in the placement of the cutting disc, the lengths of the two pieces of pipe needed will be identical. A light touch on a grinder will clean up any ragged metal at the cut site and you are good to go - with a welding ‘V’ already in place. If you have to cut the pipe with a saw, be as careful as you can and be extra careful when welding to insure the squareness of the tube to the base plate.

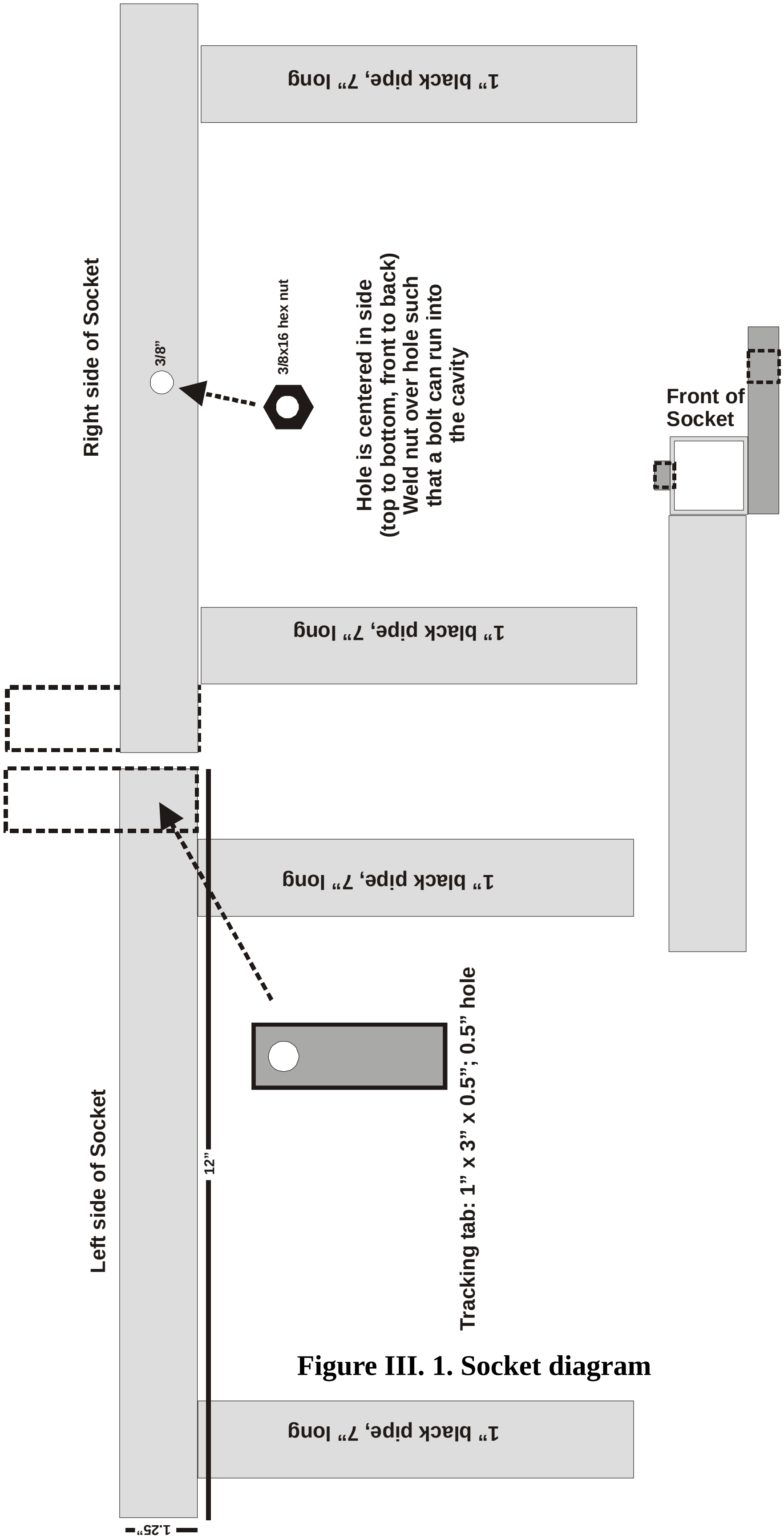
The length of the square tube is also somewhat flexible. You want it as long as possible so as to support the arm but not much longer than it needs to be. The length is ultimately controlled by the diameter of the motor, the depth of the base plate and the height of the standoffs. In the grinder described here, 12” is about right. The forward standoff is welded to the front of the tube (maybe back by a half inch or so). The rear standoff is welded to the rear of the tube such that it does not compromise adjusting the location of the motor. Since we don’t know just what that is yet, it’s better to play save and weld the rear standoff a couple of inches from the rear of the tube.

The tracking arm pivots on the tracking tab which is welded to the rear of the tube. The tab will be subjected to heavy loads so something like 3” of 1” x 0.5” bar should be used. With 3” of length, 1.75” of bar will extend above the top of the tube. The tracking arm will pivot on a 0.5” bolt, so a 0.5” hole in the tracking tab is needed. Since the prototype tracking arm is made from 1” x 1” material, the hole was drilled a little over 0.5” from the top, leaving a bit of extra room between the bottom of the tracking arm and the top of the tube and obviating the need to round off the bottom rear edge of the tracking arm. Once the tab is drilled, weld it to the left side of the tube as shown (the right would work just as well).

A bolt is required to lock the grind arm in the tube. A hole of the bolt diameter or slightly larger needs to be drilled on the right side (away from the belt) somewhere near the center of the tube. The prototype uses a 3/8x16 bolt, so a 3/8” hole was drilled 6” from an end and half way between the top and bottom surfaces. Since the wall thickness of the tube is only 0.065” thick, a 3/8x16 nut needs to be welded at the location so that a bolt running in the nut can penetrate the interior of the tube.

The only other component of the tube that is needed is a

Socket Diagram



Hole is centered in side (top to bottom, front to back) Weld nut over hole such that a bolt can run into the cavity

Figure III. 1. Socket diagram

means to secure the tensioning spring. Regardless of whether the spring is a leaf spring, a compression spring, or a cam wheel, it has to be locked to the tube. The prototype was built with two 10" long side plates of 1" x 1/4" steel with tapped holes. A much simpler system is outlined when the spring is discussed so don't let the discrepancy of details of pictures versus the text throw you.

IV. Tracking Arm & Bar

The tracking arm is a mechanism that simultaneously allows for belt tensioning and control of tracking. The arm rests at an angle to the top of the socket with the tensioning spring between the arm and the socket. The angle (and hence the size of the spring) is controlled by the 72” belt length and the distance between the drive wheel and the contact surface on the grind head. Since it isn’t going to be easy changing the spring and/or the angle, those are held constant and the movement of the arm in the socket handles preserving the overall geometry of the system.

Tracking is controlled by the position of a tracking wheel whose center of rotation (or axle) is at a nominal right angle to the belt. By altering that angle, the belt can be shifted left to right as needed. If the grinder is made with sufficient precision, changing from station to station on the 4-station grind head or from contact wheel to contact wheel on various arms will require only modest alterations in the tracking (read that as perhaps plus or minus 2 degrees or 1 revolution of the tracking screw). To be able to alter the angle of the tracking wheel to the system, the wheel is positioned on a tracking bar that can rotate relative to the tracking arm’s lower limb. The alteration in angle is accomplished by using an Acme lead screw to push the front of the bar to the left (away from the lower limb) and a compression spring at the rear of the bar to push it back.

The tracking arm (or more correctly, the lower limb of the arm) is made from 14” of 1” x 1” square stock with last 2” turned down to 0.62” (the internal diameter of 3/4” Schedule 40 black pipe). A 0.5” hole is drilled left-to-right 0.75” forward from the rear of the arm. A 1” x 1” x 1” boss is welded to left side midway. A 3/8” hole will be drilled top to bottom along the center line of the boss (running right-to-left) but the distance from the arm to the center of the hole is yet to be determined. The location of the 3/8” hole (or more correctly, the center line of the boss) will now be our reference point and the measurements to follow will be relative to the center line. A 1/4” hole is drilled left to right at 2.75” from the center of the boss (or 9.75” from the rear of the arm). That hole will help lock the tracking bolt mechanism to the lower limb of the arm. A bracket is needed to support the end of the compression spring. A 1” x 0.5” x 2” block is welded to a 1” x 0.5” x 1” block to form an ‘L’ (see cross-section “A” in the Tracking Arm diagram if this isn’t clear). A 3/4” diameter recess is drilled into the face of the ‘L’ looking across the top of the lower limb and towards the tracking bar. The ‘L’ is then welded to the right side of the lower limb in the position indicated (2.5” back from the reference point). If you have it, use a 3/4” end mill to flatten the bottom of the recess.

Eight inches of Schedule 40 3/4” black pipe is welded to the front of the lower limb (over that 2” turned section) and is bent 45 degrees up and to the right (away from belt). If a lathe isn’t handy, use 12” of stock for the lower limb and just weld the pipe to the front end of the lower limb. That isn’t as strong as the system with the insert but if you don’t have the tools, it’s a lot easier. All you really want is a handle that you can lean on to overcome the spring tension and move belts on and off the grinder, so whatever you come up with will probably suffice. In the picture on Figure IV.1, the arm is made from rectangular tube and was simply notched, bent and welded to form the handle. Just be creative.

The tracking bar is 6.5 inches of 1” x 1” square stock. A 0.375” hole is drilled top to bottom at the center. A bolt will be run through this hole and the corresponding hole in the boss that was welded on the left side of the lower limb to create the pivot of the bar on the lower limb. A 3/4” recess is drilled 2.5” to the rear of the 3/8” hole (identical to the other recess described above) on the right side of the bar. The two recesses are the seats that will hold the compression spring that counteracts the lead screw. A 0.5” hole left to right is drilled about 2.3” from the 3/8” pivot hole. The bar sits on top of the boss on the lower limb and is secured with 3/8x16 bolt and Nylock nut. A thin copper washer is used between the bar and the boss to reduce friction. DO NOT drill the hole in the boss yet. The location of the hole along the right-to-left center line of the boss is the primary adjustment used to align the center of the tracking wheel to the centers of the drive wheel and grinding head wheels or idlers. You need to know where those centers are to know where to drill the hole and you won’t know that until the grinder is virtually completed.

If you think about the geometry of the system, the Acme lead screw moves left to right but does not pivot. The bar it is pressing against does pivot and if the lead screw is extended too far to the left, the end of the screw might slip off the end of the bar. That would argue that we ought to set the lead screw closer to the center of the system (or add some length to the front half of the tracking bar) and/or shift the tracking wheel closer to the center of the bar. However, the closer the tracking wheel is to the center of the bar, the less mechanical advantage the screw will have. That means increased effort needed to change the tracking. This discussion is somewhat academic (Hey! what do you expect from a retired professor) since the compression spring will limit the degree to which the bar can pivot outwards. The measurements given here do work.

The tracking adjustment bracket is formed from 7” of 1” x 3/16” steel bent 90 degrees at 1” from the end. With the 6” section of the bracket on the right side of the lower limb and the 1” section on the bottom of the lower limb, mark the bracket through the 1/4” hole in the lower limb. When you drill a 1/4” hole at that location in the bracket, a 1/4” bolt can be run through the bracket and the limb. Next, drill a 0.375” hole in the bracket about 1.375” from the bend (that

Tracking Arm & Bar Diagram

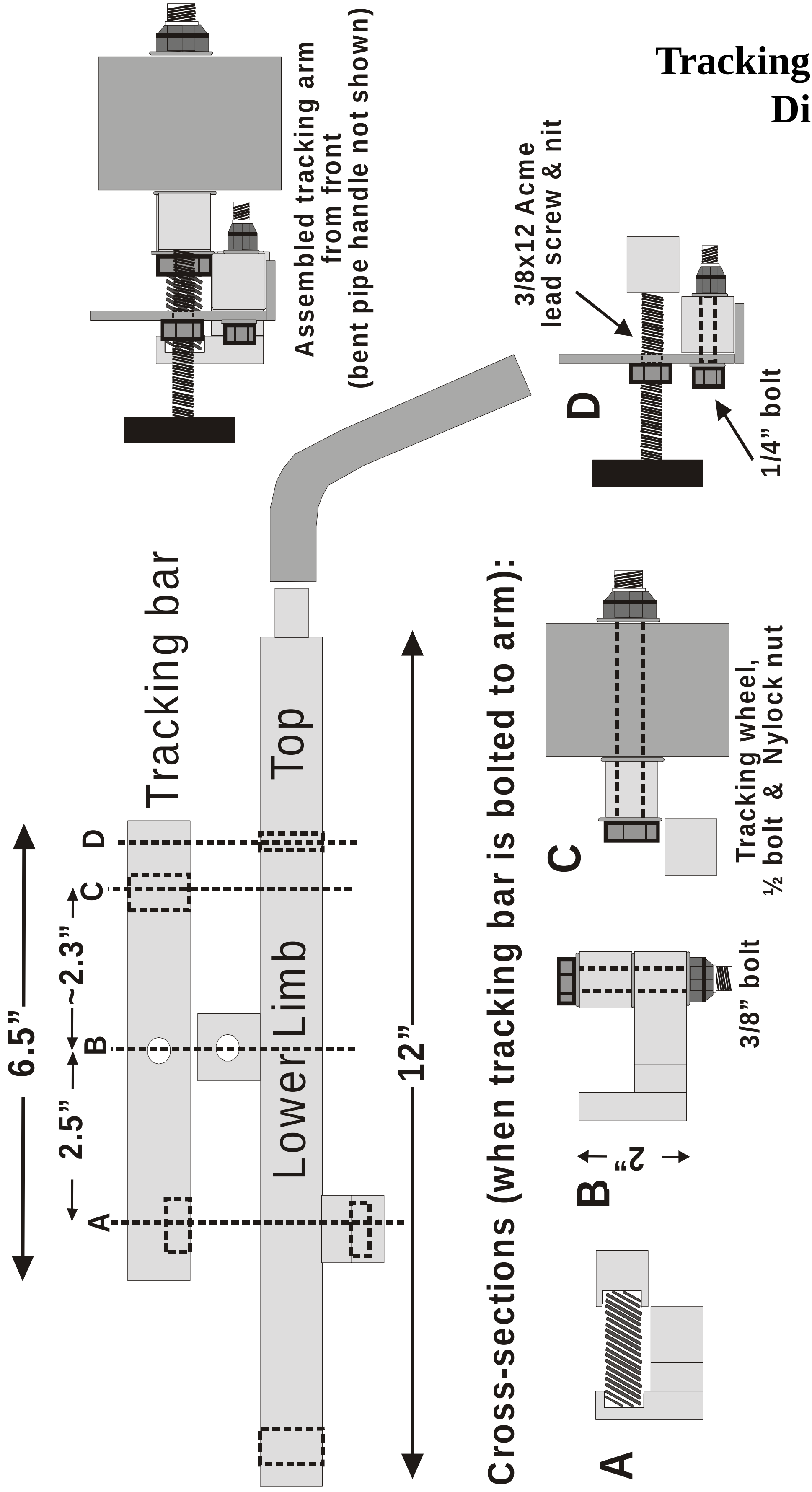


Figure IV. 1. Tracking Arm & Bar diagram

ought to leave about sufficient air space between the top of the tube and the bottom of the lead screw). Drill another 0.375" hole close to the end of the bracket's 6" section. That hole will be used for attaching a spark arrestor (see Accessories). Finally, weld A 3/8x12 Acme nut on the outside of the bracket around the 1st 3/8" hole. When nutted down, the bracket is securely fastened to the lower limb. If you are really confident of the geometry, you could just weld it down and forget about the 1" bend and 1/4" holes - just hope the Acme nut doesn't wear out or that the lead screw's position on the lower limb isn't quite right.

