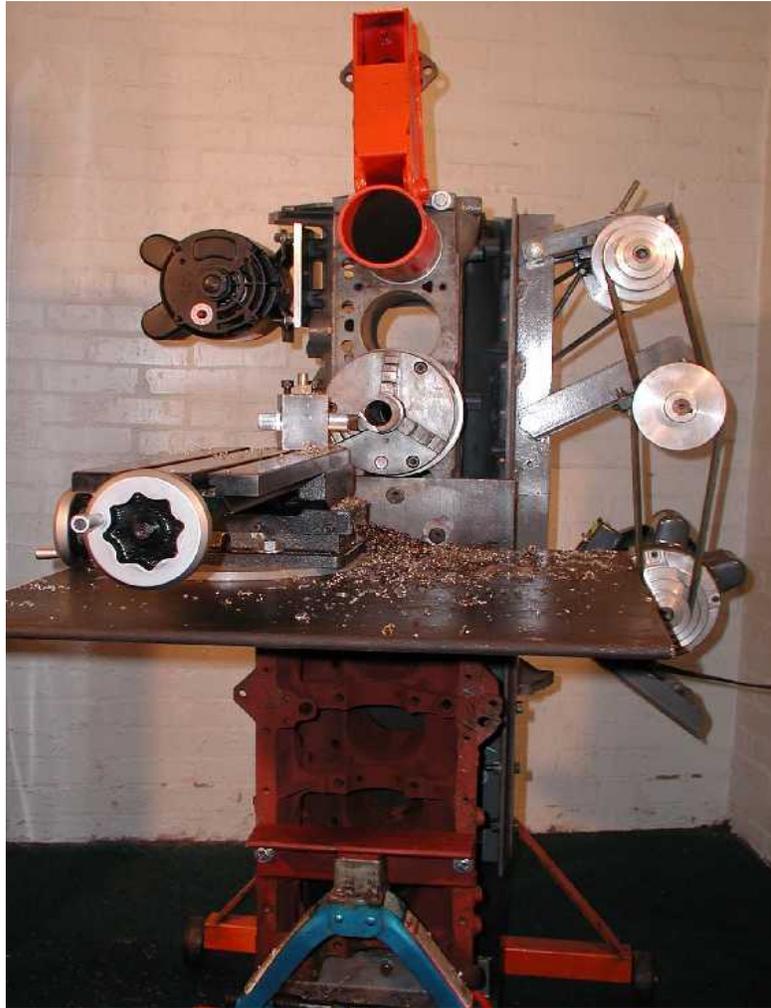


MultiMachine, an open-source machine tool



The MultiMachine -- a complete machine shop in one tool. Entirely built from scrap material.

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**Support at:
<http://groups.yahoo.com/group/multimachine/>**

Introduction

The MultiMachine is a multi purpose machine tool* that a semi-skilled mechanic with just regular hand tools can build using scrap car and truck parts. Electric power is not needed.

In Developing Countries, the MultiMachine has the potential for saving or improving the lives of many thousands of people. These machines can be used in many ways:

In the **health** sector by its use in building water pumps, filters, water well drilling rigs and hospital furnishings.

In **agriculture** by its use in building farm machinery and irrigation pumps.

In **transportation** by its use in building and repairing parts for vehicles.

In **communications** by its use as a cell phone charging station.

In **village life** by being a source of battery power for home lighting.

In **education** by providing vocational education students with machine tools that they build themselves and then are able to take back to their villages when they graduate.

It could provide a local self supporting infrastructure that would be available to keep water and irrigation pumps in repair. Many NGOs go to great effort and expense to drill water wells and provide pumps in rural areas of underdeveloped countries. These pumps often fail because there is no person able to repair them. A small MultiMachine based business could provide a pump repairman with the means to earn a living in an area where these pumps and wells are used. The pump repairman could support himself by doing machine shop type jobs like making and sharpening agricultural tools and equipment and resurfacing vehicle flywheels, brake drums and disks.

Machine tools often draw power intermittently from gas or diesel engines or electric motors. Any surplus power could run a welding machine built from a vehicle alternator and also recharge batteries that in turn could be used for home lighting or recharging cell phone batteries.

The combination of a MultiMachine and a welder can be used to build different types of metal bending and rolling machines that can be used to manufacture fuel efficient cook stoves, pots, pans and similar products.

The MultiMachine also provides a way to machine simple zinc and aluminum castings made from the metal found in old car parts. Without this machining, the castings are of limited use but simple machining can turn them into hundreds of different kinds of products.

Vocational education takes "hands on" learning. Few vocational schools in developing countries have sufficient numbers of the machine tools that are necessary for training students. This is no problem with student built MultiMachines.

*** A machine tool is a powered mechanical device, typically used to fabricate metal components**

Look around you. Almost every manufactured product that is made of metal is a combination of parts that have been machined (castings, screws and bolts) and sheet, bar and tubular metal that has been welded, bent, rolled or spun into a needed shape. The essentially free MultiMachine and the tools it can produce can do all this.

A group of specialized MultiMachines can do much more. The MultiMachine can be easily built in dozens of special versions that are specially built to do just a single type of metal working job. If these special machines were grouped together and driven from a common power source, they could be used in a form of Developing World mass production. Most of these machine versions could be built with just one or two broken vehicle engines, a piece of pipe, a few feet of steel bar, a sack of cement and a few easily made zinc/aluminum castings.

I am certain that MultiMachine newsgroup members will help adapt our designs to the types and sizes of material available in any community.

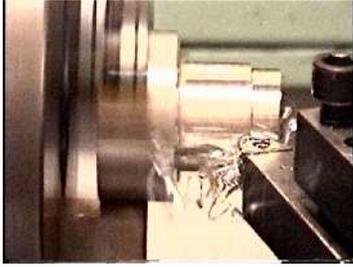
Special thanks to George Ewen of “Engine Mill” fame, Jeff Hansen, Kevin Olson and to my craftsman friend, Frank Patterson.

And a very special thanks to my wife, Clarissa, who put up with me during the four years this project took.

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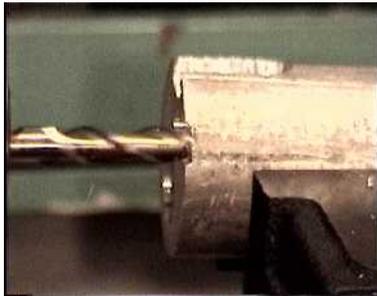
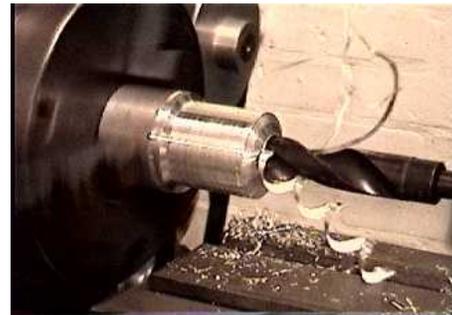
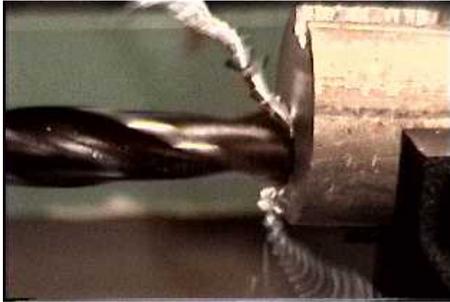


The MultiMachine is a metal lathe that can be built to machine something as big as a manhole cover!

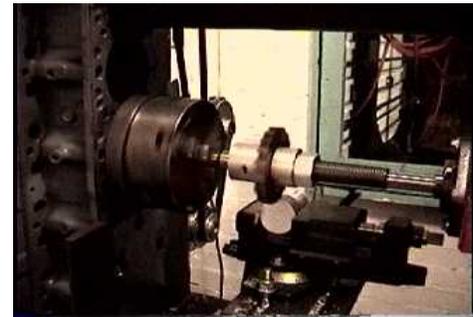


It can face and cut tapers by simply rotating the cross feed on the "turntable."

It can drill and bore in many different ways



It's an end mill



It's a horizontal mill that can work well with really cheap eBay cutters! This resharpened cutter cost 75 cents!



My MultiMachine made a 400rpm single pass-cut of .822" x 1/2" in this piece of 6061 aluminum.



Other arbors can be easily made for fly cutters, wood and metal saw blades, surface grinding wheels and sanding drums and discs.

How can the MultiMachine do all these things?

In almost every kind of machining operation, either the work piece or the cutting tool turns. If enough flexibility is built into the parts of a machine tool involved in these functions, the resulting machine can do almost every kind of machining operation that will physically fit on it.

You may have heard of 3-in-1 machine tools -- basically a combination of lathe, mill and drill press. The MultiMachine starts there but adds many other functions. It can be a 10- in-1 (or even more!) machine tool that is built by using vehicle engine blocks in a LEGO-like fashion.

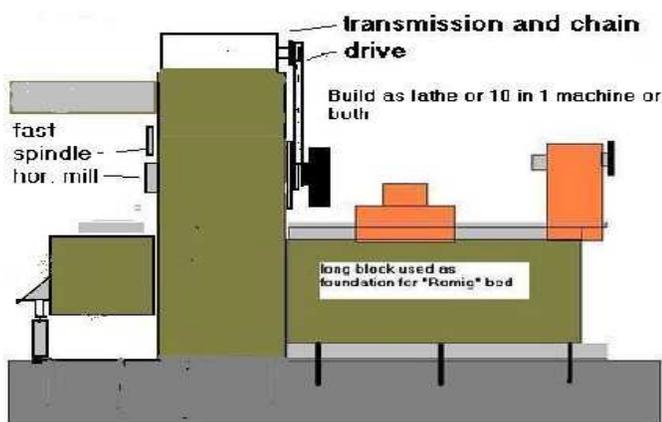
It can be built as a one-engine block machine with a plate and angle iron vertical slide.



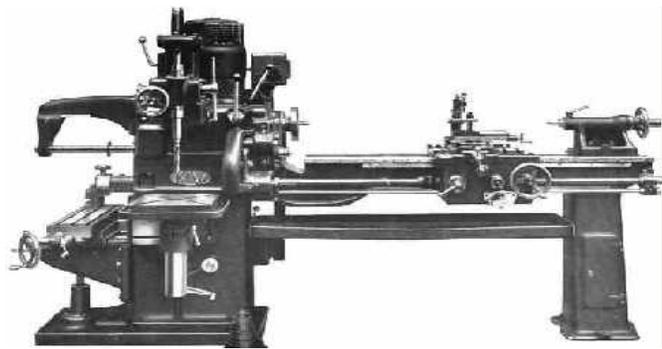
Or as a two-block version with an engine-block-based vertical slide.