The Acme lead screws were sourced from Enco (useenco.com). Three feet of 3/8x12 right-handed low carbon Acme lead screw (part # 328-2765) will set you back $8.06 . You actually only need 4..6" but it is cool stuff to have around. The nuts (Part # 328-1105 = 3/8x12 Acme Heavy-Duty Hex Thread Right Hand) are $2.75 each. Buy a half dozen or so - you will eventually need them, but for this project, only one is needed (if you don't foul up when welding). I have a collection of 3/8x16 knobs scavenged from old exercise equipment but if I didn't, then a 5-lobed elastomer knob with a 3/8x16 through hole (Part # 328-2273; $1.78 ea) would serve. I clamped a 5" section of the lead screw in a vise (using wood blocks to protect the threads) and ran a 3/8x16 die down about 1/2". Screw the knob on tight and you're good to go. Of course, you could spring for 2 more of the Acme nuts, bore out the knob, and clamp the knob between the nuts. You could, but it's just not as elegant.

After painting, the assembly of the arm is straightforward - bolt the tracking wheel in place (bolt head to the right, Nylock nut towards the belt). You do not want the wheel to drag, so use a washer between the bar and the wheel. I found that drilling a 3/8" washer out to accommodate a 1/2 bolt was the ticket here (as well as for mounting the Beaumont idlers to the 4-station grind head). Use a 3" long 3/8x16 bolt and a Nylock nut (washers top, bottom and between) to attach the bar to the lower limb. Squeeze and fight the compression spring into the recesses , then thread the lead screw into place. One of the aspects of buying surplus and squirreling material is that you don't know the source and/or actual specifications on items. That applies to the compression spring. The ones that have worked for me are 2" long (uncompressed) and 5/8 to 3/4" diameter. The wire is ~ 0.1" in diameter and the tension is such that a hard squeeze between the thumb and forefinger doesn't seen to do anything. A reasonable match can be found for $1.31 at the local ACE hardware - Stock#18534 (#34 in the big gray plastic drawers labeled "Extension & Compression Springs"). The spring is 3/4" diameter x 3" long, so expect to cut an inch off unless you back off the "L" bracket another inch to the right. Basically get the strongest spring you can find since it has to fight the belt tension. Speaking of belt tensioning...

V. Belt Tensioning (the Spring)

Belt tensioning is done with a spring scroll (Figure V.1). The size of the scroll is controlled by the angle between the tracking arm and the socket. A gap about 3" to 4" wide and about the same distance from the rear pivot point seems optimal. The spring is tool steel - 5160 or O1. Use a 7" long piece - 1" x 1/8" to 3/16". Put a right angle in one end (maybe 1/4" or so), then forge then rest into scroll about 4" in diameter (with the bend end toward the center - see diagram). The spring will need to be heat treated. If you are using either of the tool steels mentioned above, bring the scroll to 1550^o F, oil quench and temper at 650^o F for an hour or so. If you do not have an oven that will do 650^o F, a molten lead bath on simmer or hot-blueing salts held at 650^o F will do. You can even use a torch and wash the spring with the flame to turn it pigeon blue - not as good and not easy to get it uniform, but it is possible.

The spring needs to be locked into place and that is what the spring saddle does. The saddle (see Figure V.1) is formed from two 3" pieces of 1" x 1/4". There are 3/8" holes drilled at the ends of both pieces such that the holes align. The top of the saddle is notched to accept the spring. The plates of the saddle are joined by 3/8x16 bolts as shown. All you need to then is to clamp the spring to the top of the socket with the resulting 'U' bolt. This allows you to move the spring forward as back as needed.

After alignment and welding the motor mounts in place, the actual tension is adjusted by attempting to place a belt on the machine. If it is too difficult, grind off some of the thickness of the spring along the belly. Keep adjusting until you can just barely get a belt in place. Be careful not to overheat the spring when adjusting.

An alternative approach is to use a strong compression spring and add spring seats on the bottom of the tracking arm and the top of the socket. I didn't have a spring with sufficient resistance to tension a belt correctly, so I opted for the spring scroll.

You want the belt to be held firmly to minimize slipping but loose enough that you can compress the spring. It is possible to stretch belts if the spring tension is too high. When that happens, the belt may wobble. The beauty of this grinder design is that all you have to do to correct that is to slack the belt, move the arm out a 1/4 to 1/2" more. Of course, eventually, the belt will give up the ghost and may come and talk to you as it flies by - so keep an eye on the splices.

There is an alternative to a spring - it's called a cam. Replace the spring and the saddle with something that conforms to the picture to the right. The cam lobe has a 'flat' (upper diagram, to the right side). When the cam arm is rotated towards the rear of the machine, the cam rotates and increases

Belt Tensioning Diagram

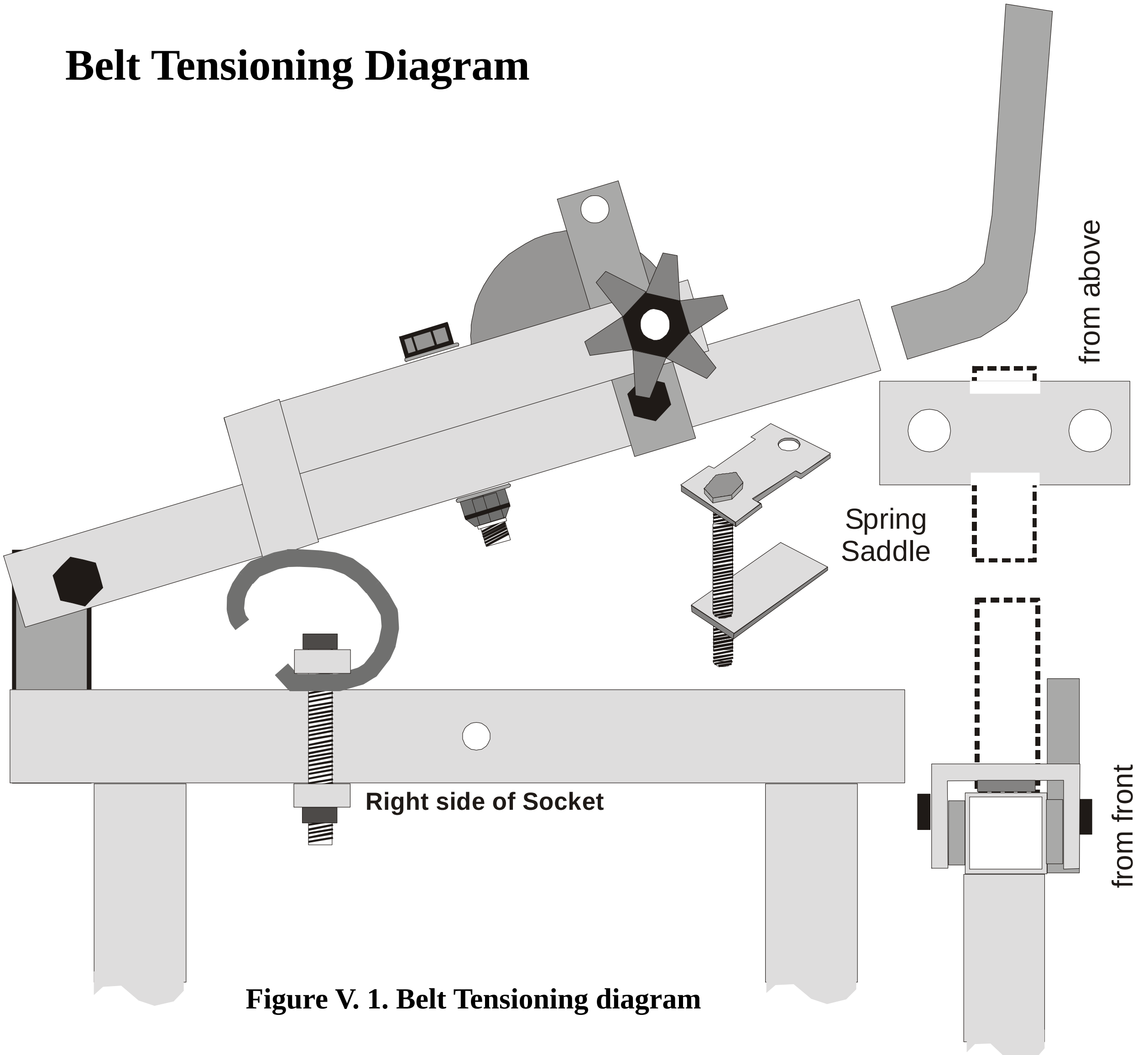
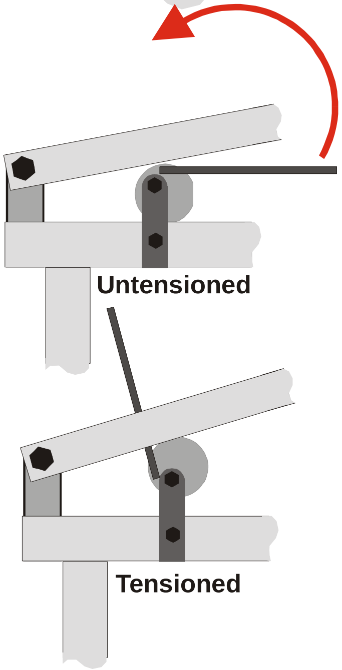


Figure V. 1. Belt Tensioning diagram

the angle of the arm and the socket Eventually, the flat connects to the underside of the arm and the arm “settles” into position. The actual amount of tension is controlled by the cam and the extension of the grinding head arm. I have experimented with using the geometry of a system to tension a belt rather than using a spring. I stretched a lot of expensive belts. Maybe you will have better luck if you want to go this route.



VI. A. Grinding Heads - Flat-Platen

Because I like flat-platens (and I'm writing this), I start the discussion with those. A flat-platen is simply a structure with an idler wheel (typically 2" x 2") on either end and a 6" to 8" gap between. There is usually a piece of angle iron (2" x 2" x 1/4" or 2" x 3" x 1/4") fastened to the structure bridging the gap between the idlers (see the diagram on the facing page or look at the cover figure). I have found that I like several flavors of flat-platens - based on different treatments of the angle iron. For general grinding, I use a hardend steel plate welded to the angle iron. So that I can use the edge of the belt for freehand sculpting of things like finger guards, I like the edges rounded over. Of course, if I an doing a plunge cut, sharp edges are good. Occasionally, a softer backing is nice - like when grinding down metal parts on a handle without scalloping out the wood parts. This can be accomplished by contact gluing a piece of rubber floor mat to the angle iron and then gluing a piece of graphite impregnated fabric over the rubber. Of course, not having any backing is very nice when doing handles (often referred to as 'slack belt' grinding).

So---that's 4 platens and 8 idler wheels - at $45 each, that's $360 and we haven't talked about the main idler ($58) and the drive ($82) wheels yet (see www.beaumontmetalworks.com or call Stephen Bader Co.). Wouldn't it be nice to somehow cut those costs a bit and make the system really convenient to use? Well...that's what the 4-station grind head is all about.

Take a square of steel plate (I used 0.40" x 9.5" x 9.5" plate). Locate the dead center and equally distant points in each corner for mounting the idler wheels (Figure VI.A.1). Locate points between the wheels for locking the angle iron to the plate. Be very precise in all of this - making a template and measuring thrice is not a bad idea! In fact, there is half of what you need in a page or so. What you want is that when the plate is rotated 90 degrees, the essential geometry of the all the wheels doesn't change. In the best of all possible worlds, tracking will be unchanged regardless of the edge forward. By making this head, you save $180 and a lot of time changing accessories. Hole locations are critical and must be symmetrical, i.e. when rotated 90^o around the central 0.5" hole, all holes should coincide. The locations of the idler wheels are 0.75" in from the edge. The tapped 3/8x16 holes are also 0.75" in and 3" apart. The four holes flanking the central hole should NOT be drilled initially. These specifications should not be taken as "TRUTH", they are just what I used, given the initial plate size. Just be consistent and be precise. To aid you, a template is provided as Figure VI.A.2. Get a copy of that page and cut the template out. It is 1/2 of what you need. Place the template on the plate and mark the holes. Flip the template over, align the center holes to the center marks you just made and mark the other side. Then confirm all the points with an accurate ruler (see the Alignment section on where to get one). Be sure to measure from the center point to each corner point. All four must be identical. It is possible to make an equilateral triangle system (3-station). I'll leave that as an exercise for the student. Note that one of the edges of the plate has been recessed approximately 1.5". That's the slack belt location.

We now have to talk dimensions. The available idler wheels are 2" wide and 2" in diameter. Those from Beaumont Metal have a bearing in either end and accommodate a 1/2" bolt. Those from Bader have an internal bearing with a 5/8" diameter by 1" long shaft extending from one end. The shaft is internally threaded to take a 3/8x16" bolt. The critical alignment measure in the grinder is wheel center to wheel center, i.e., the center of the 2" wide idler wheels must align with the center of the 2.25" drive wheel and the center of the 2.5" tracking wheel.

If using the Bader wheels, the plate has to move 1" to the left relative to using the Beaumont wheels. You will have to weld 1" thick blocks in the corners of the plate, drill 3/8" holes through the blocks and the plate (at those critically determined corner locations), and then drill 0.9" to 1" deep holes (5/8" diameter) into the surface of the blocks (or just use some 1/2" Schedule 40 pipe (internal diameter = 0.62"), so bore them out with a 5/8" bit - and remember to use that pipe cutter). Doing all of this is MUCH nicer on a decent mill compared to a drill press. If possible, run a 5/8" end mill into the blocks to flatten the bottom of the holes. You will also have to weld 1" thick spacers over the angle iron lock holes to move the angle iron out to match the idler wheels.

If using the Beaumont idlers, you only need to drill 1/2" holes at the corner locations and fabricate a washer (as mentioned earlier) that allows the bearing to turn freely when the bolts are snugged down. Nylock nuts and 1/2" bolts with long, unthreaded shanks are a good idea.

I elected to use the Beaumont parts on the prototype. Since I just completed the grinder, I cannot speak for the longevity of the Beaumont material but they have an excellent reputation (look up KMG grinders on the web). I have yet to burn out a bearing on a Bader idler in over 20 years of using them. I've worn the outsides down to cones, but the bearings seem to be smith-proof. Bader does not post their prices on the web but they are a few bucks less expensive than the Beaumont units. Given the overall costs, the difference is meaningless and I can tell you in a few years if the longevity is equivalent..

As for the platens themselves, I use 3/8" holes, tapped for 3/8x16 bolts at the lock positions for the angle iron. Three six inch long pieces of angle iron (2" x 2' x 1/4") form the body of the platens. I welded (using stainless rods) 2" x 6" slabs of O1 to the front surface of two of the platens. The O1 was run up to 1550^o F and oil quenched. It was not tem-

Flat Platen Diagram

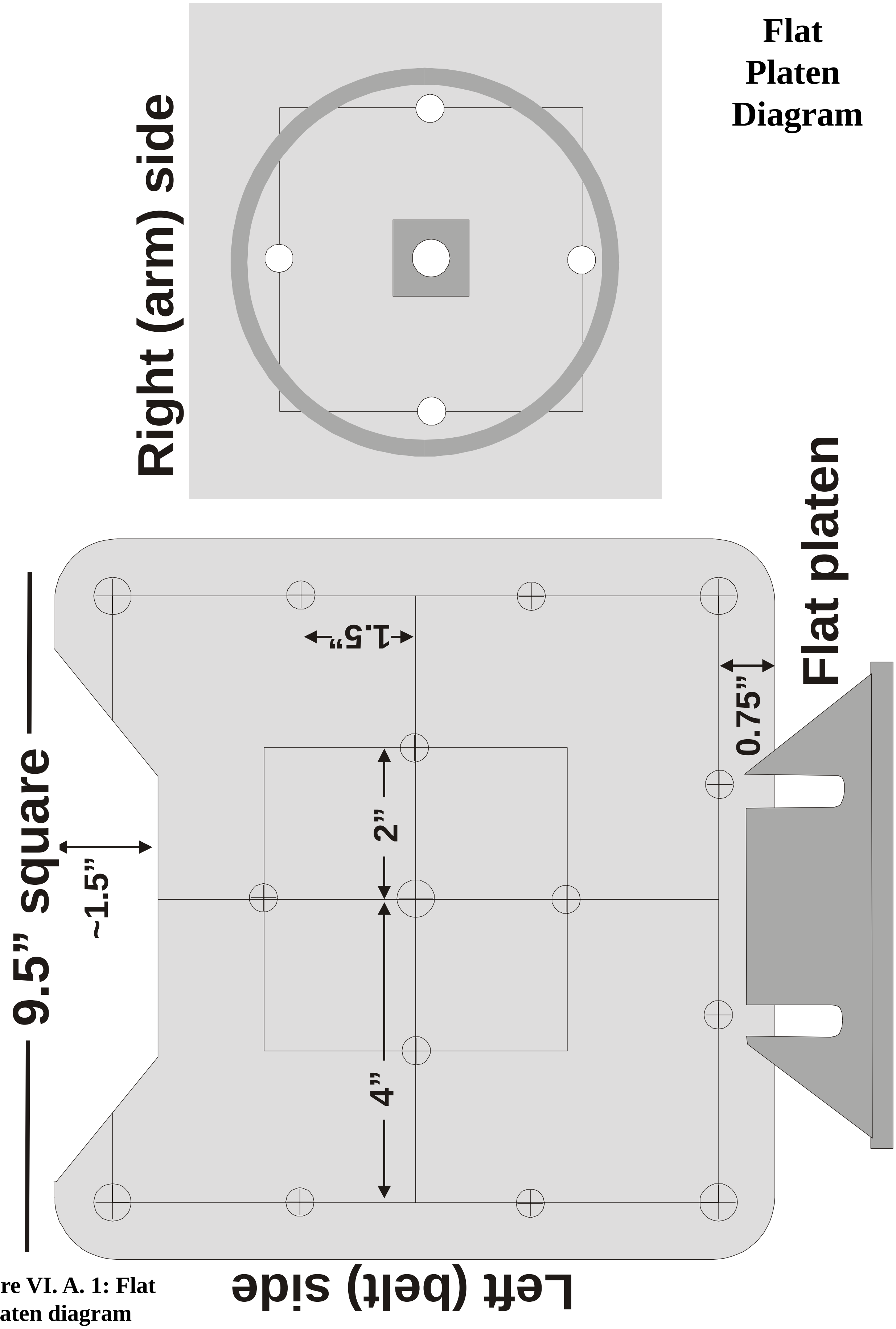


Figure VI. A. 1: Flat Platen diagram

pered, so it should be at something like 66 Rockwell C. One of these platens had the edges rounded over (to about a 3/8" diameter) and the other was left as is. The third platen was given a "soft" backing by literally cutting off a 2" x 6" corner of an antifatigue mat in my shop (which started life as a conveyer belt). Barge cement was the glue of choice. The soft platen is completed with a coat of graphite-impregnated fabric (sourced from Texas Knife Makers Supply - GR1 at \$4/ft). The platens were slotted to slide over bolts in the 3/8" holes along the three uncut edges of the plate.

To stiffen the plate (and for spacing reasons), a 6" x 6" block of 0.4" steel was welded on the backside of the plate (the backside being the surface towards the arm). To ease rotation and allow for the thickness of bolt heads in the corners, you will need a boss 1" x 1" x 0.5" welded to the back center of the plate. Extend the central 0.5" hole through that boss. Forge a ring ~ 4.5" in diameter from 1/2" square stock, center it around the boss and weld it in place. The boss and ring should be ground or milled to the same thickness. If you do not have access to a mill and a surface grinder, just do the best you can.

Now - variations and adjustments... If you typically use a holder for your blades (for example - you make folders), you will want to relieve the edges of the non-slack belt stations to accommodate the holder you use. You need enough clearance that you can do the plunge cut on the left side without hitting the edge of the plate supporting the idlers with the blade holder. I have found that a 3/8" deep recess seems to work for me but you should evaluate what you need while the cutting torch is still lit. You could fabricate the 9.5" square plate by simply welding strips of steel onto the 6' square back plate. As an example, run a 14" x 1" x 3/8" piece diagonally across the 6' square and cented on it. Then add two 6.5" x 1" x 3/8" running at right angles to that piece and centered to produce a 10" x 10" 'X'. Then cut 4 pieces that bridge the gaps between the limbs of the 'X' to provide a place for the platen mounting holes while being back 3/8 or 1/2" from the edge. Weld those pieces in place and grind everything smooth. Or just use a single plate....

Location of the 4 flanking holes around the center are critical. First fabricate the arm. A drawing of the arm is provided with the section on contact wheels - the 10" wheel's arm is identical to the one needed for the 4-station head. Start with least 20" of whatever arm material you are using (here 1" x 1" square stock). Drill a 0.5" hole 3" from the front end. Drill and tap for a 3/8x16 hole 0.75" from the same end. Drill a 3/8" hole no more than 2" from the 0.5" hole, i.e., at 5" from the end - this is the lock location. The location of the lock must fall within the ring. Bolt the plate to the arm and verify that the edge is perpendicular to the arm. Mark the plate with a transfer punch in the lock hole. Drill that hole (a 'Q' bit should be used). Reassemble the arm and plate and rotate the plate sequentially 90° to mark the other three holes. Drill and tap all four holes for 3/8x16 bolts. You could try to drill the holes using the plate diagram or measurements but the method outlined here is more likely to place the holes in the plate exactly where they are needed to insure perpendicularity. You can use a 3/8x16 bolt and a wrench to operate the lock mechanism but the swing-lever bolt described in the accessories section is far cooler (and way more convenient).

4-station grind head template - mark hole locations with center punch, flip over, align center holes to those marks and mark the rest

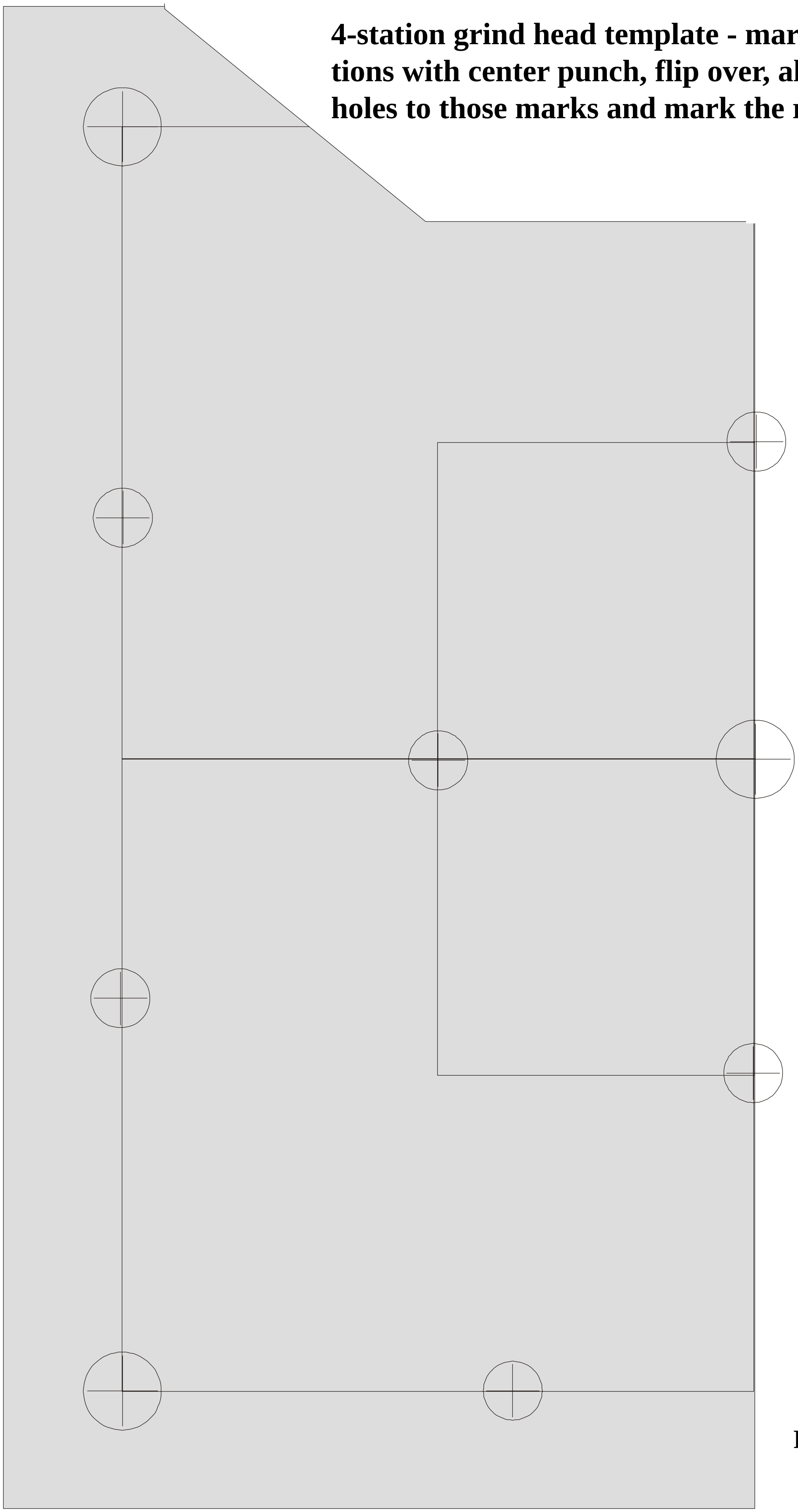


Figure VI. A. 2. Flat Platen template

VI. B. Grinding Heads - Contact Wheels

The contact wheels used in the prototype were acquired from Bader and have the 1” long x 5/8” diameter bearing extension. In this application (using Beaumont idler wheels on the 4-station grind head), a 1” cube with a 5/8” hole had to be welded on the left side of the arms over the central 3/8” hole position. A 3/8x16 bolt extends from the right side, through the arm and into the bearing extension. The other 3/8x16 tapped hole indicated in the diagram is to accommodate the steady rest (see Accessories).

An explanation is needed concerning the relationship of the 4-station grind head to contact wheel assemblies. In all cases, the center of the surface of a wheel - whether it be a 2” x 2” idler, a 10” diameter x 2” contact wheel or a 0.5” x 2” contact wheel (typically called a “fork” wheel) - must align to the center of the surface of the tracking wheel and the drive wheel. Since the Bader contact wheels have the 1” extension and the arms are 1’ thick, the absolute minimum profile would have been achieved by sinking the 1” extension 0.5” into the arm and leaving a half inch for the bolt that locks the bearing in place. This would place the center of the contact wheels 1.5” from the nearest arm surface (our reference surface). The 4-station head, however, is (at the minimum) 0.5” (the boss & ring) plus the plate thickness (in my case, 0.8”). Assume a washer of 0.1” thickness and a loss of 0.1” from the boss and ring due to grinding. The result is that the center of the idler wheels would be 2.3” from the reference surface, so the 4-station head is too thick by a factor of 0.8”. Since we cannot make the 4-station plate thinner, the solution is to add 1” of thickness to the arm and drill the 5/8” holes 0.7” deep. So from the reference surface, the 4-station head is 1.3” thick plus half of the idler width or 2.3”. The contact wheels are 1.0 + 0.3 + 1/2 of the contact wheel width or 2.3” and we are golden. If I had not added the extra 0.4” plate to the back of the 4-station plate, I would have had to sink a 5/8” well 0.1” into the actual arms and grind a corresponding amount off of the 1” spacers to get the same result. Adding the plate seemed easier.

The arm for the 10” wheel is identical to that needed for the 4-station grind head (Figure VI.B.1). Arm length is somewhat flexible. There should be 9” in the socket plus whatever is needed to reach the center of the wheel plus whatever is needed to move the wheel out to tension the belt. The last isn’t easy to determine until the grinder is completed, so go long if you can or wait until the grinder and one grind head is done. You can then determine the correct length for all others.

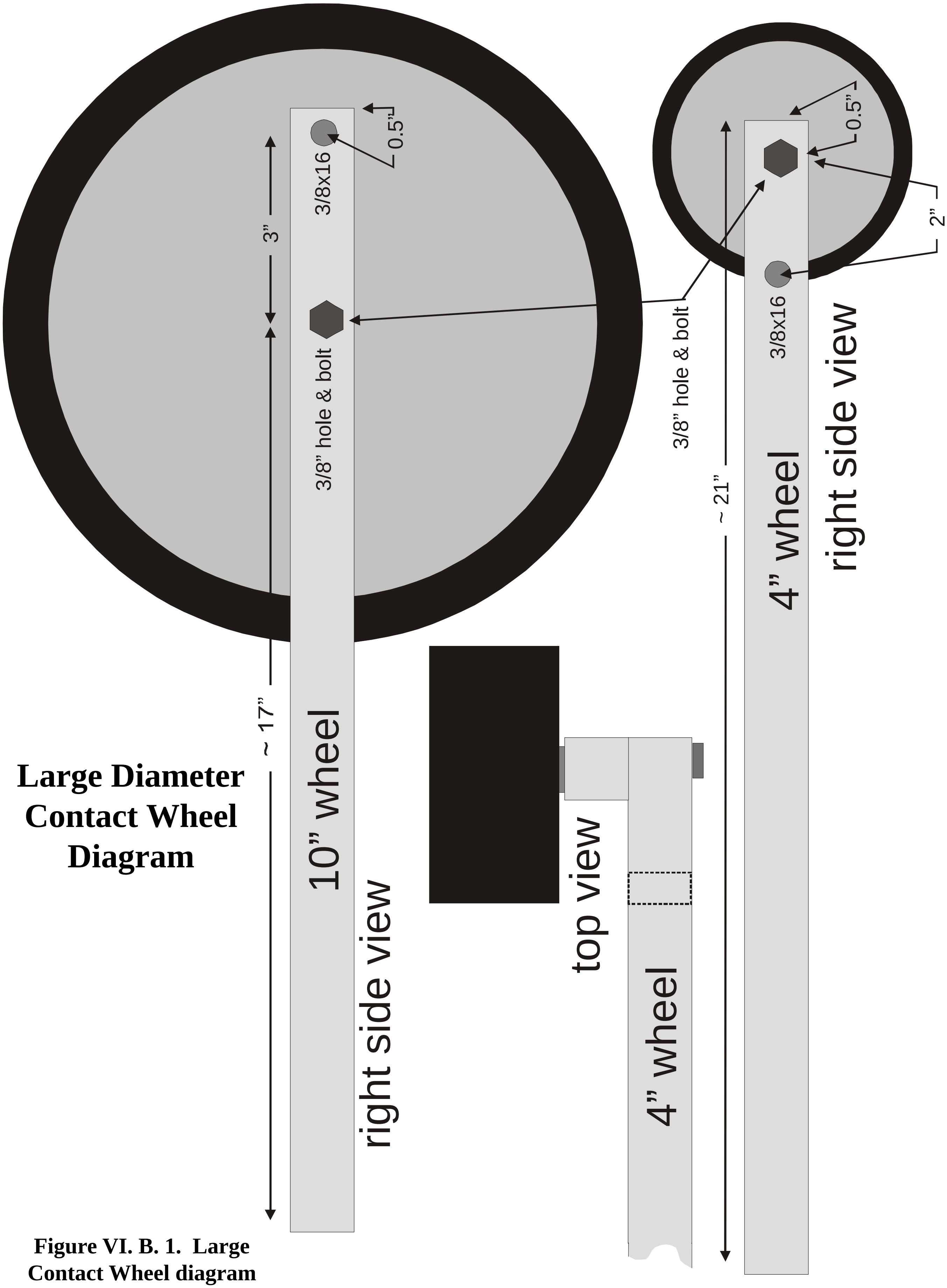
The arm for small contact wheels (2” down to 0.5”) is somewhat different from those already described due to a significant change in the wheel configuration. The 0.5” contact wheel (and there are others which follow the same pattern) is a 2” roller with axle extensions on both ends. To use this type of wheel, there must be support on either end and that support cannot interfere with the belt. Bader’s solution was the ‘fork’ and the prototype follows that lead (see the Small Contact Wheel Diagram).