Or as a two-block-lathe-only version. (See the fixed lathe bed version below.)

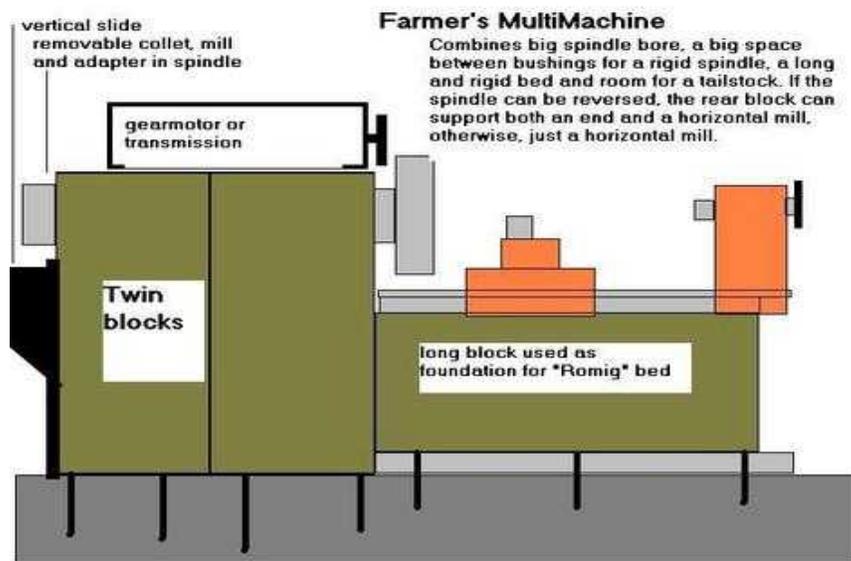
This is a three-block version with a fixed, long lathe bed and a rear-mounted vertical slide. Great if you have limited space! This version is similar to a Kitchen and Wade multipurpose machine (below) that was used aboard ships for many years -- a far more useful design for a machine tool than the common 3-in-1 machine.



«



“Double-sided” MultiMachines (lathe on one side, all-function machine on the other) are perfect candidates for Variable Frequency Drives that make the machine spindles both variable speed and bi-directional. Pictured below is a four-block version with doubled vertical blocks mounted back to back so it can support a 4'-long spindle – useful with a heavy chuck. The machine can also have a rear vertical slide, and a 4- or 5-block version with a Bridgeport-like head could have an added horizontal block with powered spindle added on top.

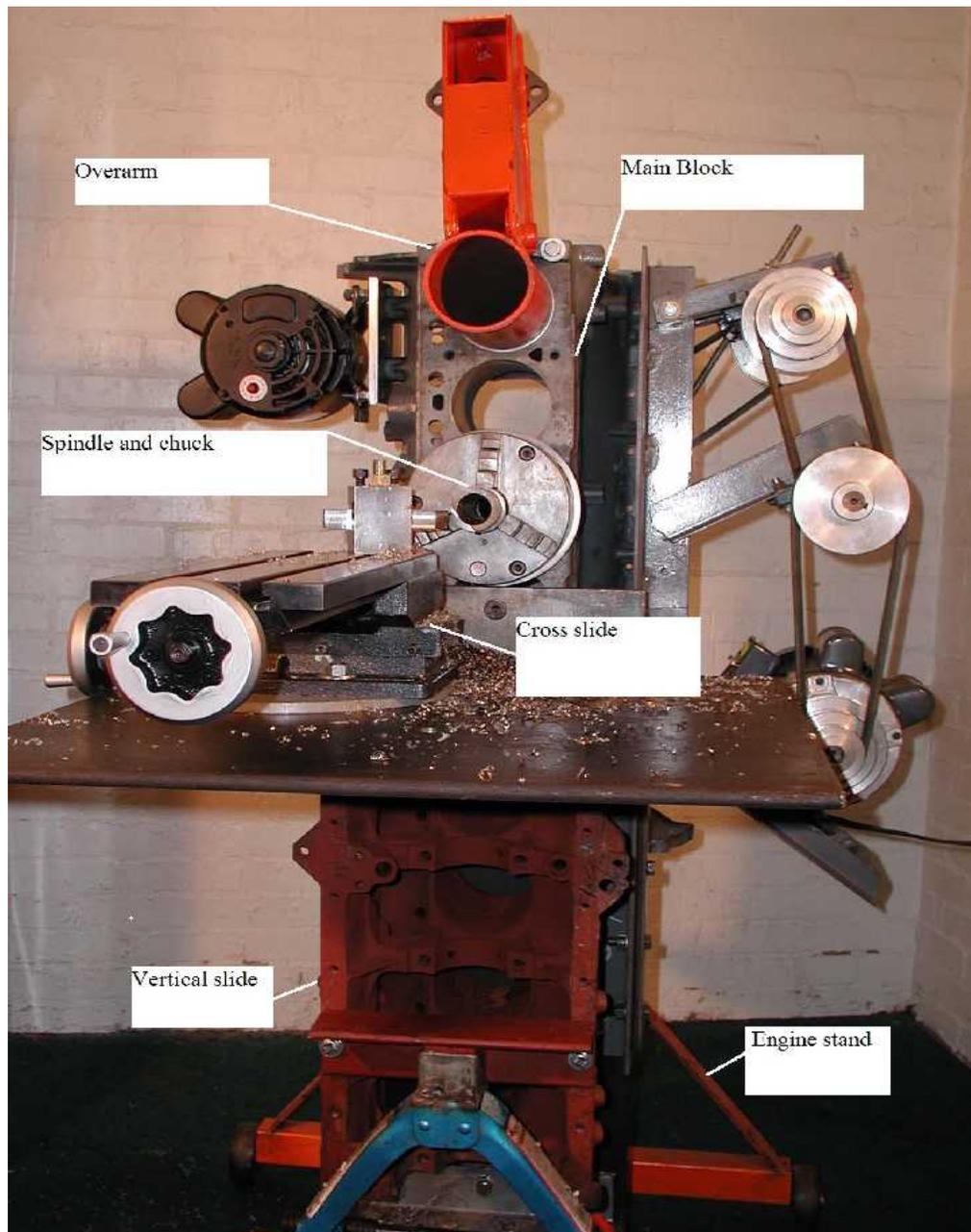


The most common size for a MultiMachine has 12-to-15" of table vertical travel and a 32" lathe “swing.” The horsepower required for regular lathe-type cutting tools makes them hard to use large work pieces. BUT...If you replace the cutting tool with a simple \$30 bench grinder or even a homemade toolpost grinder, you can machine really big jobs. You can even resurface large clutch and brake parts for a truck.

By using the simplest metal casting technique, a skill that has been around thousands of years, you can turn out products using machined aluminum alloy. It then becomes possible to build things like pump parts and to cast alloy bushings that could replace expensive ball bearings. One common alloy, ZA-12, contains about 12% aluminum, with zinc as most of the remainder. Both

aluminum and zinc are materials commonly used in vehicles, making them easily available. ZA-12 has a tensile strength approaching that of cast iron and is such a good bearing material that it is used for bushing-type bearings in steel-rolling mills.

See the possibilities?



The MultiMachine is extremely simple - basically 6 unusual construction techniques that we call “secrets” and 5 very simple “modules” that bolt to an engine block.

*Using engine blocks as building blocks is the **first MultiMachine “secret.”*** Since cylinder bores are bored parallel to each other and at *exact* right angles to the cylinder head surface, MultiMachine accuracy begins at the factory where the engine block was built.

The second MultiMachine secret! In the most common version of the MultiMachine, one that has a roller bearing spindle (the kind I built), this precision is maintained during construction with simple cylinder re-boring of the #3 cylinder to the size of the roller bearing outside diameter (OD) and re-boring the #1 cylinder to fit the overarm OD.

The best part is that the cylinder-boring operations will probably cost less than \$50. An engine machine shop provides the most inexpensive and accurate (.0005" on a 4" cylinder!) machine work commonly done anywhere and guarantees you that the spindle and overarm will be both aligned and at an exact right angle to the face (head surface) of the main engine block that serves as the base of the machine.

The third MultiMachine “secret!” The spindle can be as simple as a piece of pipe machined to fit the inner diameter of the bearings.

The fourth “secret” is the addition of a third bearing to the spindle. The three-bearing spindle is necessary because the “main” spindle bearings just “float” in the cylinder bore so that the third bearing is needed to “locate” the spindle, act as a thrust bearing, and support the heavy pulley.

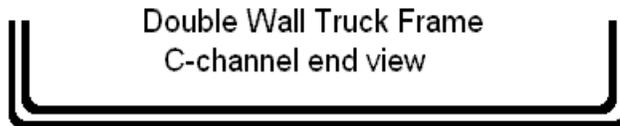
The fifth MultiMachine secret! The main engine block and the vertical-slide engine block fit together with the help of two 1/2" x 12" steel plates, along with my unique way of clamping the plates together. It's easily built, easily adjusted, and easily clamped into position without the workpiece moving. Far superior (I think!) to a homemade attempt at a four-foot-long dovetail.



Long, angled cuts similar to this commercial dovetail assembly on the cross slide shown below would be far more difficult to build than the MultiMachine's simple, square sections that are bolted together. **While the MultiMachine vertical slide requires only a drill to build, a long dovetail requires a very large milling machine. A hugely important difference!**

The use of smaller steel bar stock or angle iron may be necessary in some areas where the ½” x 12” steel plate may be hard to find. Pieces of truck frame rail could be used. Alignment of these “foundation” parts is critical, and substitutes for the preferred steel plate may be harder to adjust. Don't let the difficulty of making a sliding fit deter you from getting started. Build a fixed-bed lathe version first and later add a MultiMachine-type vertical slide to the rear of the block.

Here is one kind of substitute that could work well: “doubled” frame walls that are common in big trucks. The rivets can be ground off and the two pieces made into a good sliding fit.



The sixth MultiMachine secret is a device similar to this that can be clamped to a shaft. It can have capscrews that pass sideways in order to push or pull another device or can be made large enough to do dozens of jobs by itself. More about this later!



The 5 simple modules that attach to the engine block:

(1) **The vertical slide module** is basically a short engine block with a steel plate bolted to the head surface and a cross slide attached to the end bell (upper) end. There are many kinds of cross slides that can be bought or built. If you have a little money to spend, think about buying a \$69 ENCO one to use at first (in developing countries, however, a similar one may be the equivalent of a thousand dollars). Later, you can build something like a massive concrete and steel “Romig” single or twin lathe bed and cross slide. (See the “Romig” turret lathe design in the MultiMachine newsgroup “files” section.) J.V. Romig designed machine tools that were featured in Popular Mechanics magazine for almost thirty years. The designs still work well. This small cross slide also can be used for many other projects. Example: you can fit it on top of a turntable and use it for cutting tapers. (A turntable could also be fitted to the top of a big “Romig” bed to cut tapers.)