Because I can and I was running out of arm material, I elected to make a double-head arm system. The arm is drilled and tapped for four 3/8x16 bolts. Each pair of bolts are on 2.5” centers and the pairs are offset by 5/8”. The first hole is 0.5” from the front end of the arm. Given that the arm is 1” thick (and stainless), there is no need to tap the entire depth of the arm. A ‘Q’ diameter hole was drilled through the arm at each of the locations and a 13/32” drill was used to widen the holes to half the depth in the pattern shown.

Eight inches of 7/8” x 7/8” stock was drilled to accommodate 3/8x16 cap screws aligned to the rear set of holes in the arm (those being #2 and #4 where #1 is closest to the front end of the arm). The front of the block was narrowed as shown in the diagram and a 1/8” hole was drilled left-to-right 0.2” back from the front end of the ‘nose’. The hole was widened to 3/16” on the surface away from the arm to match the diameter of the axle of the contact wheel. This construction matches the one used by Bader and represents one of the seats for the contact wheel. Note that larger diameter wheels of this style may require holes wider than 3/16”.

A 0.5” x 2.25” x 1.5” block was welded 4.4” from the end of the side support just described. Two tapped holes (1/4x20) were created 3/8” from either end in the free 0.5” x 1.5” surface. This block forms the “back” of the fork. A 3.6” long 0.5” x 0.5” piece forms the outboard side of the “fork” and was drilled to provide the other seat needed to support the wheel on one end and to accommodate 1/4x20 cap screws aligned to the tapped holes in the rear block. From the discussion above concerning offsets, we now know that center of the wheel ought to be at 2.3” from the reference surface (the near side of the arm). For the 0.5” wheel, there is a 0.2” clearance between the side of the wheel and the inboard fork surface (here provided by the 7/8” x 7/8” x 8” block). We thus have 0.875” + 0.2” + 1.0” or 2.075”. I could add a spacer 0.225” thick between the arm and the inboard side of the fork or I can just turn the tracking knob a half turn or so (yes, I should have used 1.125” square stock instead of 7/8” stock but that’s what I found in the scrap bin).

The forward set of holes (#1 & # 3) in the arm can be used for the steady rest, for a belt “squeezer” (see Accessories), or as a mount for other small wheels that don’t require support on both sides. As background, I was given a box of serrated wheels ranging from 2” to 1” diameters and widths from 0.75” to 1.5”. All of these wheels rotate around a bearing with a 3/8x24 threaded extension. A support bar or mount was fabricated from 1” x 1.375” x 8” block of steel (see the Small Contact Wheel Diagram). The wheels thread into a



Large Diameter Contact Wheel Diagram

Figure VI. B. 1. Large Contact Wheel diagram

“nose” and a long 3/8” slit accommodates the two 2.5” long 3/8x16 bolts residing in holes #1 & #3. A 0.7” thick set of spacers is inserted between the arm and the support bar and moves the wheel centers to 2.1” to 2.5” from the reference surface - a discrepancy from the optimal 2.3” that lies well within the scope of the tracking system.

The two-sided arm highlights one of the advantages of the square arm plus socket arrangement at the heart of this design. The arm can removed, simply be flipped over, and reinserted to change from one contact wheel to another. Even if the belt tension is not correct, sliding the arm in and out will take care of the problem.

Small Diameter Contact Wheel Diagram

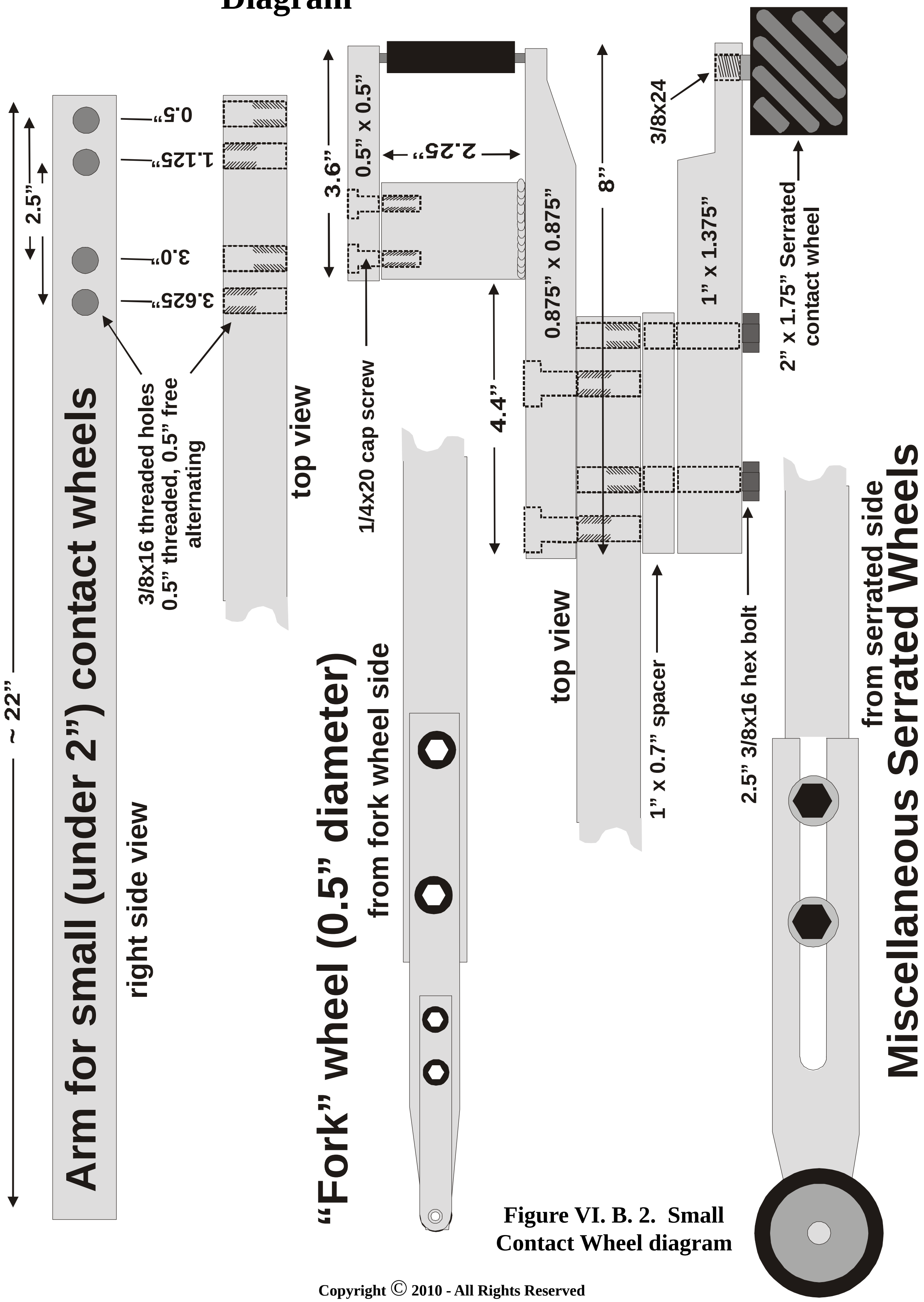


Figure VI. B. 2. Small Contact Wheel diagram

VII. Alignment of the System

The most critical aspect of a grinder is the alignment. Get that wrong and the beast will be a PITA. At best, there are three wheels - drive, tracking, and contact. If you like flat grinding, then bump that to four. If any of these are seriously at odds with the others, you will have tracking problems.

Alignment is simple - just get all wheels in the system (3 or 4) locked in three-dimensional space such that the center of each wheel falls into the exact same plane and moreover, the vector representing the perpendicular to the rotating surface falls into the same plane. Okay, for those of us who grew up on cartoons, look at Figure VII.1. The three "wheels" inline (less than more) in "A" are obviously off line with regard to centers and vectors. If we move them into the arrangement of "B1", the center of the wheels align but the vectors are still wrong. If we align the vectors but not the centers, we get "B_2", still not there. Finally, if we adjust both the centers and the vectors, we finally get what we want - "C" where everything is aligned. Well, that's exactly what we need to do with the grinder. Next, let's look at the generalized relationship we have to work with (boy, that professor thing gets irritating doesn't it?).

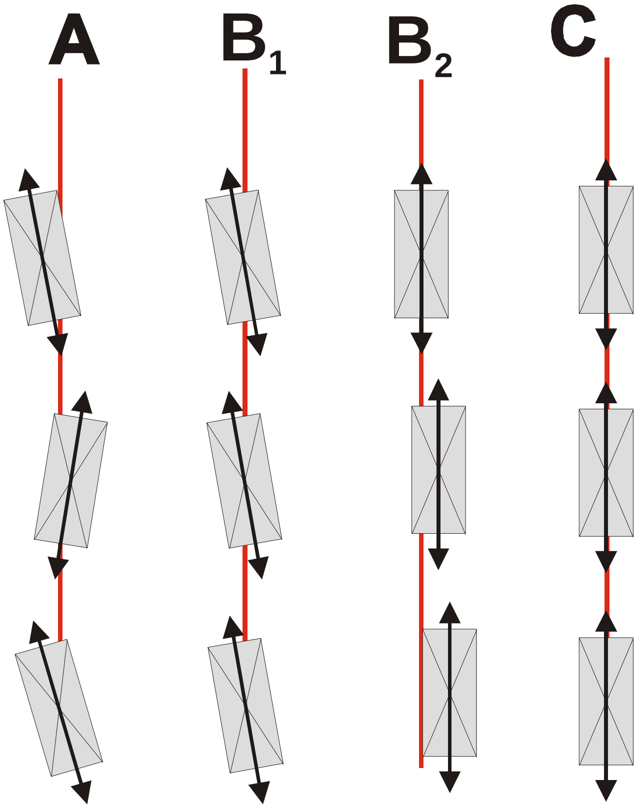


Figure VII. 1. Alignment scenarios

If the manufacturer of the wheels (drive, tracking, or idler) has done their job properly, the we can assume that the axle of the wheel is at a perfect 90° to the rotating surface. If you have used decent material for the arm, we can also assume that the reference surface (the side of the arm nearest the wheels) is also straight and true. This means that whatever connects the wheel to the arm, the connector, controls whether the wheel is running at 90° to the reference surface. Let's take a worst case scenario - one of the corners of the 4-station grind head. Further assume that your drill press is (to be kind) a bit off and the hole in the corner is drilled at an angle (20°) to true. When you bolt in the idler wheel, you get the situation pictured in Figure VII.2. Not good! The bottom line is that you MUST check that the drill bit is really at 90° to the surface - regardless if you are using a drill press or mill. That's why they make squares! Using a drill press, there is no shame in using a sharp small bit to make the initial hole - in fact, there is no shame in using a spotting drill bit to get the hole started in the correct location (can you tell that I have a Harbor Freight drill press?).

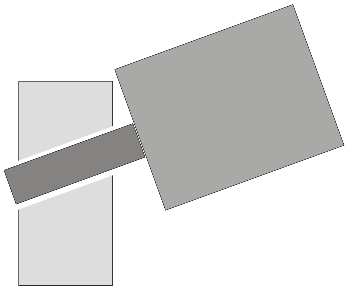


Figure VII. 2. Drilling error

So, the first battle is construction. Anywhere I talk about drillling a hole, think about the drawing above. If there is a rotating surface involved (the center and corners of the 4-station head, the front ends of the contact wheels), be afraid - very afraid. Make sure that it is square. I can guarantee you if you don't, you will wish you had!

If you've done this, you can reasonably be sure that the rotational surface is at right angles to the mount and therefore, at right angle to the arm. Since we are talking about the three items - drive, tracking and grind head, we can forget about the motor and the drive wheel -- ah -- we haven't welded that down yet, have we? So cancel that.

What we need to do is transition from "A" to "C". If we have made and/or purchased decent wheels and were anal about the drilling, we ought to be at "B_2". We now need to move onto to "C".

The first step in doing so is to have a decent measuring stick - NO! not the beaten up old tape measure with the wonky end. Spring for a decent steel ruler (maybe two) with measurements in the 100th of an inch (like Enco part # 319-9569). Now, mark the center of the wheels (using whatever you think is the most commonly used grind head - in my case, the 4-station head) with a sharp pencil. Okay, you're back from looking for a pencil sharpener and you used the stone grinder - as long as it is sharp, you're ok. Mark those wheels.

Figure VII. 3. Motor Alignment

The biggest problem in accurate measurement is knowing where the base line is and we've got that covered - it's the surface of the arm closest to the belt. So, mock up the relationships of the parts - I recommend using the most sophisticated system you have -- or a coffee cup and a wood wedge and some reasonably straight pieces of material (see below). The point is, that when an extra length arm is extended back through the socket and pressed to the left inner surface of the socket by the lock bolt, you can simultaneously measure the distance from the center of the drive wheel to the center of the grind head or arm (see Figure VII.3).

In that picture, the motor was already welded and the socket was being adjusted. In your case, it's the opposite - the socket is already welded and the motor is floating. The principle is the same. Run a straight piece of material from the drive wheel forward to the end of the arm (the longer, the better). Make sure the material contacts the front and back of the drive wheel. Measure the distance at right angles from the material (red in the diagram) to the arm. Then measure the distance from the arm in front of the socket to the same surface of the material. The distances should be equal. If not, swivel the motor and/or move it left to right on the base plate until they are equal (see Figure VII.4). Remember, you will be living with the results for years to come, so take your time and be precise.

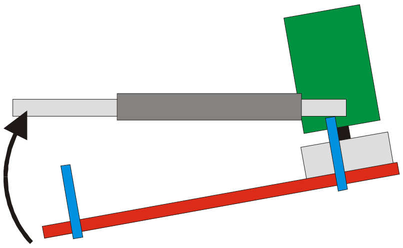


Figure VII. 4. Motor adjustment

Once you're satisfied, scribe a line along the motor mount so you know exactly what angle it makes to the base plate (hopefully 90^o). If you can, vise-gripping a bar of steel to the base plate such that the bar kisses the side of the motor mount is a good idea. If you have been rigorous about controlling the offsets on the various arms and heads, there is really only one more thing to do - center the drive wheel.

Put the grind head you plan on using the most in the socket with the arm extending back over the motor. Lock it in place with the lock bolt. Measure the distance from the reference surface on the arm to the center of the contact wheel or idler on the head. Then measure from the reference surface to the center of the drive wheel. Both measurements, of course, are made at right angle to the reference surface (now, where is that square?). Move the motor left or right until the measurement at the motor matches the one at the head. Tack weld the motor mounts to the base plate. You can fine tune the centering of the drive wheel by moving it in or out on the motor shaft if the belt seems to hang off the drive wheel inside or outside respectively but hopefully, this will not be needed.

It's now time for the tracking arm. Bolt the arm to the tracking tab with a 1/2x13 bolt and a Nylock nut. A thin copper washer between the arm and the tab is a good idea. You want it as tight as possible while still being able to move the arm in an arc. Lay the arm down on top of the socket and place the tracking bar on the boss. You already know what the distance is between the reference surface on the grinding head arm to the center of the drive wheels and the contact wheels and/or idlers. Our goal is to put the center of the tracking wheel on a line connecting the centers of those other wheels (see "A" in the diagram on the facing page).

There are two approaches you can take: you can think like a machinist or you can think like a smith. As a machinist, we can simply calculate the distance from the left surface of the tracking arm to the center of the hole in the boss welded to the tracking arm. The numbers are laid out in as "B" in Figure VII.5. We know that the distance from the grind arm reference surface to the center of the drive wheel is 2.30". We also know that the wall thickness of the socket is 0.0625" and that the tracking arm's left surface lies over the outer surface of the socket's left side (because the tracking tab is welded to that side and the tracking arm is bolted to the tab - and yes, I'm ignoring the thin copper washer between the tab and the arm). The result is that the left side of the tracking arm is 2.24" from the center line.

Now, the tracking wheel is 2.5" wide, so the center is 1.25" from the right side of the wheel. Allow 0.1" for a washer and 0.5" to the center of the tracking bar. This means that the pivot hole in the tracking bar has to lie 0.39" (2.24 - 1.85) from the left side of the tracking bar. Measure, mark and drill. You can see why we didn't want to drill that hole way back when we welded the boss on.

Now, as a smith, there is a simpler way to get to the same result. Lay something straight from the center mark on the

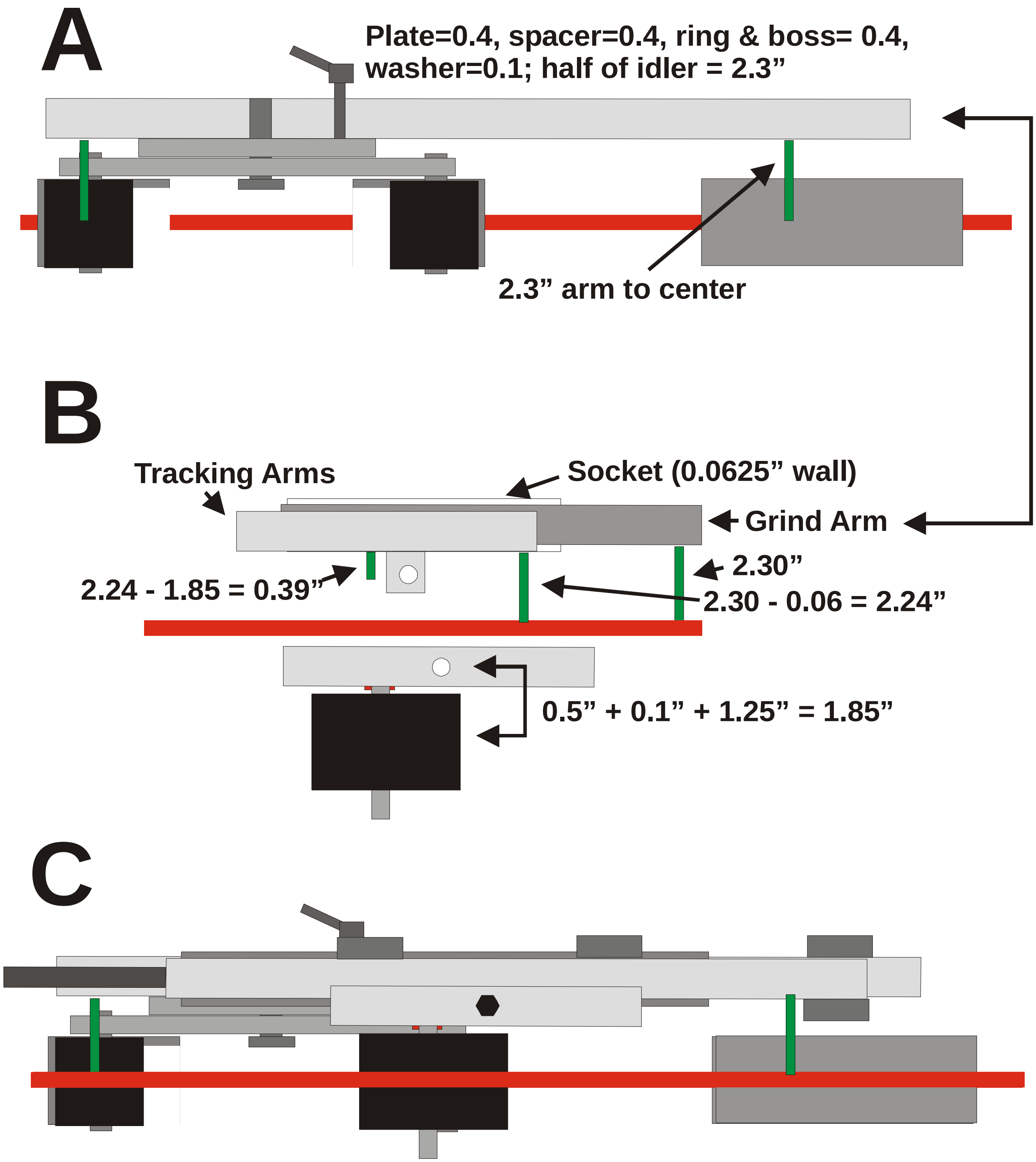


Figure VII. 5. Track bar Alignment

drive wheel to the center mark on the contact wheel or idler such that an edge is right on the center marks. Use that edge as the reference. While keeping the tracking bar parallel to the tracking arm, move the bar left or right until the center of the tracking wheel is on the line. You can now mark the location of the hole in the boss on the tracking arm by using a transfer punch in the pivot hole in the center of the tracking bar. If you want to hedge your bets (and you should), move the bar another 1/16 to 1/8" towards the tracking arm before marking. Drill the hole and lock the bar to the arm with a 3/8x16 bolt and a Nylock nut. Remember the copper washer in the interface. You can now check the location of the center of the tracking wheel to the reference line. If you did hedge your bets, you can shim the tracking wheel with a washer or two so that its center falls back on the line. This method may be more appealing than the machinist approach and either method is a lot easier than removing 3" or so of steel from the left side of the tracking bar to move the wheel towards the arm because the pivot hole in the boss was drilled in the wrong place..

You can now install the spring and adjust spring tension as described earlier. If all seems well, remove the motor, finish welding the motor mounts, unbolt everything you can, and get a coat of paint on your baby. With luck, you will not have the unit apart for years to come, so now is the time to stop rust.

VIII. Final Assembly

Once the paint has dried (mine has fingerprints in it since I'm way too impatient), bolt the tracking bar to the tracking arm, the tracking arm to the socket, the motor to its mounts, and dig the VFD out of its shipping container. It's time to hook up the electrical connections and bring the grinder to life.

You will probably need a source of 220-240 V AC single-phase current. There are VFDs that use 110-120 V but the draw will be correspondingly higher. Normally, 220 is the ticket. It is well beyond the scope of this manual to tell you how to run a 220 V line and install an outlet, so we'll assume it's done. I use 20 amp outlets (those are the ones with one of the prongs at a right-angle to the usual 110 V setup) talking through a 10-2 Romex line. So, assume you have an outlet and a matching plug. You need to run a three-connector cable (ground, black, and white) to the VFD. My local ACE stocks 12-gage AWG cable (7/16" diameter, each line being 5/32"). Since 12-gage handles 20 amps and the motor (1.5 to 2 HP) will draw around 6 amps, we should be good. If you've got questions, talk to an electrican.

The input cable (3 wires) runs to the VFD and four lines (L1, L2, L3 and ground) run to the motor. You want to seal the system as tight as you can to prevent dust from killing the electronics. So, both input and output cables need to be well sealed when they contact the VFD. Since I needed 4 lines from the VFD to the motor and the space in the conduit was at a premium, I stripped the external sheath of the cable mentioned above from twice the length from VFD to the motor. I then used 2 black wires with one marked so I knew which was which.

VFDs are built for industrial use. The cable ports (at least on the unit I have) are two 1" diameter holes in the bottom of the enclosure. That's a touch tight for 3/4" electrical conduit and connectors and way loose for 1/2" ones. The motor's port was sized for 3/4" electricals. I decided to use an intermediate chamber between the input cable and the VFD. The input cable was secured with the typical metal cable clamp in the side wall of that chamber (a fence charger housing designed to be weather proof). The lines were routed through a 220 V switch located on the front wall and then run up into the VFD through a specially built conduit connector that locks the VFD and the chamber together. The output lines ran back into the chamber through the other port in the VFD and out the rear wall of the chamber through a Carlon Carflex connector. These connector are designed to be watertight, so they should be sufficient. They are plastic, seal with 'O' rings, and are

Figure VIII. 1. Carflex connector

available at Lowes (if not other big-box stores). See the Figure VIII. 1 for a search image - I found them in an obscure box in the conduit section of my local Lowes. A second connector was located on the motor's port and a flex cable that goes with the connectors ran between the two. The cable is a bit more flexible than armored cable and simply pushes onto the ends of the connectors (a heat gun helps).

Okay - what's with the chamber? I live out in the country in lighting-prone Florida. I wanted to add a bit of insurance that if there was a significant surge in the line, it would not blow out the VFD, so I added a switch that effectively cuts both hot lines when it is off. I could have just added a third Carflex connector on the input port, sealed it with heat shrink tubing and/or silicone caulk, and then unplug the unit when not in use. You do whatever seems best to you.

If you have not played with a VFD before, there are some rather opaque bits of information in the manual. Mind you, my experience with VFDs is limited - in fact, as the statisticians say, "the N is 1", that is, I can speak only of the single TB Wood's SE1 Microdrive I bought, but I suspect what I found is industry-wide. The units are not intended for consumer use. The writers of the manual assume that the reader is an electrican trained in heating and cooling systems - where most VFDs are used. Further, the units are typically controlled digitally by a computer while all we are interested in is the front panel or keypad controls. And finally, the various settings are controlled by input from the key panel as well as by jumpers installed on a circuit board. The odds are extremely good that the settings that were set in the factory will not be the ones you need.

All of this sounds bad but it is actually fairly straightforward once you wrap your mind around it. Using the SE1 as an example, there are 14 parameters set from the key panel. The panel consists of 5 keys - [Start], [Stop], [Up], [Down], and [Navigate]. When the unit is powered, holding down the [Navigate] key for a second or so will shift the system into the menu mode. In that mode, the [Up] and [Down] keys allow you to scroll through 14 parameters. When the desired parameter number is displayed, hit the [Navigate] key to access the setting and then use the [Up] and [Down] keys to adjust the setting.

Most of the settings are controlled by the characteristics of the input current and the motor. The values listed below are those used on the prototype system that were at variance with the default settings. For the SE1:

P-01	maximum motor speed	3420 rpm*
P-02	minimum motor speed	250 rpm
P-03	acceleration ramp time	2 sec.
P-04	deceleration ramp time	5 sec.
P-05	stop mode	coast-to-stop
P-08	motor rated current	1.15*
P-09	motor rated frequency	60 Hz*
P-10	motor rated speed	3420 rpm*
P-12	Keypad mode	1 (on)**
P-14	Activate extended menu	101

* from the specification plate on the motor

**the default is '0', that is, the keypad is off line. The implication is that if you are just messing with the VFD before setting the parameters, you might end up thinking the unit is dead!

Assuming that the value '101' is entered for P-14, you can make your way to the P-19. When it is set to '0' and "digital input 1" is closed, the system ought to run. Soooo.... what is "digital input 1" and how do you "close" it? And why has nothing happened yet?

It turns out that there is a set of contacts (little holes with screws over them) inside the enclosure. They kind of look like Figure VIII.2 which was reproduced from the manual. Take a good look at Screw # 2 (=Digital I/P 1). The schematic shows that the default condition is 'open', that is the switch symbol is not closed. So to close that "switch", all we need to do is run a wire from the #1 screw (power source) to the #2 screw. When that is done and P-19 is set accordingly, the VFD finally wakes up and runs.

Complex? Yes. Impossible? No. Just don't lose the manual!.

Once it is programmed, the VFD is easy to use. Punch the [Start] key and it runs the motor up to the last set speed taking the amount of time specified by P-03. Punch the [Stop] key and the motor spins to a halt. In you set the ramp times too low, you are putting a lot of strain on the components, so something like 2 up and 5 down seem reasonable. If you want the motor to speed up, hold down the [Up] key. The system will initially increase by a few rpm's and then (if you continue to hold the key down) by hundreds and then thousands until it hits the maximum allowed (P-01). The [Down] key does exactly the same thing but in reverse. Whatever speed you last used will be there when you come back.

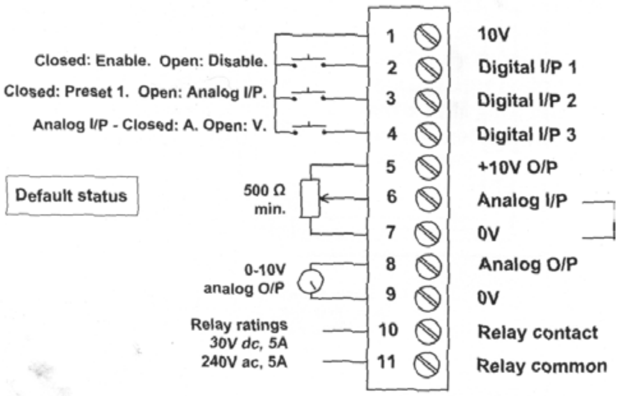


Figure VIII. 2. SE1 connector diagram

IX. Accessories

One of the great things about building your own grinder is that you'll be comfortable enough to build the accessories that greatly incrase the overall cost of a commercial system. Moreover, you may end up inventing an accessory to make your work faster, more accurate and more pleasant - or -- maybe just come up with an excuse to burn some time in the shop. The most common and in many ways, the most useful accessory is the....

Steady Rest: One of the simplest but often critically useful accessory to a grinder is the steady rest (see diagram on the next page). The real question is why are they so expensive to buy commercially? A rest is often used in plunge cutting (the transition from a knife bevel to the ricasso) and just when you need better control.

A versatile unit can be made by first making a slotted arm - typically 6" to 12" of 1" x 0.5" bar with a 3/8" wide slot cut down the center. If you find cutting slots a problem, buy some beer for someone with a mill or make a series of the arms with holes in the right position for each of the grind heads you use. Alternatively, you could bolt several sections of bar together in different configurations to get what you need. In any event, the end of the arm (or last section) terminates in a cube of steel that is welded to the arm. A 3/4" hole is drilled through the block at right angles to the slot and a 3/8x16 tapped hole is made on one of the open faces (there are three - top, front and bottom with the front being preferred - at least by me). That cube is the first elbow and the arm is the "vertical" arm.

The "horizontal" arm is made from 6" or so of 3/4" round stock and it terminates in another elbow - just like the first one. Again, you can put the lock bolt on any open surface but, as before, the one to the front is the most convenient.

For some of the contact wheels, a secondary arm may be needed. It is simply a 4 to 5" bar (1" x 0.5") with a 3/8" hole near each end. See Figure XI.1 for the real thing and Figure XI.2 for a diagram.

Finally, a stage or rest is needed. It is a 5 to 8" piece of 5/8" round stock terminating in a flat plate of steel welded at right angles to the round stock. The size of that plate varies depending on what you are doing. Typically, there may be one set of arms and many rests - some small, some long, some with pins and/or pin holes, etc. If you are thinking about the blade holder described here, a quick stage can be made from 24" of 2" x 2' angle iron and a 3/4" piece of round stock welded to one leg "inside" the angle.


Figure XI . 1. The steady rest

Using the rest is fairly obvious if somewhat of a pain initially (talk about one-armed paper hangers!). You bolt the slotted arm to the side of the grind arm using the 3/8x16 holes specified. You try to guess at the angle and the "correct" position of the slot, but you'll be back in a few seconds. Slip the horizontal arm into the 1st angle and twist it to have the hole in the 2nd elbow point up. Move it left to right to get the hole close to the center of the contact wheel or platen. Snug up the bolt on the 1st elbow. Slide the stage into the 2nd elbow. Note that it is not at the correct angle to the belt. Free up the 1st elbow and twist the horizontal arm. Find out there isn't enough room. Free up the slotted arm to get more room. Drop the wrench in the bucket of water in from of the grinder....You get the picture. Eventually, the stage will be close to the belt, at the correct angle, and at the right level. You can finally start grinding.