(2) **The drive unit module.** There are literally dozens of ways to drive the machine. A combination of small and large pulleys makes a good medium-speed drive. Other setups might include multiple-groove pulleys or even the transmission from a lawn mower, garden cultivator, or pickup truck. Power can be provided by anything from an electrical appliance motor to a car or truck engine.



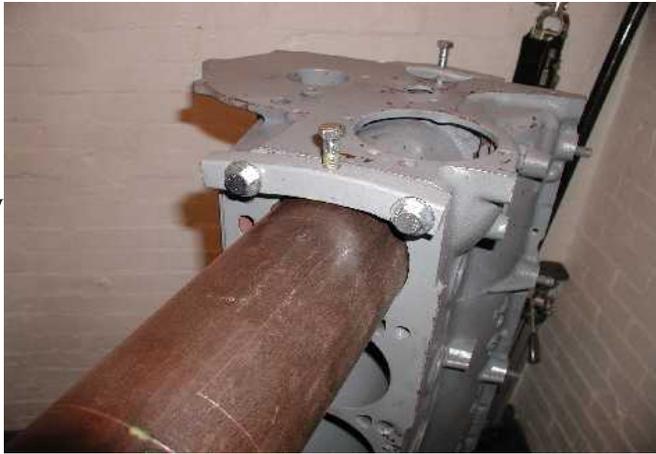
(3) **The machine mount module**

The quality of the finish your machine can make will be greatly affected by the rigidity and weight of the base. Since I lack work space, I had to have a machine that I could move around. Mine is built with an engine stand and mobile base. (A permanent base made from concrete or a heavy steel frame would be much more rigid.)

An overhead hoist is a necessity since you'll be using a machine that may weigh well over a ton. If you decide to use an engine-stand-type machine mount, try to make it a one-ton model. In the USA, Harbor Freight has these for about a hundred dollars.



(4) **The overarm module** may not even be needed by some people but others may see it as the heart of an entire tooling system. Because it is important that the overarm always stay in alignment, *the #1 cylinder is re-bored to fit your overarm pipe at the same time the #3 cylinder is re-bored for the spindle.*



(5) **The spindle module is the heart of the machine.** No machine tool can do a proper job with an inaccurate spindle. **Because the bearings actually run in the professionally bored cylinder bore of the engine block and the spindle is finish-machined on the MultiMachine itself, accuracy is achievable even by a novice machinist.** (To be treated in much more detail later)



Accuracy, money, tools and skills

Your machine's accuracy is determined by the care you put into building it. There's no one checking your mistakes but you. Compounding a few barely-good-enough fits could make you end up with a machine that chatters too much to use. The chattering may be so severe that you can't even discover what causes it.

Safety also depends on you. ALWAYS use protective guards on your machine. I can't stress it enough. Also...the MultiMachine is taller than it is wide, is very heavy, and is prone to fall over! Mine fell on me once and now I have a new, titanium knee! I liked the old one better.

A little extra work lets you save a lot of money! I'm assuming that you would like to spend as little money as possible on this project. If you can afford to spend a lot, just search eBay and Craig's List for some of those wonderful machines left behind when US jobs went to China.

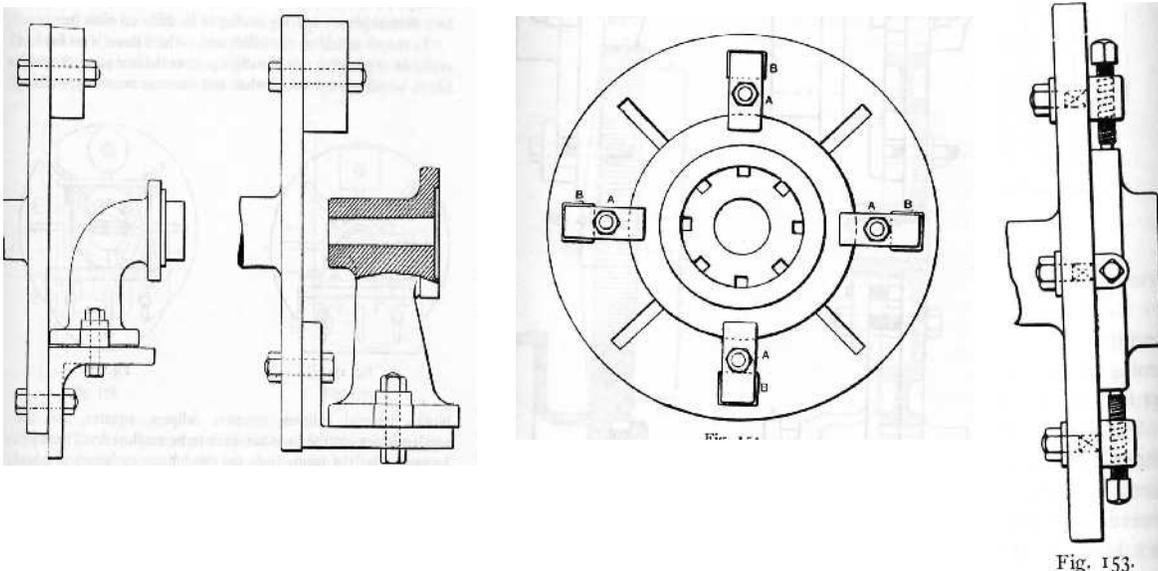
When I built my MultiMachine, I tried to find ways to build it that could take almost no money and little or no electrical power either for building or operating it. I wanted a machine that could be built and run anywhere in the world – outdoors, in a shed without power, or in the finest workshop. The result is a machine that could be grouped with others like it to make a small factory. The machines could be powered by a single gas or diesel engine running an overhead shaft that is connected to them by simple pulleys and belts.

You may have to learn a few new skills to build the machine, but these skills are also needed to make best use of the MultiMachine.

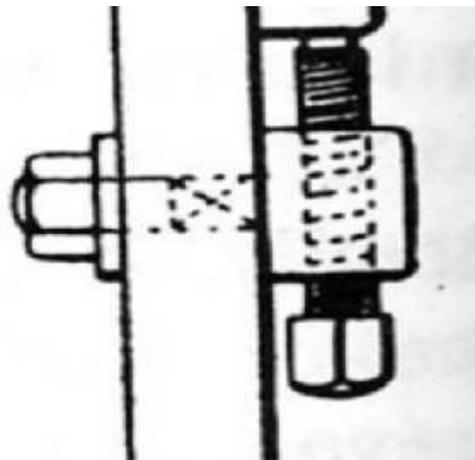
Two important skills covered in many old machining books are grinding cutting tools to the correct shape and clamping work on a lathe faceplate. These kinds of subjects are also usually covered in just 20 or 30 pages in almost any of the older machining books that can be found in your local library, In our MultiMachine newsgroup or elsewhere on the web.

The shape of the cutting tool is important in every lathe, milling and shaping/slotting machine operation. The tool has the same basic shape for many of these different operations. Learning the basics of grinding metal-cutting tools to the proper shape will save you lots of money.

How to clamp work to a lathe faceplate is the other basic machining skill needed. There are many ways to do this that are described in older books. (See samples below.) Since three- and four-jaw chucks were not common for the first 80 or 90 years of wide metal-lathe usage, metal workers did without them. So can you if you have to.



Incidentally--- The enlarged picture taken from the faceplate (shown on the right above) shows a wonderfully useful clamping device. To make it, just weld a short piece of threaded rod to the side of one of the long, coupling nuts commonly used to connect two pieces of threaded rod. Then add a bolt and a nut. It may help to grind a slight angle on the coupling nut so that the screw forces the work-piece into the face plate. That's all it takes!



Knowing how to cast aluminum alloy is vital to building a really cheap (or almost free) MultiMachine. Cast aluminum alloy parts can replace expensive bearings, spacers, adjusters and pulleys in your machine. Since you don't need fancy pattern-making for the MultiMachine, casting for it is simple. You can just cast round sections and turn them into the parts you need by using one of the "temporary" lathe designs found at the end of this booklet. These cast parts let you adapt junk-priced pipes and shafts to the sizes you need so you can avoid buying new stuff at retail prices.

Tools you will need

For those who don't have a power drill (or power), see the end of this booklet for a way to build a **ratchet drill**. If you have only a **pistol-type electrical drill**, you should buy or make some kind of stand for it.

If you have a **small, bench drill press** that can be made to run at slow speed (by changing pulleys?), turn the head around and clamp the stand to the work. If you have a **big drill press**, lower the head almost to the ground and make a ground-level 2x4 and plywood table to put your work on. This provides a safe way to drill holes in 120-pound pieces of steel. For large holes, just "step" drill (start with a small drill bit and work up an eighth of an inch at a time.)

A **hacksaw** (and a bunch of high-quality blades such as the 43-cent Starrett ones from ENCO) will work for sawing. If you don't have a electric **grinder**, you can use a hammer, chisel, file, and a hand cranked grinder (for grinding cutting tools) as mechanics did for hundreds of years.

I was serious when I said only basic tools were needed but I need to add three kinds of more unusual tools that some mechanics won't have. One of these is a set of transfer punches. A set of these will usually cost under ten dollars. Transfer screws (one half inch long pieces of threaded rod with a point ground on one end) are extremely useful in machine building. A mechanic should be able to make both these tools The third tool is a dial indicator that also is usually under ten dollars. The dial indicator is needed for checking spindle and elevating table adjustments.

Transfer screws



Dial indicator



Transfer punches

You can weld some of the machine parts that don't have to be in perfect alignment. Your **welding setup** can be as simple as connecting 2 or 3 car batteries in series (positive on one to negative on the next) by using long jumper cables and keeping the welding job a safe way from the batteries. Carefully protect the batteries from any welding spark! **Don't weld anything that can have the slightest effect on machine alignment! The fastest way to ruin any machine tool is to weld it**

Two things to keep in mind when reading this booklet: I am an inventor and not a precision machinist (or precision anything else!) or an engineer. Take everything I say as my personal experience and nothing more.

Safety again... Every machinery book or video stresses safety, and well they should. Lifting and drilling accurate holes in the MultiMachine's big, heavy parts requires a lot of thought. **THINK! Measure everything several times and work on heavy stuff as close to the ground as possible. A slippery, hundred-pound piece of oily steel on top of a steel table can be very dangerous.**

Construction starts!

Construction should be almost foolproof. In the final chapter I'll tell how to build an even bigger (may weigh five or more tons) MultiMachine that can be built with no store bought stuff at all! It also can be built by using only hand tools and no electric power.

How to build a “middle” size roller bearing version that is based on easily available car and light truck engine blocks. Middle sized or not, this is no toy since just the spindle assembly, bearings, chuck and pulley may easily weigh well over 130 pounds and the whole machine may weigh over half a ton.

The Spindle in detail

Let's start with the spindle since it is the heart of the machine and there are many ways it can be built. Each of these different ways affects the way the rest of the machine is built.

Look carefully at the roller bearing spindle picture and you will realize that the spindle works just like a bicycle front axle with just three small differences.

The big spacer that separates the bearings, the way the bearings are adjusted and the third spindle bearing that functions both as a thrust bearing and to support for the weight of a heavy pulley.

But first lets talk about spindle and bearing size so that you can keep these things in mind when we study the individual parts.

The maximum spindle size is closely related to the bore size of your engine block and also to what is the machine going to be used for.

If the MultiMachine is going to be used in a model makers shop, a small 6 cylinder block with a bore of 3.5” to 3.6” would be fine. Chuck thread size would probably be the very common 1 1/2” 8 and the spindle would have a bore of about 1”.

One similar to the one I ended up with would probably have cylinder bore of 3 7/8 or 4” (This 1/8” difference can be very important because the smaller bore can just be re-bored without needing to be sleeved. It can easily have the very useful spindle chuck thread size of 2 1/4” 8 (like the South Bend heavy 10 lathe) and would also have 1 3/4” spindle bore. This is a much more useful machine than one just that is just slightly smaller because having the largest possible



spindle bore size is very important. Modern lathes do not usually have long beds and a long bed is especially difficult to have on a conventional MultiMachine since the vertical slide would have to be deep (long) enough to support the bed. A long bed like this could be difficult to raise evenly. Modern lathes feed the work through large (or giant) spindle bores like one on our largest MultiMachine designs. Strangely enough the 100 year old Lindsay book "Practical Metal Turning" talks about just this as the "modern" way!

I would choose one of the common Chevrolet, Jeep or similar straight 6 cylinder engines with a 3 7/8" bore. I would use 100 mm OD bearings and bore the block to that size. (3.937"). For a spindle I would use a 20" piece of 2 1/2" xxhy pipe (a pipe size chart is at the end of the book) that has an OD of 2.875" and an ID of 1.771. This would allow plenty of room for a 2 1/4" 8 thread and the shoulder and register that the chuck "centers" on when it is mounted.

Simple so far. The reason for the metric bearing size is because they seem to cost a lot less. I used 4 1/8" OD Timken bearings in my 6 cylinder Ford 300 cubic inch pickup block and the cheapest roller bearings I could find were \$75 ea, I later found metric 100mm 32013x and 32011 bearings for \$22 to \$32 (probably different quality). These bearings have an ID of 65mm and 55mm respectively which is perfect for this size pipe. It also means that the spindle can be threaded (use a dial indicator to center the spindle thread on the bore) and room left for the "register", shoulder and bearings. The #1 cylinder can be bored to the size of a "cleaned up" piece of 4" OD pipe or tubing that is used for the overarm.

Like everywhere, there are trade offs here, and in this case it is that "x" at the end of the 32013x bearing number. This is not a heavy duty bearing even though it is supposedly rated for automotive use. If we would go to a heavier duty bearing (32011) with a 55mm or 2.165" ID then the spindle wall is just .2" thick which seems thin but will probably work fine. Nothing is written in stone in this project, a clean 100mm cylinder bore gives you many choices in spindles that use single or double ball bearings, tapered roller bearings (like mine) or cast aluminum alloy bushings. If you spend a nice afternoon at your NAPA dealer, you will probably be able to find inexpensive bearings to fit almost any block within a 3.75" to 4.25" range of bore sizes.

So what to use if you are totally broke or stuck a hundred miles from nowhere in Kenya? No problem! Just build our ratchet drill and one of the "temporary" lathes described at the end of this booklet, cast bushings or take apart every front and back axle that you can find to harvest the bearings, pile these and whatever pipe pieces that you can find under a good shade tree and sit down and think! MultiMachines are thinking peoples tools. I guarantee you will find a way since there are dozens of ways to build the spindle (and almost everything else here)!

Lets start from the front end of the spindle to keep things in some kind of order. I am going to assume that you have a way to thread the spindle but if you don't, no problem again! You will soon learn about our "miracle" device that can cure almost every problem! **It can mount a big chuck on one end of an un-threaded spindle, be a roller bearing adjuster, a thrust bearing, a pulley mount or a mounted pulley and also clamp all kinds of attachments to the back end of the spindle.**

But first, what size pipe to use for the spindle? It could be almost any size! But since we have to

start somewhere I am going to assume you chose to use the size of pipe I recommended above (and found, which may be hard in some places). (pipe chart at end of this booklet)
This picture (below) shows the critical spindle “nose” that you would thread 2 1/4” 8 threads per inch to match a chuck backplate.

NEXT comes the important part! Look carefully at the little section between the thread and the spindle shoulder. It is called the “register”. The register area centers the backplate on the spindle when the backplate is screwed on far enough to hit the spindle shoulder. This is extremely important since it means that the spindle can be threaded on another lathe and still be accurate on your MultiMachine. After you get your machine powered up and the bearings adjusted, take light cuts on the register and shoulder surfaces until the chuck backplate



is a “wringing” (gently screwing the backplate forwards and backwards until it works it's way over the register) fit. The chuck backplate will then be a custom fit on the MultiMachine itself. **The spindle threads don't center the chuck, the register and shoulder do!** After this careful fitting is done, take a cut (machine the surface) on the chuck backplate to make sure it is running true before you bolt on the chuck. The MultiMachine newsgroup “files” section has an excellent article about mounting chucks.

How long should this shoulder be? In this case, at least an inch and a quarter. If you eventually want to be able to cut threads, add another inch to this for a timing gear pulley that will drive a thread follower device that is currently being developed. Remember that a 1/2” plate bolts to the front of the block and that you will need additional shoulder space for set screws etc.

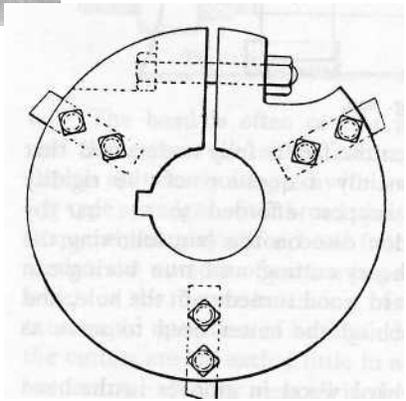
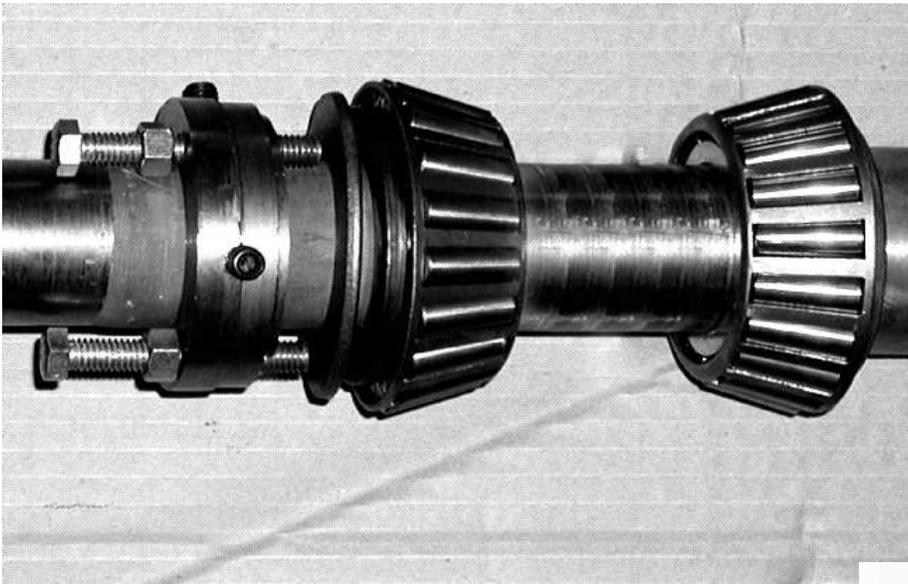
After the shoulder comes the space for the front roller bearing.

The big spacer between the bearings takes the place of the bicycle hub and must be carefully made and fitted so that the roller bearings are absolutely parallel. The spindle can be slightly undercut the same length of the spacer to make it easier to press the front bearing on.

The inner roller bearing should be a slightly (polish with emery cloth) looser fit on the spindle to make it easier to to adjust. If you over-tighten this bearing then slightly back off the adjustment screws, run the machine and let it “shake” lose a little.

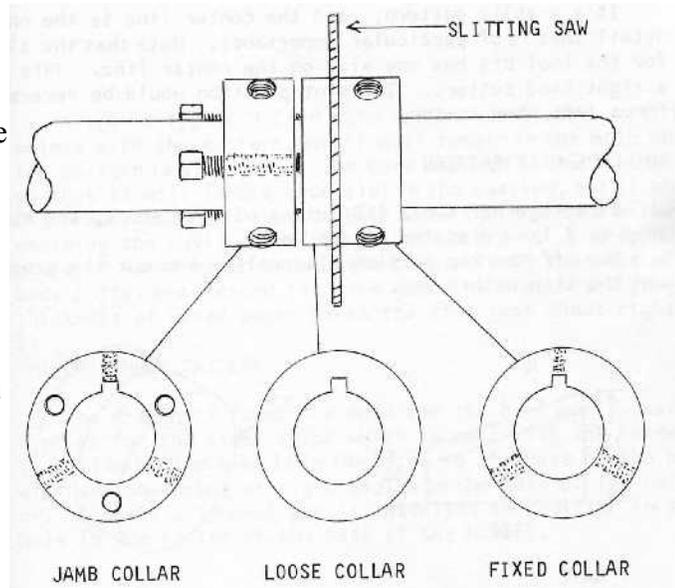
The adjuster is the really BIG MultiMachine secret! It is not the usual nut on a threaded spindle. It is a combination of two common industrial devices. Dave Gingery used the idea on his horizontal milling machine arbor and I added the clamp bolts to avoid having to pock mark the spindle with set screw marks. This design is a wonderful idea that can be used many times in

machine construction and also in building necessary tooling.
This is an early adjuster design, a better one would also have clamp bolts like the designs on the right and below. A hub with twin clamp bolts would be even better.