I have found that 3/8x16 cap screws work well as the lock bolts. There is less of a tendency for the tool to slide off the bolt and it is easier to tighten them down adequately. A box of 100 from Enco is $12.50. You can also fabricate toggle bolts -- described in a couple of pages from here.

An extremely versatile variant is to weld the block on the slot arm at 90° to that shown in Figure XI.1 such that the hole runs front to back. Make two arms like the horizontal one shown in Figure XI.1. One of the arms inserts into the slot arm block and moves in and out and the block on that arm is oriented so that the hole looks left to right. The second arm runs in that hole and the hole in its block looks up and down. The stage runs in that block. The end result is shown in Figure XI.3. As the weight of the arms and the stages increase, it becomes increasing difficult to lock the slot arm in position. If you make this version of the steady rest, you might want to drill a 3/8" hole in the slot arm and tack weld a block to the backside in a strategic position to keep the arm from rotating (see Figure XI.3 to see an example of this). If you do this, take into account the length of the 3/4" round stock length on your stages so that the

Steady Rest Diagram

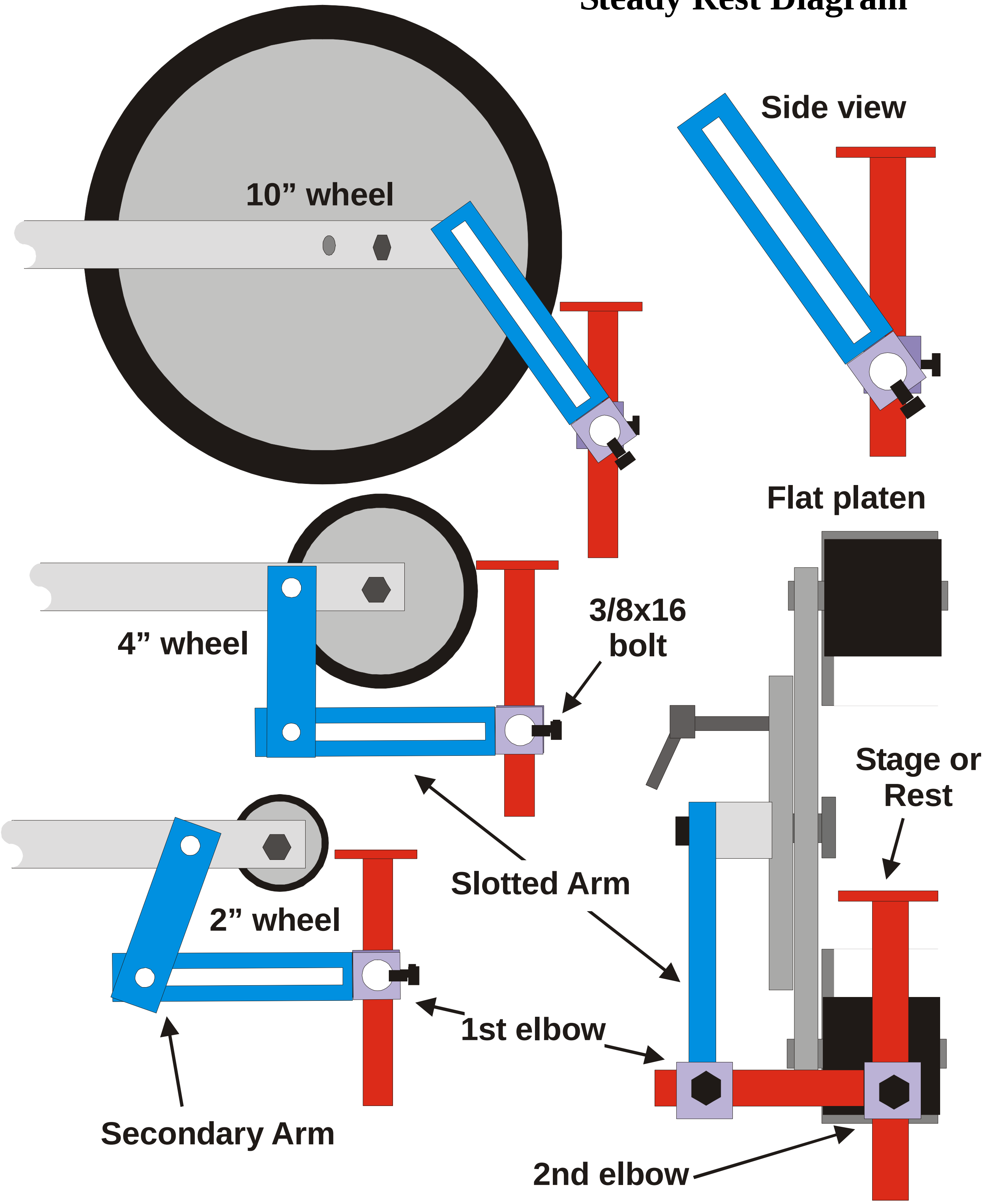


Figure XI. 2. Steady Rest diagram

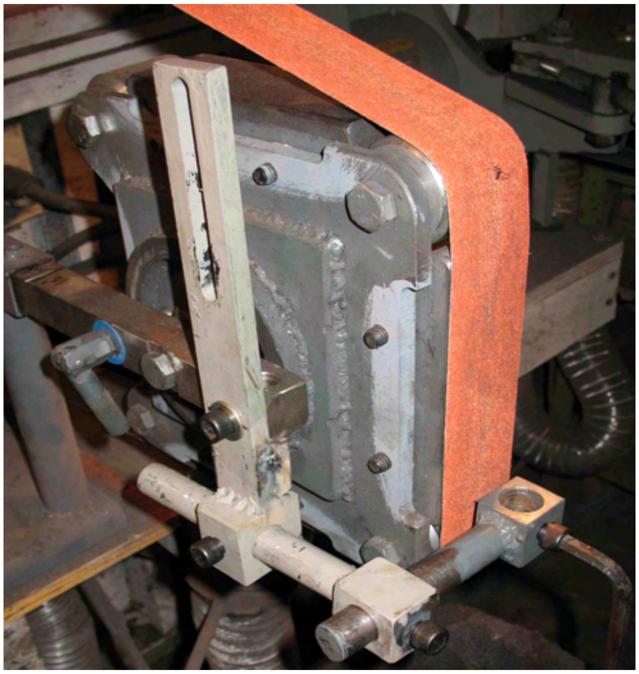


Figure XI. 3. Three-arm Steady Rest

stage surface is positioned on the belt where you would like it to be. In the example shown, the slot is actually not needed, so maybe you can drink the beer instead of using it as a bribe for your machinst friend. Incidentally, I have never seen a commercial unit approach this level of convenience and as far as I know, it's another IronFlower innovation.

Blade Holder Grinding Jig: Where the three-arm variant of the steady rest shines is when you use a jig to position blades for grinding. As blades get small (for instance, when making folders) and/or when the blade design requires a plunge cut, it becomes progressively more difficult to get acceptable results when free-hand grinding.

If somehow you could control the angle of attack of the blade to the belt, you can control the bevel. If the angle the long axis of the blade makes to the belt edge is also controlled, then the angle the plunge cut makes to the blade will also be under control. It would also be especially sweet if whatever mechanism is used allow you to quickly switch from one side of the blade to the other. Well -- it is do-able. The details of the design are given in Figure XI.4 and photographs of a unit are given in Figures XI.5 to 7.

The idea is really simple - first hinge a piece of angle iron to a slab of steel that will be the base of the jig. In the example here, 4” of scrap pipe (ID ~ 3/8”) was centered on and welded to a 6” piece of bed rail (Figure XI.6). Two 1” sections of the same pipe were welded to a 6” piece of 2” x 3/8” plate such that when a 6” piece of round stock (actually just a huge nail from the scrap heap that happened to sleeve into the pipe) was run through the pipe sections, a hinge was formed. Okay - I could have just used a steel commercial hinge, but that would have meant a trip to the hardware store.

Next, a 6” long piece of 1/8” x 1/2” stock was welded to the front lower edge of the bed rail and a 6” piece of 1/8” x 1.25” was welded to the 1/2” piece to form a slot. A tab (~ 3” x 2” x 1/8” was welded to the underside of the bed rail. A 1/4”x20 hole was drilled and tapped in that tab. A piece of all-thread was bent into an ‘L’ shape and it and a lock nut was threaded into the hole. What we now have is a shoe that can slide back and forth on a long stage sitting in front of the belt. The stage needs to be at right angles to the face and to the edge of the belt, hence why all those arms are nice and why locking the slot arm to the grind arm is so critical. The bevel angle is controlled by the ‘L’ bolt -- screw it in and the front face of the jig tilts towards the belt surface. Adjust the bolt until you think the angle is correct and then lock the adjustment with the lock nut.

The last item is something to actually hold the blade. I used a piece of 1.5” wide x 1/8” scrap (the thickness was actually 0.110”). The concept is that whatever you use, it ought to fit into the slot snuggly. You can always use a slightly thicker 1/2” strip at the bottom of the slot to widen the slot if you can to use 1/8” material for the holder. If the holder is too loose in the slot, you can drill and tap a hole in the back plane and use a bolt to snug the holder in place.

A short section of the holder material was welded on one end and it was drilled and tapped for 8x32 cap screws. A “cover” was fabricated such that when the cap screws are tightened, tang of a blade is trapped (Figure XI.7). There is no real need for the secondary short piece - just drill and tap a couple of holes in the holder’s end and make the cover plate.

To use the jig, square up the rest as described above, lock the blade at the desired plunge cut angle in the holder and set the bevel angle. Fire up the grinder and looking down along the belt surface, start your plunge cut with the edge of the belt at the desired location. Move the jig back and forth on the stage to grind the bevel. Whenever you feel like it, pop the holder out of the slot, flip it around, press it home and grind the other side. It really does work!

The dimensions given here are based on my scrap pile, so feel free to improvise. The offset in the holder was made to accommodate folder blades as where the overall dimensions. If you are working on larger blades, you will probably want to scale up the dimensions. As the weight of long stages and larger jigs goes up, that tack welded block on the slot arm of the steady rest becomes more important.

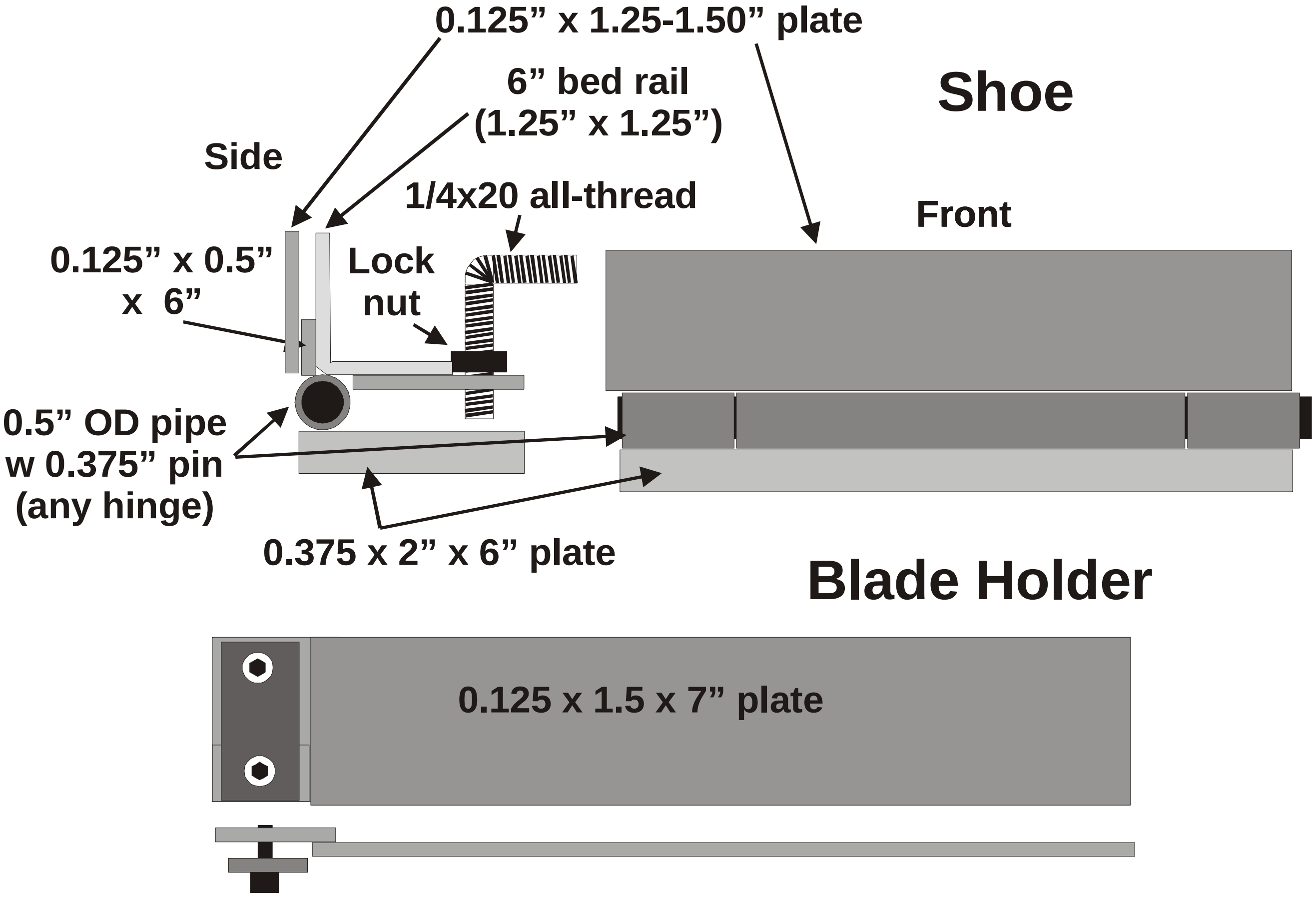


Figure XI. 4. Blade Holder Grinding Jig

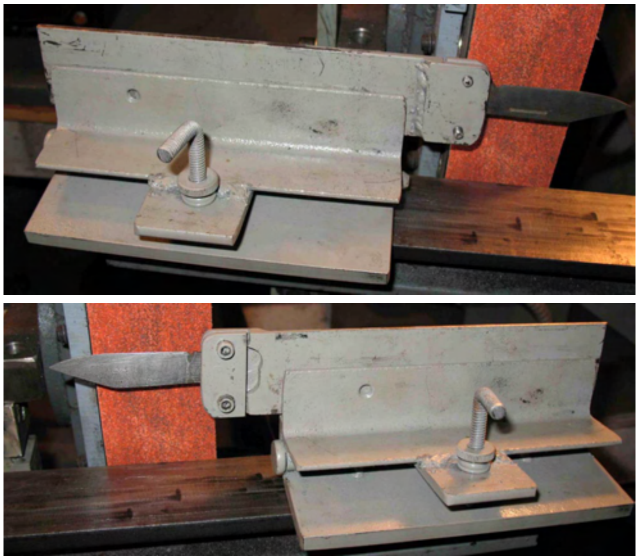


Figure XI. 5. Blade Holder on the rest

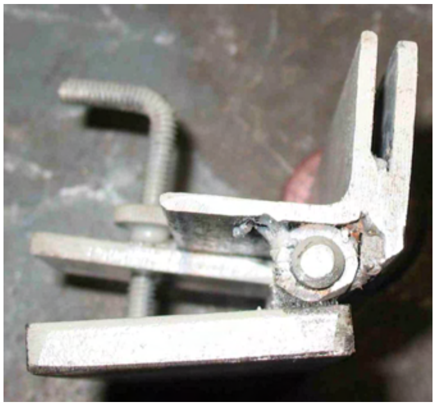


Figure XI. 6. Blade Holder end on

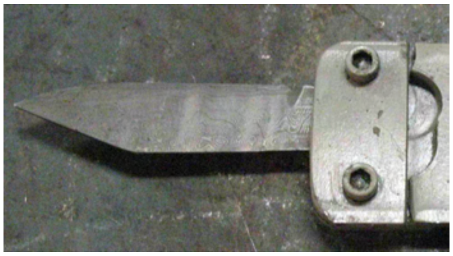


Figure XI. 7. Blade Holder detail

Spark Arrestors: One of the less charming aspects of a grinder is that the sparks from the grinding don't all shoot down off the front of the belt. Some travel all the way around and fly off from the tracking wheel. Even with safety glasses, having your facial hair light off can be bothersome. A simple solution is shown in Figure XI.8. Run a bolt from the top of the tracking bracket (now you know why we drilled that hole) so that it runs over the top of the belt but with sufficient clearance to still get a belt on the wheel. Lock a piece of sheet metal to the bolt and extending in your direction. I found that a scrap piece of 1/2" square tubing made a convenient "sock" to slip over the belt but a piece of pipe with an appropriate inner diameter would do just as well. Secure it to the bolt with a wing nut and angle it close to the belt. If you want to go elaborate, you can add a clamp system to hold scrap pieces of old belts to act as a brush (visible in Figure XI.3 but not on my grinder anymore). With the arrestor, the spark problem pretty much goes away.

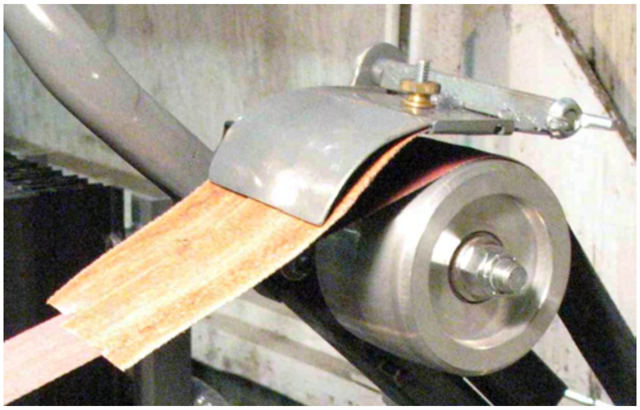


Figure XI . 8. The spark arrestor

Toggle Lock Bolts: You can always use a wrench to tighten bolts and you can always misplace the wrench or drop it on the floor or whatever. A much nicer solution is shown in Figure XI. 9. Forge a piece of scrap into a "U" with the legs being about 3/4" long and the gap being 3/8" (using a scrap of 3/8" plate as a mandrel during the bending pretty well takes care of gap. Square up the end and weld it to a 1" x 3/8x16 bolt. Find a few inches of 1/2" round stock and grind a tenon on one end (~ 3/4" long and 3/8" thick). If you have knurling capacity, use it. Finally slip the tenon into the gap, drill a 3/16" hole (be careful about that 90^o thing again), and set a rivet. Make two of these - one to lock the arm in place and one to lock the 4-station head to its arm. Spending the time to make these will pay off in the long run. Of course, if you have a dead machinist vise in the scrap heap, you might be able to "re-purpose" some of the hardware - it all depends on the threading. There are a couple of other variants shown in Figure XI.9 - however you fabricate it, having the wrench right there all the time is nice.

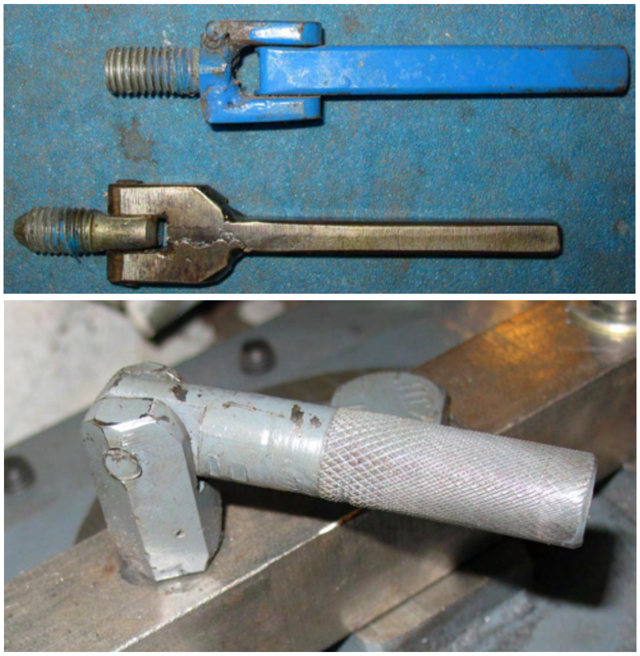


Figure XI . 9. Toggle Lock Bolt

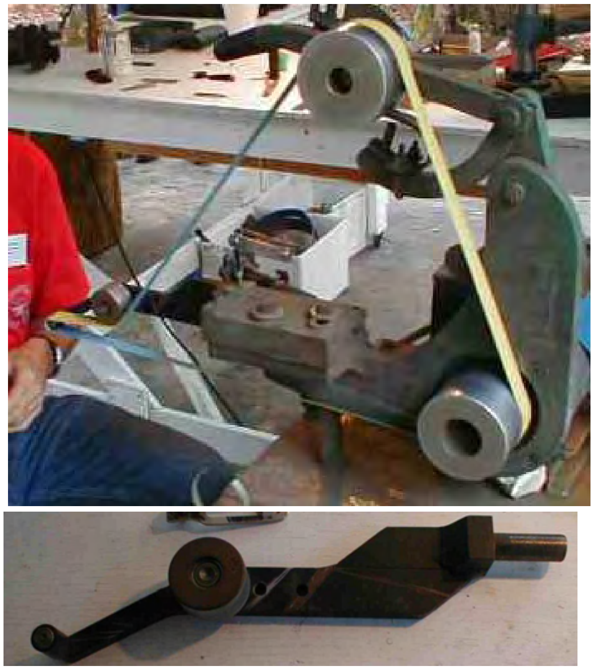


Figure XI . 10. BII "squeezer"

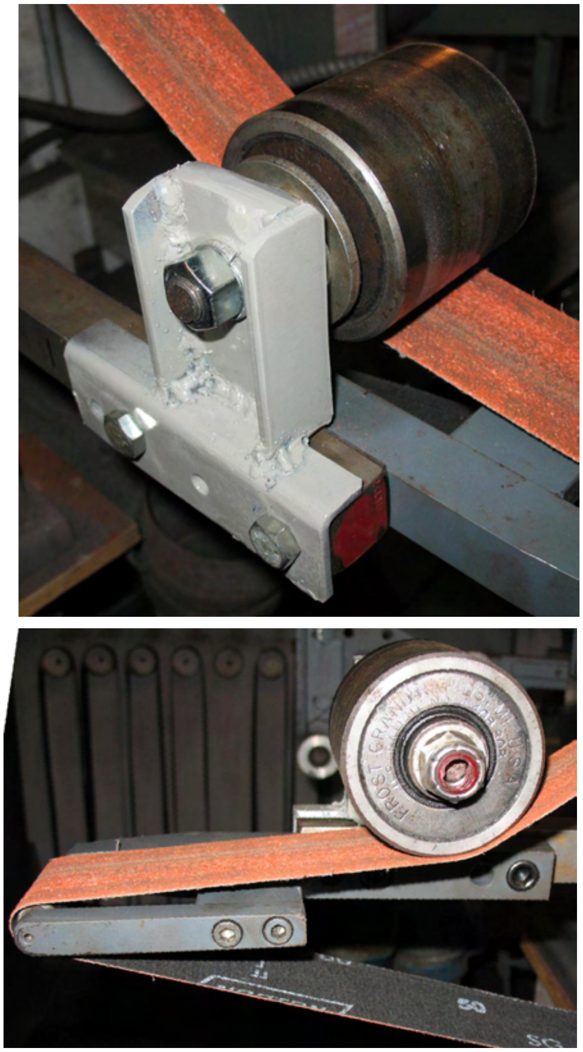


Figure XI . 11. Belt "squeezer"

Belt Squeezers: The rationale for the fork wheel (0.5" diameter) is to grind small radius notches - like for integral guards on full tang blades. One way to minimize the spread of the belt as it runs from the tracking wheel, over the small contact wheel and back to the drive wheel is to "pinch" the belt by running another idler wheel just above the belt. I first saw this idea during a demonstration by Ed Halligan (designer of the K.I.S.S. knife) (Figure XI.4). His unit was installed on a Bader BII. It isn't that hard to use the two "extra" tapped holes on the small contact wheel arm, some scrap steel, and an old idler wheel to come close to the same utility (Figure XI.5)

Stag Holders: If you build hidden tang knives and use crown stag for handles, you know just how much fun it is to grind the handle so that it is perfectly flat and touches the back of the guard all the way around. Well - there is a way to make that a bit easier - a special stage for the steady rest, a shoe to hold the stag, and an alignment jig that is a mock-up of the blade and guard. Start with making a mock-up of the tang to be (I'll let you figure out how to make the cavity in the stag) (Figure XI.12). The pseudo-tang needs to protrude an inch or so from the stag. The second item is the alignment jig (Figure XI.13) which is made from a couple of 3" to 4" long pieces of 1" x 1" x 3/16" (or whatever) angle iron. A pair of 1/4x20 tapped holes and corresponding 1/4" holes allow a couple of bolts to lock the jig onto the pseudo-tang. Just adjust the angle of the front surface of the jig to be parallel to where you want the guard to eventually be while the back edge of one of the pieces of angle iron contact the stag.

The next step is to somehow lock the stag with jig in place to the grinder. That's done with the shoe (Figure XI.14). The shoe consists of two parts, a stage and a holder. The stage is a steady rest stage with a 3/8" x 1/4" slot milled into the surface (or just a couple of pieces of scrap 1/4" bar welded 3/8" apart on some more scrap). The holder is a foot with a bar corresponding to the slot on the bottom surface and a tab welded to the top surface. The tab has a pivot hole (3/8") and a tapped lock hole (1/4x20). There is a "T" shaped upper section. The stem of the "T" will have a pivot hole and must be long enough that when a bolt is run through the pivot holes, the top of the "T" clears the top of the bottom tab. In the unit shown above, the stem was a section of 2" round stock that was lying in the scrap box - a rectangular bar would have done just as well. There are a pair of 1/4" holes drilled into the ends of the "T"s crossbar which is

Figure XI . 12. The mock tang

Figure XI . 13. Alignment jig

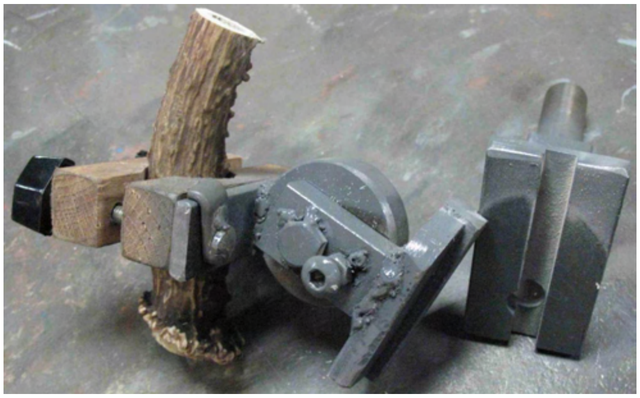


Figure XI . 14. The shoe

Figure XI . 15. Aligning the holder to the belt

about 4” long. The holder is completed by a pair of oak “V” blocks (1” x 1” x ~4”) with holes to match the 1/4” holes in the crossbar. A pair of wing nuts complete the system (Figs. XI.15 & XI.17).

The stag is locked into the holder using the wing nuts. Depending on the shape of the handle, there may eventually be a family of blocks - it all depends on the spurs and shapes of the stag. Once the handle is locked in the holder, it is time to lock the holder to the grinder.

The steady rest is placed on the grinding arm with the stage of the shoe in place. The various angles are adjusted until the front surface of the alignment jig is flat to the belt (Fig. XI.15 & 16). The shoe is lifted off the stage, the alignment jig is pulled out of the handle, and the shoe replaced on the stage. All that is left is to fire up the grinder and carefully slide the shoe forward, planing off the handle until the end is uniformly flat and ready to be mated to the actual knife & guard.

Figure XI . 16. Adjustment

Figure XI . 17. Grinding the interface

XII. Cost Comparisons

There are two commercial machines comparable to the unit described here, the Bader BIII and the KMG Grinder. All prices cited here are from the respective websites as of June 2010.

Typically, dealers (including buying from Bader directly) offer packages consisting of the base machine, a contact wheel and an arm, and a fork wheel with a small diameter contact wheel. As an example, Texas Knife Supply (texasknife.com) offers a Bader BIII Grinder complete with 1-1/2 HP, 220 volt, 7 amps, variable speed, DC motor with / Nema 12 control, HD arm, plain or serrated rubber 8" x 2" wheel with bearing hub and flanges, adapter arm with fork tip and your choice of 1/2", 5/8", 3/4", or 1" diameter x 2" wide fork wheel for $2,500.00. Another dealer (hawkinsknifemakingsupplies.com) offers a Bader III BENCH MODEL; 2 HP 220 volt digital AC VFD & inverter rated motor, HD arm, serrated rubber; 8" x 2" wheel with bearing hub and flanges, Adapter arm with Fork tip and 1/2", 3/4", or 1" diameter x 2" wide wheel for $2340.00.

KMG (beaumontmetalworks.com) divides the machine from the motor. Their KMG-8 package is comparable to the above examples with the exception of no fork arm but they add a work rest. Cost is $920. A comparable motor (1.5 to 2 HP, VFD) is $814, for a combined cost of $1734. Toss in a fork arm and subtract the work rest and the cost is near $1850.

For most users, you will want the flat platen system ($176 for 4 stations) versus buying four 2" wide platen units with two 2 x 2 wheels (from Hawkins) for $127.00 each (a total of $508). Work rests seem to run about $50 to $60. Making them yourself will cost a few bucks, so let's total up the damages (comparable to the packages listed above). If you are building the IronFlower Grinder, you will need a motor ($90), a VFD ($275), a 6" drive wheel ($132) and a tracking wheel ($58). To make it comparable to those listed above, you need to add a 8" x 2" contact wheel ($233) and a 0.5" contact wheel ($50). You can also expect to drop another $30 to $40 or so for the miscellaneous electrical parts (wire, Carflex, plug, etc.) and hardware. The total is now running about $870. How much steel can you buy for $1000 to $1600? How much is your time worth? You decide.

Now is there a way to even cut the costs more? Obviously, using scrap steel would help but the costs in that area aren't that high anyway. Where there are potential savings are in the wheels.

From the Surplus Center, they sell a 10" x 1.75" semi-pneumatic wheel (# 1-2853) for $6.95. The specs are "New, semi-pneumatic rubber tire over painted steel hub; Ribbed tread pattern; Symmetric hub; Ball bearings: 9-3/4" tire O.D.; 1-3/4" tire width; 1/2" bore; 2" hub width; Shpg. 5 lb.". Quarter inch down on the width but $287 down on price. Might be worth an experiment, no?

As for tracking wheels, what about a 3" caster wheel - New, hard rubber caster wheel with roller bearing hub: Outside Diameter 3"; Tread Width 1-7/16"; Bearing Size 3/4" ID x 1-3/16" wide; Hub width 1-5/8"; Load Capacity 250 lbs.; . (#1-3172) at $2.49. Gang two together to get a 3" wide wheel. There is always Item# 1-1908 - $2.99 for 4" x 1 1/4" Polyurethane conveyor roller ; 21/32" ID ball bearing; Capacity 500 lbs - buy two and turn down the outer edges to get a crowned tracking wheel and save about $50.00.