The Gingery horizontal mill arbor. I would replace the three setscrews that position the fixed collars with just one setscrew and a clamp bolt (or bolts) like the horizontal mill cutter.

If you don't already own the Gingery casting and cast machine tool books, buy them! Combining the power of the MultiMachine with skills that you learn from building the Gingery tools will let you build almost anything!



I mentioned the third bearing earlier. It locates the whole spindle assembly. It serves as a thrust bearing which is necessary with the roller bearing spindle because these bearings just "float" in the cylinder bore and it also supports the drive pulley. **This pulley may weigh 20 to 30 pounds and be 10" out from the inner roller bearing so additional support is vital.** Three bearing spindles are unusual because of possible alignment problems, we will cover our easy solution to this a little farther along. The thrust bearing/bushing can be as simple as a cast sleeve with a shoulder that would bolt to the main bearing pads and two thin versions of our "adjusters" clamped to the spindle.

Now... something I consider very important. Everybody will want to put his own "stamp" on his machine. Think carefully before you do it here. The spindle MUST be centered on the cylinder bore because this lets you align the lathe bed or cross slide with the block cylinder head surface. Trying to align machine parts by using the short piece of spindle that sticks out from the main block is almost impossible. Think carefully before you change something here. Think ease of re-alignment FIRST! The table can go up and down 16" or more and the cross feed may be able to rotate 360 degrees but all this will be wasted if the table and cross slide has to stay locked in place because they are simply too hard to re-align!

Another extraneous but very important thought!

The size and weight of the MultiMachine really do matter! In the late 1800's the vertical slide alone on a similar capacity horizontal milling machine commonly weighed 3000 lbs. In the early 1900's Cincinnati, the great American milling machine company increased the weight of their machine bases by over 600% when they found that under heavy cuts the cast iron bases were flexing like drum heads. Today 2 or 3hp Bridgeport milling machines weigh over 2400 pounds for a good reason. Your MultiMachine may weigh only a third of this so always keep in mind the importance of using sheer mass to suppress vibration.. Concrete is your friend, when you get your machine to work like it should then fill the base of the main block and also the vertical slide with polymer concrete mix.

The most important rule for building anything! (I think)!

"Pay infinite attention to detail" This is an old Mercedes Benz racing team slogan. Work as carefully as you can. A careless fit will cause "chattering" (cutter vibration) that may take months to diagnose! Several careless fits will compound the errors. Because of the flexibility of the MultiMachine you will eventually try things that are almost impossible! Give the machine a chance!

So... to work!

Step 1, What do you want your machine to do?

What kinds of machining jobs are likely to come up in the future? Should it be able to make models or oil field tools. Should it weigh 100 lbs or 150 times that much. The smallest and largest machines can be built in almost the same way and in each case there are interrelated choices between things like cylinder size, spindle size, spindle bore size and bearing and chuck type and size. Remember that a vertical slide that is meant to be raised and lowered is not going to be long enough or wide enough for some kinds of jobs (of course no lathe is long enough for some jobs!). The MultiMachine can make up for this by having a huge bore in the spindle for the workpiece to pass through. Most modern lathes work this way but few have a 4.8" or larger bore size that is easy to get on a MultiMachine that is based on a Dodge/Cummins pickup engine block. Every design decision involves trade offs. A really big spindle and chuck in a relatively light MultiMachine will only work at low spindle speeds. High speed sawing and grinding will be almost impossible without careful and expensive balancing.

Step 2, Really learn the instructions!

Unless you have a lot of money to waste, don't begin construction until you have thought out every tiny detail of how the parts will fit together. Having to build a machine twice makes it cost twice as much and worse than that, may relegate it to your unfinished project pile! As far as I know no machine tool is built using engine blocks like LEGO and no machine tool uses a 3 bearing spindle in this way. Sit back, think everything through. Know where every single part is going to come from and that includes every bolt and nut! The extra extra heavy walled pipe that is used for the spindle may be common in one area but hard to find in another. You may have to redesign your whole machine if one component can't be found. Be sure to know the exact size and condition of your chosen engine block bore and to what size it can be re-bored to for our purposes (not to hold water).

Step 3, Getting the stuff together.

You obviously have to have planned every detail first.

This is what would be needed for a conventional two engine block version.

(1) The "big" 6 cylinder engine block, this can be anything from a Mercury 6 cylinder outboard block for an apartment sized MultiMachine to a 10+ foot long industrial engine block. For these instructions I'm going to assume a size common in the USA, a 3 7/8" bore 6 cylinder engine block. Similar sizes have been used for trucks in many other places. The first place to look for

engine blocks is in the junk pile behind engine shops. These usually have the big advantage of being de-greased!

You will need a smaller cast iron block for the vertical slide.

Well, not exactly at this stage but you will need it when assembly first begins and it is easier to search for it while you are searching for the "big" block. What ever you choose, it needs to be as short and heavy as possible. An iron V6 will probably work fine or look for a very common small Dodge D50 truck four cylinder block. I've used everything from a Model A Ford to a Volvo turbo block.

(2) 4' of 4" OD "round" (if possible, most is not truly round) pipe for the over arm. Remember that the overarm may not be needed for some machines but is critical for others. At the very least, make the #1 cylinder bore able to be retro-fitted to an available size of pipe without having to take the entire machine apart to have it re-bored later.

(3) A 20?" long piece of extra-extra heavy wall 2 1/2" xxhw pipe or a similar sized hollow bar to use for the spindle. The length of course depends on the size of the engine block that you use. Try to leave at least three extra inches of spindle outboard of the pulley. Different kinds of tooling like a traveling head boring bar may need this space. Try not to settle for less than a 1 3/4" spindle bore on a short bed lathe that is to be used for a wide range of projects.

(4) 2 roller bearings and a flange or home cast thrust bearing The roller bearings could be anywhere from about 2 1/8" to 2 3/4" ID (assuming 2 1/2" xxhw pipe) and between 3 7/8" and 4 1/8" OD. The flange bearing (third spindle bearing) bore could be a little smaller than the roller bearing IDs and the pulley bored slightly smaller still. Think seriously about using those Metric 100 mm spindle bearings.

(5) A threaded chuck or back plate to test the spindle thread if you are going to use a threaded spindle.

(6) A 1 1/2" slice of 3-1/2" steel shaft or a similar sized ZA-12 casting that can be bored to fit the spindle. It will be needed for the bearing adjuster. Get at least 6 extra two inch "slices" for horizontal mill arbors, boring heads, fly cutters, thrust bearings etc.

(7) A 2" washer for the floating part of the adjuster.

(8) A 1 or 2 groove 12" OD pulley that can be adapted to fit the end of the spindle.

(9) An approx. 6" long piece of 3 1/2" pipe to make into a separator for the roller bearings. **Important**, length is bore length less the width of the bearings. This spacer "floats in the cylinder so it should be just a few thousandth of an inch smaller than the bore, use shim stock and Loctite to make a snug fit because a loose fit can be the source of strange noises. Ends must be accurately machined or the bearings will slightly "cock" and cause great trouble! The spindle can be slightly undercut in the area underneath this spacer to make it easier to press on the front bearing.

(10) Used head gaskets for both blocks. (an easy way to mark holes but not absolutely necessary)

Every one of those parts should be on hand when you start the fitting process.

Step 4, The machine and engine shops

The engine shop bores and/or sleeves the block to fit the bearing and overarm outside dimensions. Simple enough, but if for some reason this boring is not possible and the cylinder bores are not badly worn then simple sleeve type bearing adapters could be made. Remember there is the potential of a loss in accuracy with each bearing adapter you use so be very careful here. The spindle is the heart of the machine and is not a good place to make shortcuts. If you do have to use bearing adapters, all you may really need is the very top and bottom end of the of the cylinder to be true and unworn.



Step 5, When you get the blocks to your shop

It is important to find out how they fit together. Mzny combinations of blocks will work but now is the time to find out exactly how. The blocks should be carefully tested to see how they fit together. Lay the big block on it's back. Lay on a piece of the steel bar than you plan to use or an identically sized piece of plywood and then lay the small block face down on top of the main block. Check for clearance for the clamps that hold the blocks together. Try to get at the very least 2" clearance on each side. To help get this clearance, protrusions may have to be ground off and either the plate or the small block that is used for the vertical slide may have to be offset to one side.

Step 6, The MultiMachine needs something to sit on

Concrete is always best, two steel tables or frames that would isolate the power unit from the MultiMachine would be almost as good but mine had to roll around so I chose to modify a store bought engine stand. It has worked very well even though it tends to rock back and forth under a heavy cut. One inch jack screws on each corner would be a good idea. Just burn holes in each corner of the stand, weld on nuts and use bolts or allthread to slightly raise and level each corner.

The completed engine stand

It bolts to the engine main bearing pads instead of the end bell.

The vertical post should be cut at the point where it connects to the horizontal frame and re-welded so that it will be in a truly vertical position.

The post has had 3 diagonal braces added. 1" pipe would be best here.

the front brace must stick out no more than the normal height of the block or it will interfere with the big plate that bolts to the front of the block.

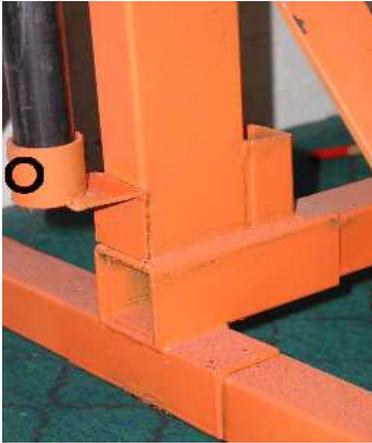
It's had a "crane" added.



Don't mount your "crane" like this!

The 1 1/4 pipe base of the 1" crane pipe should really be mounted as low as possible on the square tube that the wheels are attached to. The bottom crane support should **allow the base of the crane to rest on the floor**. The mount should also stick out at least 1 1/2 " more than is shown in this picture..





Drill at the circled position, weld on a 3/8" nut for a clamp bolt so that the crane won't swing under load.

If you have to work in a spot with a low ceiling, the top support should be removable. I found out this when the crane was in the way of something I was trying to do. I tried to use the crane to hold up the block, power unit and vertical slide plate. Big mistake! the crane tried to swing the load behind the engine stand, knocked me through a big window.

Add 1" jack screws at each corner or take the wheels off and back it up against a wall if you are going to try something with the slightest risk!

The original mounting plate was notched with a grinder and lined up perfectly with the main bearing bolt holes.

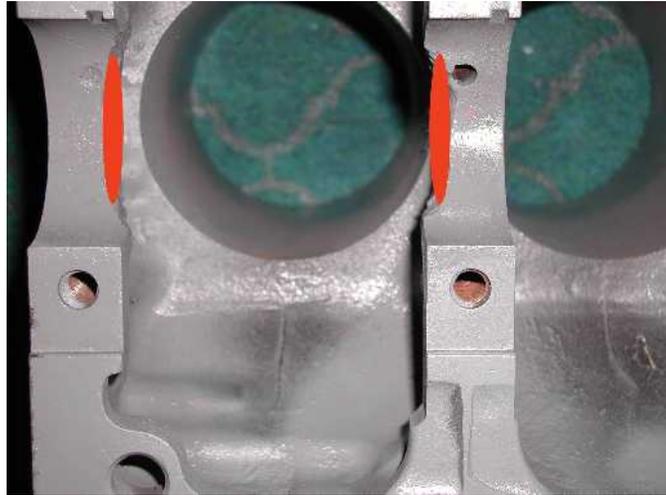


Step 7, Modifying the block

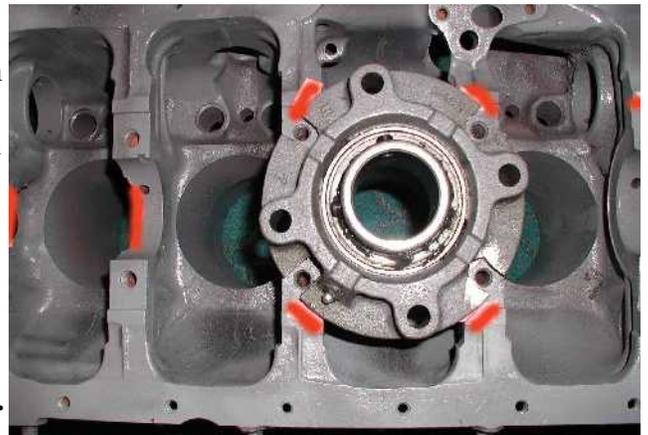
Boring the block to fit the overarm and the spindle was the first step in block modifications. Grinding extraneous bits off is next.

First, one important point, grinding cast iron is not a clean process, try to do it outside if possible. Also, be very careful with safety here, I had iron particles bounce off my face and get under both a face shield and safety glasses and then ended up in my eyes. Have lots of filtered water or eyewash easily available. I have used quarts of "eye wash" that was just filtered water from my refrigerator on this project

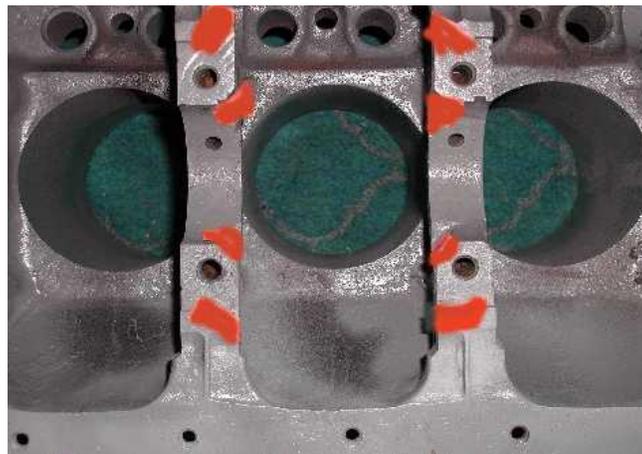
Grind away anything that is going to get in the way of the overarm and the spindle since they need to pass all the way through the block. No grinder? Use a smaller chisel to make small notches along a line that marks what you want to remove and then use a bigger chisel to chip away the excess up to that line. I have already mentioned the different kinds of bearings that can be used in the cylinder bore, There are lots of choices for thrust bearing also. The block modifications are about the same for whatever bearing you choose. Be certain to check for clearance so that the **spindle assembly can be inserted from the rear**. Also check for clearance around the main bearing bolt holes so that the thrust bearing can be bolted to the main bearing pads.



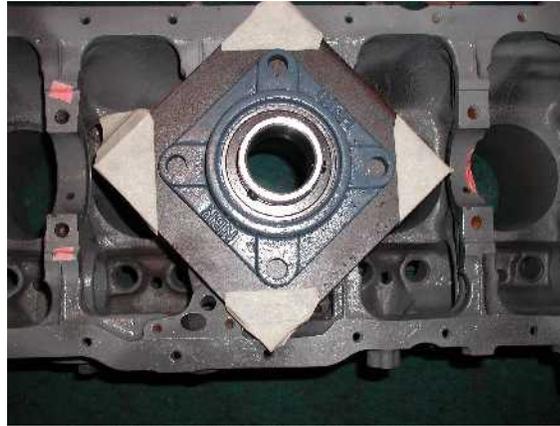
A round flange type bearing that can fit into the main bearing pads works with spindles up to about 1 15/16" in diameter. In the USA, Surplus Center often has these for about \$20. **Special note....Import flange bearings seem to be of very uneven quality. I originally used a LinkBelt flange bearing on the front end of the spindle (as shown in some of the pictures) but quit when the next one I bought was too loose to use. If you buy one for the pulley end of the spindle, be sure to check it out before you install it. Premium USA made flange bearings may be far too expensive to use.**



This was what was cut away for the round Linkbelt bearing.



You can easily see that a really large pipe spindle thrust bearing is just not going to fit on the main bearing pads even with some kind of adapter. Incidentally the one shown here should have the ends marked with tape cut off. One alternative would be to not mount the bearing on the main bearing pad at all but instead use a large adapter plate that would mount on the flange that the oil pan normally attaches to. Bigger bolts would probably be needed and there may not be room for them however. The best (and by far cheapest!) way would be to cast a simple bearing/bushing out of ZA-12.



The cast bushing could be a simple bushing with a flange that would bolt to the main bearing pads. You could use two of our clamp type collars (adjusters) on the spindle. Bronze rings should be used between the ZA-12 parts but there is probably no rush for this if you are careful to keep every thing well oiled.

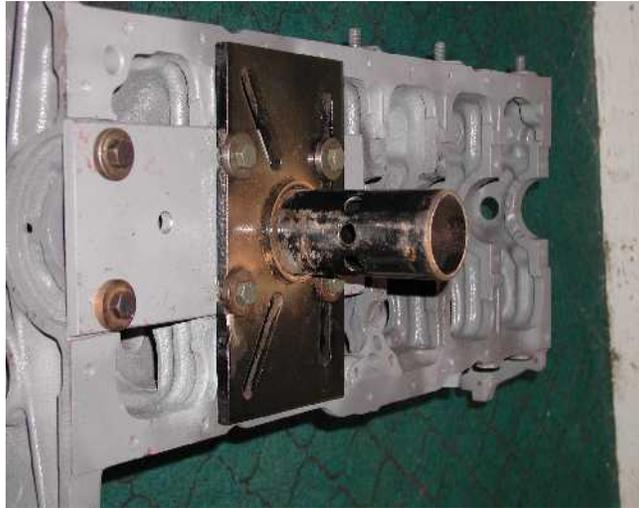
Two important points about this thrust bushing.

Before the thrust bearing is installed, install the pulley and run the spindle with very little belt tension for a few hours as you adjust the bearing adjuster. Let everything wear in until the spindle turns freely and yet has no measurable play shown on a dial indicator. Fit the bushing then and mark the flange bolt holes with transfer screws. Drill the flange bolt holes with no clearance for the mounting bolts and bolt the flange up evenly. This will insure that all three bearings are in alignment.



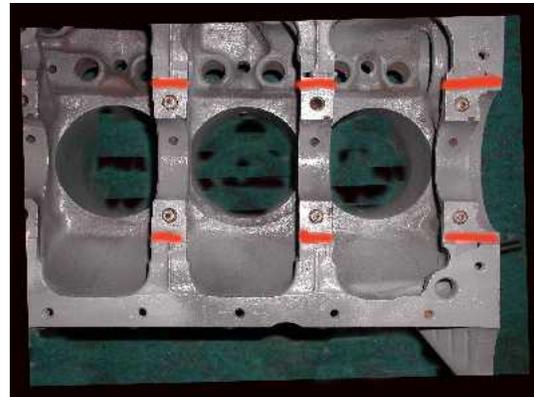
Is the support plate that I put between the block and the engine stand mount really necessary?

Probably not if the big front plate goes to the top of the block.



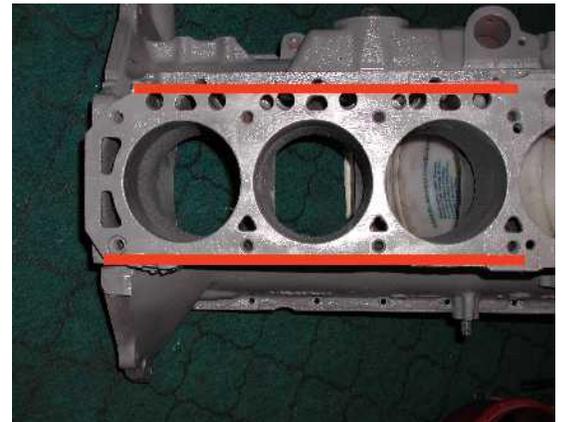
These were the only block modifications I needed for the support plate. I only had to grind off about one sixteenth inch off the edge of the main bearing pads. Look carefully at the main bearing bolt holes and you will see the transfer screws I used here.

One more thing, the engine stand motor mount adapter wasn't meant to bolt to main bearing pads so grind off anything that gets in the way!



Necessary changes to the front of the block?

You found out what was needed when you first fitted the blocks together. Now is the time to get any grinding done. In my case it actually took very little.



Step 8, Mounting the block

The crane is great for lifting heavy tools and workpieces, picking up the block like this was simple.



Step 9, Powering the machine

If a steel or concrete table is to be used for MultiMachine, make certain that it is wide enough to have a two foot space off to one side to use for the drive unit. If possible give the drive it's own table since that is a good way to suppress vibration. If the drive is to be attached to the side of the block then it is easier to build it while the engine block is turned on its side. Be careful here because the heavy swinging electric motor is very hard to handle. The motor and its mount can be dangerous.



If you plan to use the machine only as a horizontal mill used for milling iron or steel then a single 50 to 100 rpm speed range is needed but may take six 2 groove pulleys. If you want a very useful, simple general purpose lathe, end mill and drill then a single 450 rpm speed is a good choice. I have found that this speed also works well on aluminum with a three or four inch horizontal milling cutter. Use three inch and twelve inch two groove pulleys to get this speed. Grizzly tools has some very nice cast iron pulleys that will work here. Why two groove? Three groove pulleys with matched belts would be even better but are much more expensive and also are also hard to find. Getting a 100+ lb. spindle up to speed with a 2+ hp motor causes a lot of noisy belt slipping with just a single belt.