Idlers are not so easy but at one time, the Surplus Center stocked steel roller bearing assemblies (Frost, Inc. Part #0405100) - approximately 2" diameter, 3" long, 1/2" bore with bearings (see Figure XI.11 for what they look like). Does that sound like an idler wheel? They actually work and they are about $40 less per wheel but the source I used has dried up - prehaps you'll have better luck. The moral is to keep your eyes open in preference to your checkbook.

XIII. Mechanical or Pulley Systems:

The most obvious way to get variable speeds is the same one used on drill presses, lathes, mills, etc. - a set of pulleys and a belt that is shifted from one pair of pulleys to another pair. The upside is (potentially) low cost while the downside is complexity in building, limited number of speeds, and inconvenience when shifting between speeds.

What follows is a treatise on the design of a four speed system - a system I was going to build before the lights came on. It is presented here as a potential alternative and also as a source of information for designing a pulley system.

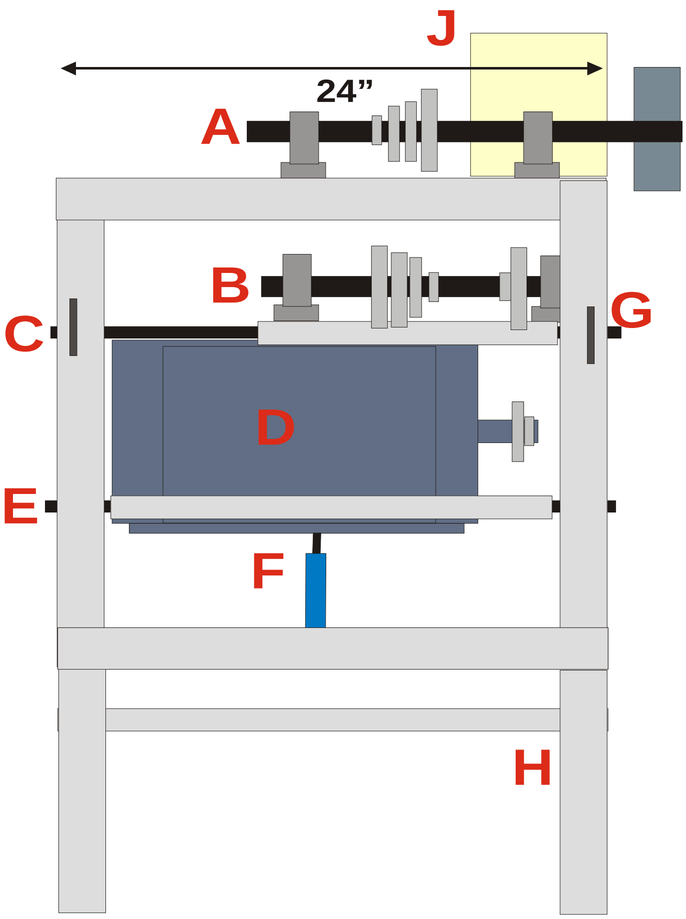
Initially, I was not convinced that infinite speeds are really needed. What is useful (based on my work), is a reasonably fast, hogging speed - not so fast as to fry belts and steel but fast enough to move the metal. I'm comfortable with the Bader BII and the 4" wheel which rolls over at 3613 sfm, so that's the first target. I have run a 6" wheel and it might be nice to have the 5419 sfm speed available, so that's the second. The 1.75" wheel turns at 1580 sfm which is slow enough not to burn up the 1/2" contact wheel, so that's the third. Finally, I might have a need for a really slow speed, something around 900 sfm, so it begins to look like a four-speed unit ought to do.

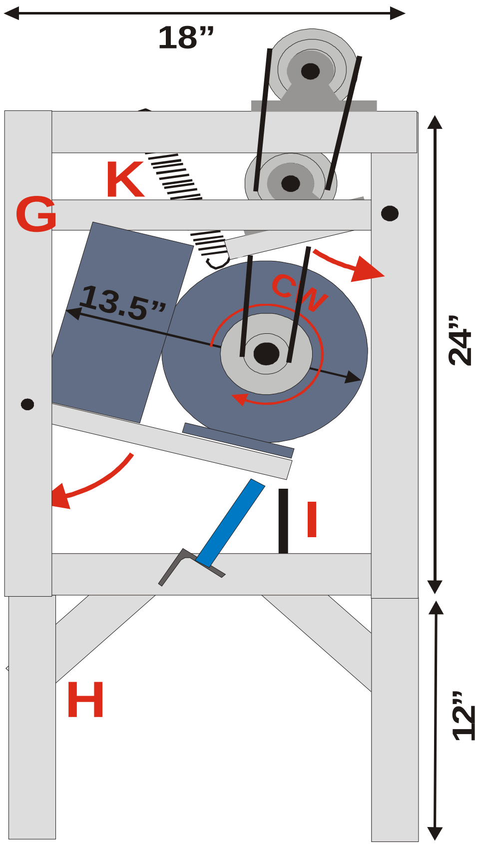
Given that, I think that something conforming to Figure 1 ought to do the trick. It has a drive shaft on the deck (two pillow blocks and a 7/8" shaft - to preserve compatibility with the Bader units), a jack shaft under the deck (basically the same specifications), and the motor on the bottom. The drive shaft (A) would have 4 pulleys and the drive wheel, the jack shaft (B) would have 4 pulleys aligned with those on the drive shaft and a single pulley aligned with the single pulley on the motor (D). Both the jack shaft and the motor would be on pivoting mounts (C & E respectively) so that the weight of the motor would tension both the motor-to-jack shaft and the jack shaft-to-drive shaft belts.

The frame would be of 2" x 1/8" angle iron, mitred, welded and gusseted (H). I anticipate making the frame in two sections with the upper section eventually encased in a light steel cover.

If I go with the pulley system, it will be sourced from the Surplus Center, so what follows is based on what they have available in their catalog. I can get the speed ranges I want from the pulleys listed in Table 1.

The resulting speeds are close to the desired speeds (84% to 100%). The problem is belt length - there is almost a 5" difference between the longest and the shortest belt when an optimal setup would have the same belt length for all speed settings.





Pulley Diameter		Speed	Bader	Relative	Belt Length
Jack	Drive	(sfm)	(sfm)	Speed	(inches)
1.8	7.0	895	--	---	17.1
1.8	4.7	1333	1580	0.84	14.4
2.8	2.8	3480	3613	0.96	13.2
2.8	1.8	5413	5419	1.00	12.5

Table 1: Characteristics of the pulley system

Now, you're probably asking - how do I know the lengths? The belt length can be estimated by knowing the diameters of the pulleys (D_1 & D_2) and the distance between their centers (L). The belt is in contact with the left half of the left pulley and the right half of the right pulley. It also has to run from the midpoint on the edge of each pulley to the other pulley on both sides of the pair (see Figure 2). So we need to calculate half the circumference of the left pulley (A), half the circumference of the right pulley (B), and the distance to connect the midpoints (C). For the moment, assume that the lowest speed pulleys are touching, so the distance between shaft centers is (D_1 & D_2) / 2 or 4.4".

Figure 2: Belt lengths

The formula for a circumference is πD where D is the diameter. So, A = πD_1 and B = πD. E is simply those diameters added together plus the gap between them, which is, of course, the distance between the shaft centers. D is half the difference of the diameters (either large-small or use the absolute value). To get C, we just apply the Pythagorean equation where C is the square root of the sum of the square of D and the square of E (that 7th grade algebra comes in handy from time to time). If we jam all of this together we get:

$$B = \pi \frac{D_1 + D_2}{2} + 2\sqrt{L^2 + \left(\frac{|D_1 - D_2|}{2}\right)^2}$$

Now if you have been following this, you ought to ask -- "**What's the 'L' in the equation?"** or maybe **"What the ...L! An equation?"**. "L" is the distance between the shaft centers.

So we have a way to calculate a belt length based on the pulley sizes and spacing. So what? Well - if we knew what B ought to be, and set D_1 to some arbitrary number, we can calculate what D_2 must be.

Looking back at Table 1, let's start with the first set of pulleys (the longest belt) and now assume we don't want them touching, so we set the separation to 10". We can then calculate the belt length, B, as 27.58" We know we want to preserve the ratio of 1.8 : 4.7 for the mid-low speed and if the drive pulley, was a 7" unit, then the jack pulley ought to be 2.68". The closest available pulley is 2.6" and the belt length would be 28.2", only 2% larger than B. In a similar manner, we can juggle the pulley sizes by what's actually available and what's close to the desired ratio and we get the results shown in Table 2.

Pulley Diameter		Speed	Belt Length	
Jack	Drive	(sfm)	Inches	Relative
1.8	7.0	895	27.58	1.00
2.6	7.0	1293	28.02	1.02
4.5	4.5	3480	27.07	0.98
5.5	3.5	5469	27.17	0.99

Table 2: Characteristics of the pulley system-revised

Not half bad - a belt length range of only 98% to 102% or less than an inch difference in belt lengths over the full speed range. It also turns out that the inter-shaft distance has little impact on this result, so it can be set to any convenient value when building the system.

Now was all of this worth it? Compared to having three belts flopping while one works, I think so. The final layout is shown in Figure 3 and projected cost (10 pulleys, 4 pillow blocks, 2 shafts) is about $120.

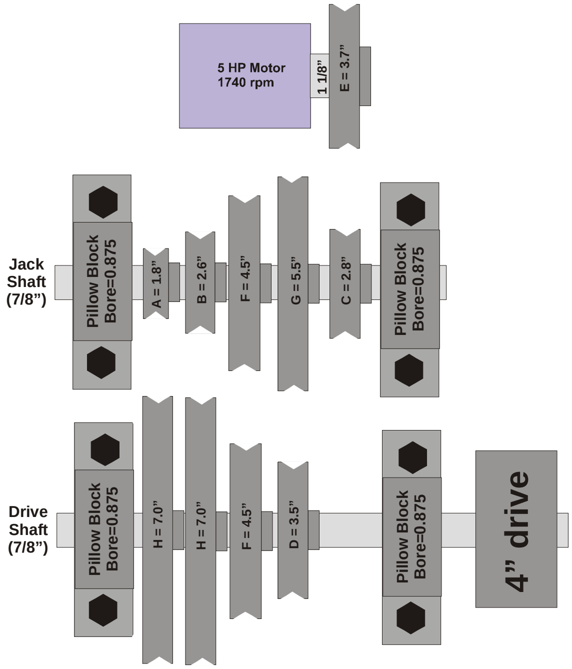


Figure 3: Final Pulley System

XIV. Materials Needed

Materials listed here are sufficient for all items described except for some of the extreme accessory items. Primary variation will occur depending on how many and which of the grind heads are to be built. I strongly recomend that you buy more than indicated. Steel doesn't go bad that reapidly. Where the items are to be used is the terminal comment in each line item.

Power System

1 Motor: 1.5 to 2 HP 3-phase TEFC 3400+rpm 3/4 to 7/8" shaft with keyway

1 Variable frequency Drive: 1-phase input (110 V or 220 V), NEMA 4 or better enclosure; capacity equal to or greater that motor (typically 3 to 4 HP)

Steel Plate

1	1/4" x 18" x 18"	Base Plate
1	3/8" x 10" x 10"	4-Station head plate
1	3/8" x 6" x 6"	4-Station thickening plate

Steel Tubing

1	12" x 1.25' x 1.25" (0.0625" wall)	Socket
1	5" x 0.5" x 0.5" (0.0625" wall)	Spark Arrestor (could be a pipe with 3/8" bore)

Steel Pipe (Black Schedule 40-measurement is pipe size, not diameter)

2	7"-9" of 1" (=1.325" OD, 1.05" ID)	Standoffs
1	8" of 3/4"	Handle

Steel Channel

2	6" x 2" wide channel	Motor mounts

Steel Bar

1	14" of 1" x 1"	Tracking arm - lower limb	*(total if building all ~ 10')*
1	6.5" of 1" x 1"	Tracking arm - tracking bar	
3	1" of 1" x 1"	Tracking arm - boss, steady rest	
1	20" of 1" x 1"	Flat-platen grind head arm	
3	20" of 1" x 1"	Contact wheel arm (reduce # to that needed)	
1	8" of 1" x 1"	Small contact wheel arm; "fork" wheel side	
1	8" of 1" x 1.375"	Small contact wheel arm	
1	2.25" x 1" x 0.5"	Small contact wheel arm; "fork" wheel side	*(total = ~ 25")*
3	3" x 1" x 0.5"	Tracking tab, Right spring seat, steady rest stage	
1	12" x 1" x 0.5"	Steady rest: 8" for slotted arm, 4" for secondary arm	
1	1" x 1" x 0.5"	Boss on back of 4-station grind head	
1	7" x 1" x 3/16"	VFD mount	
1	4" x 0.5" x 0.5"	"fork" wheel side, small contact wheel arm	
1	16" x 0.5" x 0.5"	ring on back of 4-station grind head	
4	6" x 1" x 3/16"	Small contact wheel arm; spacers opposite "fork" side	
1	14" of 3/4" round	Steady rest ((add 9" for each additional stage)	

Angle Iron

3	7" x 2" x 2" x 1/4"	Flat-platen grind head
2	14" x 1" x 1" x 1/8"	VFD mount

Hardware (assume washers for all bolts)

1	Multilobed knob; 3/8 bore	Tracking arm
1	6" 3/8x12 Acme rod	Tracking arm
1	3/8x12 Acme hex nut	Tracking arm
2	1" x 1/4x20 cap screws	Small contact wheel arm
1	2" x 1/4x20 hex bolt	Tracking arm
1	1/4x20 hex nut	Tracking arm
9	1" x 3/8x16 hex bolt	Arm lock, flat-platen head

4	2" x 3/8x16 hex bolt	Flat-platen grind head**
2	2.5" x 3/8x16 hex bolt	Small contact wheel arm
1	3" x 3/8x16 hex bolt	Tracking arm
1	2" x 3/8x16 hex bolt	Flat-platen grind head lock
2	2.5" x 3/8x16 hex bolt	Spring saddle 'U' bolt
1	3/8x16 Nylock nut	Tracking arm
2	3/8x16 hex nut*	Spring saddle 'U' bolt
5	3/8x16 cap screws	Steady Rest, Small contact arm
1	2" x 1/2x13 hex bolt	Tracking arm
1	3.5" x 1/2x13 hex bolt	Flat-platen grind head pivot
1	1/2x13 Nylock nut	Flat-platen grind headpivot
4	3.5" x 1/2x13 hex bolt	Flat-platen grind head***
4	1/2x13 Nylock nut	Flat-platen grind head***

Miscellaneous

1	6" of 2" graphite impregnated belt
1	6" of 2" wide dense rubber backing
2	6" of 2" x 1/4" O1 (or 5160) tool steel - platens
1	7" of 1" x 3/16" O1 (or 5160) tool steel - spring
1	2" x 5/8 to 3/4" compression spring (50lb?)
2-3	Carlon connectors (1/2" or 3/4")
1	12" of Carlon flex cable to match connectors
1	220 V male plug (to match available outlet)
1	10' of 12 gage 3-connector wire

Wheels

4	2x2 idler wheels (Beaumont or Bader)
1	6" x 2.25" drive wheel (bore to match motor)
1	3.5" x 2.5" tracking wheel
1	10" x 2" smooth or serrated contact wheel
1	4" x 2" smooth or serrated contact wheel
1	0.5" smooth Contact wheel
1	1.5" x 1" serrated contact wheel (3/8x24 threaded extension)

+ Spring saddle 'U' joint
** Bader idlers
*** Beaumont idlers

To use the list, you first must decide what options are not to be built - for instance, the double-headed fork arm or the 4" contact wheel arm. Subtract those materials, sum the remaining and round up. Virtually none of the dimensions are locked in stone - just make sure they dovetail with the parts they connect to.