If you try to use cheap zinc hardware store pulleys you may find that they soon fly apart! For more reduction, fit in a small truck transmission that has an extra low first gear. The best but \$300 answer is a VFD (variable frequency drive) 3hp motor and a 2 speed (4 pulley) belt arrangement. This could give you a high range of 300 to 3000 rpm and a low range of 50 to 500 rpm. The MultiMachine idea is to do everything as cheaply as possible so this goes against the grain a little but if you have money to spend, this is a good place for it to go. After thinking about all this, the single 450rpm speed may sound better and better!

A warning about belt drives and aluminum pulleys. For many years I worked on large industrial belt drives that used iron pulleys and never noticed a friction problem. However, just slightly increasing belt tension with the multiple aluminum pulleys will make my machine bog completely down to a stop. This is another reason to start with a single 450rpm speed.

Again... only mount the power unit on the MultiMachine if the machine needs to be movable. Vibration makes machining a smooth surface difficult. A mechanically isolated motor and speed reducer is the best way to reduce vibration.



There are almost unlimited ways to power the machine but no matter how you plan to power your machine, you will probably need a mounting plate like this one that I made from scrap. It is securely bolted to the side of the block. Make it as long and wide as possible and use 1/4" plate if possible. I used 3/16" and it tended to flex under load.

On the plate I used, the bottom holes were marked with transfer screws and the top holes were "guestimated" because I did not have the right size transfer screws. Big mistake! Do it right the first time! If the tapped hole is not level with the others then use a short piece of allthread, a nut half screwed on and then the transfer screw screwed into the rest of the nut. Unless you are very experienced at such things don't try to estimate the hole location.

I welded on 2 pieces of bed rail to use to mount the motor and pulleys. This was a bad choice. There is too much flexibility in the kind of steel used for bed rails. I should have used heavier angle iron rails mounted farther apart. Carefully lay everything out first. Don't forget that belts can be changed by unbolting rails and pillow blocks so mount the angle iron rails close to the plate edges. Any "twisting" of the mounts will cause belt slippage when the motor brings the heavy chuck up to speed. A 2, 3 or 5 hp motor accelerating a 40 lb chuck from a dead stop is going to put serious force on the pulleys and mounts.

The notch on the bottom right of the plate is there for clearance for the clamp bolts on the vertical slide.

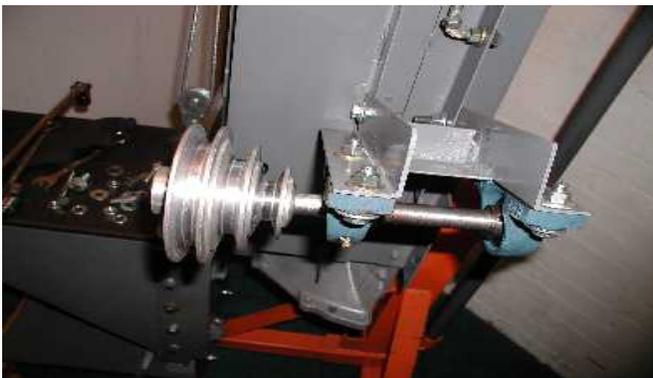


Here the plate is shown bolted to the side of the block.

An earlier picture showed the whole finished motor mount made with slotted bed rails. Slotted bed rail pieces can work well work well only if they are welded to heavy angle iron. This pipe handle was added for more than ease of speed changing, it really cut down on twisting of the assembly under load. **All the pulley brackets should have these pipe handles for this reason!** Don't forget that the motor electrical connection box can get in the way if plenty of room is not left for it.



Again, it would be best if the pulleys were mounted inboard the mounting rails if possible. Be sure to lay everything out first so you can be sure the motor and pulley assemblies all fit properly. Work carefully here and you will get a quiet, powerful machine that is less likely to "chatter".



The intermediate pulley bracket.

This is what I call the final drive bracket. It should be made out of one foot long heavy angle iron and as wide as possible. Add a pipe handle at the top to make it more rigid and easier to adjust. I reinforced this one several times and it still twisted.

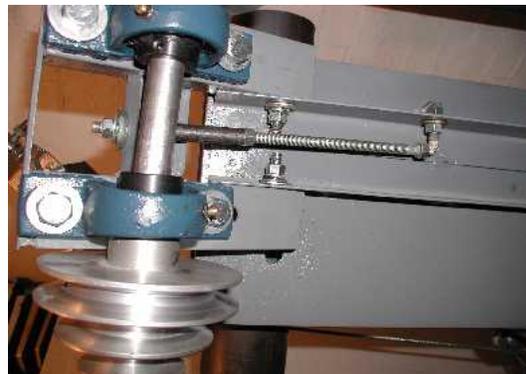


Here is the final drive adjuster. Pretty crude but like I said before, I am an inventor not a

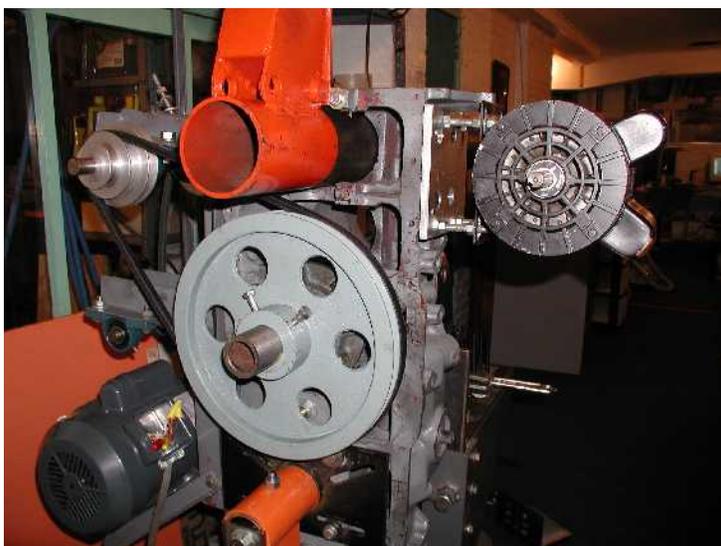
craftsman. Best use two of these, one on each side rail. If you separate the power unit from the block you will probably mount the assembly on it's back and you won't have gravity to keep the belts tight and you will definitely need 2 adjusters on the motor and two each on the pulley brackets also.



More top pulley pictures



The back of the machine. Incidentally the second motor is used to drive the spindle at a single 3000 rpm speed. It is cheaper and more efficient to do it this way than trying to use multiple pulleys get a 100 to 3000 rpm speed range. When this speed is needed for a grinder or chop saw, the spindle pulley is replaced with a smaller one that is slightly larger than the motor pulley.



Step 10, The big plate

If you have already bored the block and finished the spindle there is really just one big job left (assuming that you buy a cross slide), measuring, cutting and drilling the plates that bolt to the engine block head surfaces.

A 1/2" x 12" plate is obviously what I used but it is not for everybody. It was the easiest way for me but such a steel size may not even be available or affordable in many parts of the world

What else could you use?

How about two parallel pieces of bar stock. Two nominally six inch wide pieces *should* be about twelve inches wide. The exact width is not as important as having the outside edges absolutely parallel. Use a metal scraper or file to adjust if necessary

Angle iron could also be made to work. Two pieces of large angle iron would be needed for each engine block. Since we use both the inner and outer sides of the angle iron, the iron may have to be the lighter grade that has parallel instead of tapered sides.

Four pieces of vehicle frame rail will often be the "Developing World" solution.

One of the best ways came from Jeff Hansen of the Yahoo MultiMachine newsgroup. The "doubled" frame pieces (shown earlier) from a big truck. Cut them apart and lap them together (with sand?) for a good sliding fit

By now you have probably realized that I can't tell you how long this plate should be because I don't know how long your block will be since you can use an engine block from a Mercury outboard, a big industrial engine or anything in between.

The first thing to do is to lift the block into place and to measure how high you want the plate to go up on the block. Mine only went half way up because I was afraid of warping the plate by burning a hole in it for the spindle. My fears were groundless because later burning experiments did not warp the plate at all. If I did it again I would extend the plate to the very top of the block and burn holes for the the spindle and the overarm.

Why so long? The more mounting bolts the better. Your MultiMachine may be used for many different kinds of work in the future. You may install a slotter/shaper in the #2 cylinder. You may even add an additional horizontal block to the top of your machine for a vertical "Bridgeport" like spindle.

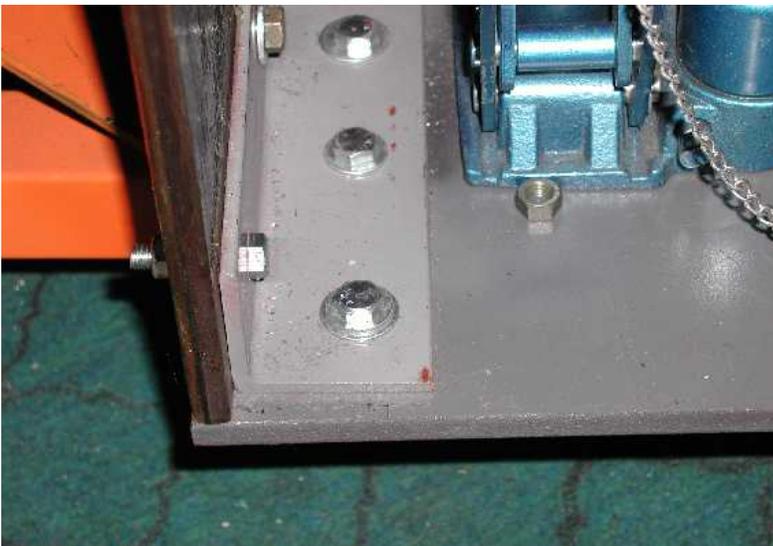


You may also use the #1 cylinder for the spindle if you don't need your machine to be a horizontal mill that would normally use this cylinder for the overarm. eBay makes horizontal mills extremely useful because of the cutters often being available at 95% discount. Even if you don't have access to cheap cutters, a homemade fly cutter is much easier to make than a homemade end mill.

If the block is mounted on a concrete pedestal, the plate could even go down into a pit and then the top of the vertical slide could be as low as floor level.

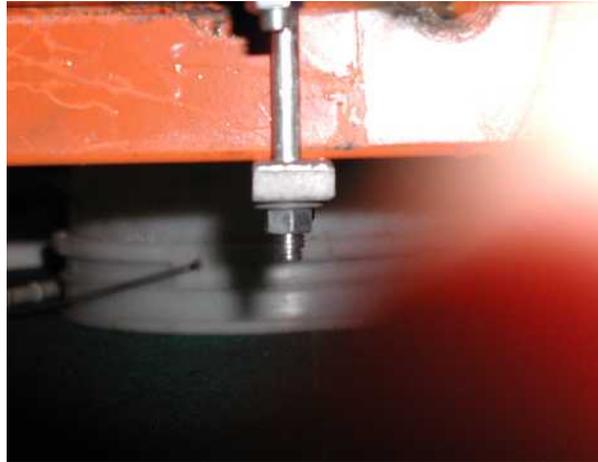
This photograph shows how I did it on my engine stand version. I used a piece of 1/2" x 12" for the baseplate and found that it was useful for suppressing vibration.

A close fit here will also suppress vibration. You also should use a heavier thickness of angle iron than I did. When in doubt about which metal thickness to use, always select the heaviest plate or angle that is practical.



Countersink the holes and use flat head cap screws in the angle iron. Regular hex head bolts always seem to get in the way here.

The base plate was attached to the engine stand using a simple clamp like this.



Important points to remember about the big plate

Flat head 7/16" screws and flat head metric screws are often hard to find. In the USA, McMaster-Carr has them in small lots.

For a totally poor boy way to attach the plate, mark the holes very carefully and drill to the exact size of cheap bolts, counter sink the holes you drilled in the plate, saw the studs off a little long and peen (hammer) the excess into the counter sinks. A heating torch would help here but it is not vital if you work carefully and **use low quality (softer) bolts instead of high strength head bolts.**

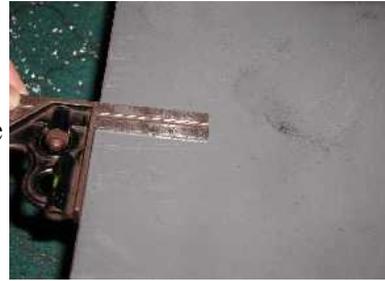
Don't use the end of a plate that has been sheared (chopped off at the steel mill). Shearing is going to distort the end so that it will be difficult to use for our purposes.

Hot rolled plate is often not truly flat. This causes no problem with the MultiMachine. The important thing to remember is that the outer edges and not the center of the two plates make contact. If there is just center contact the table will be able to rock sideways when making a heavy cut. This will cause the machine to chatter. Face the plates so that the edges touch and make these contact areas as smooth as possible. A good way to do this is to carefully degrease the plate and then use a flap type sanding disc on it. This will probably work well enough so that lapping the plates together won't be necessary.

To mark the holes in the plate, put a transfer screw in the top head bolt stud hole you're going to use and also in the bottom one. Measure exactly the distance between the top of the transfer screw point and the bottom transfer screw point. What I actually did was to lay a thin Aluminum bar across the top and bottom transfer screws and lightly tapped to mark the positions. I drilled through these marks with a very small bit to mark the top and bottom hole positions.

I located the top hole position on the big plate and center punched it then dragged (picture below) that measurement down to about where the bottom hole would be.. I scribed a line and then used the aluminum bar with the tiny holes in it to mark the position of the second hole. Check everything again and center punch and drill a shallow 1/8" hole. The easy way to mark the remaining holes is to use a head gasket and a transfer punch. If you don't have a head gasket

or want a more accurate method, then with the block on its back turn the plate over so that the punched and drilled holes face the block and slide the center punched and drilled holes over first two transfer screw points. One reason for drilling the center punch marks is that you have to feel the “clicks” when the transfer screws “fall” into the marked and drilled holes. Keep inserting one transfer screw at a time to mark the rest of the the holes.



When marking these holes be sure to keep your brain in gear so that you punch the right side of the plate.

The vertical slide plate is done in the same way. **Don't forget that many other holes have to be drilled and tapped in the plates for the clamp mechanism.**

Don't use heavy grease between the plates when you assemble the machine. Cool weather will make the grease too sticky and this makes it difficult to raise the vertical slide in small increments.

If all of this seems a little “jackleg”, it probably is but it works extremely well!

Very important! **Where should you mount the jack on your machine?** I really don't know! My outboard jack works beautifully except when I try lower the vertical slide a small amount. I often have to lower it a bit too far and then raise it again to the exact height. The dial indicator is vital here. What should you do? Most “knee” type milling machines have a large acme threaded screw about two thirds of the way out from the inner edge of the vertical slide. It is more complicated on a MultiMachine because the very heavy bed and carriage will probably be offset to the left (facing the machine) side. I suggest you try a small jack such as a scissors jack, weld some kind of a plate on top so that the top of the jack will not fall in a “hole” in the end of the short engine block and try different jack positions until you find the best one.

Step 11, Mounting the big plate

Mounting the plate to the face of the big block is simple but requires great care. Turn the block so that it is in its normal vertical position and line up the holes carefully, don't cross thread!

Don't drop on foot! Your plate could weigh over 120 lbs.

If you use a short plate or need additional reinforcement then put a long coupling nut on the center screws, attach pieces of all thread and add the reinforcing plate on the main bearing pads at the rear of the block.



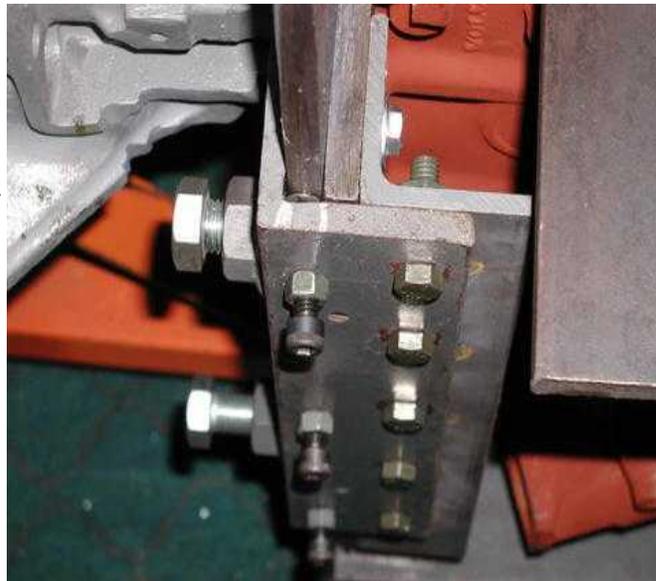
Step 12, The vertical slide

Use almost any short and heavy engine block as the core of the vertical slide.

Mark and drill the 1/2" x 12" plate the same way as the plate for the large block. I used an old head gasket to mark the holes. **Again...remember that many tapped holes for the clamp mechanism needed to be added to both plates. Think ahead!**

The "first" vertical slide clamp

This clamp actually worked well when I used a worn hacksaw blade as a "gib".

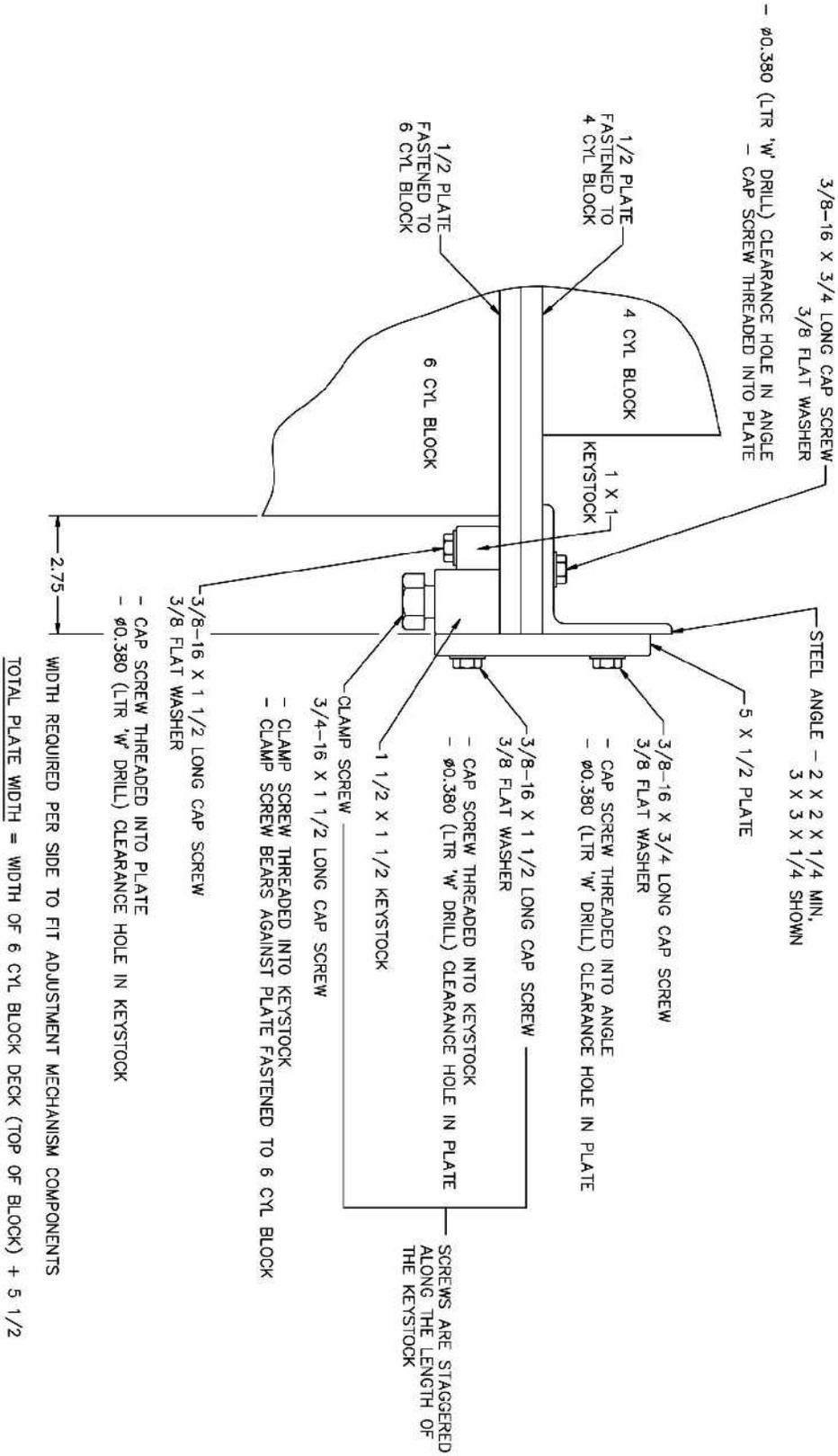


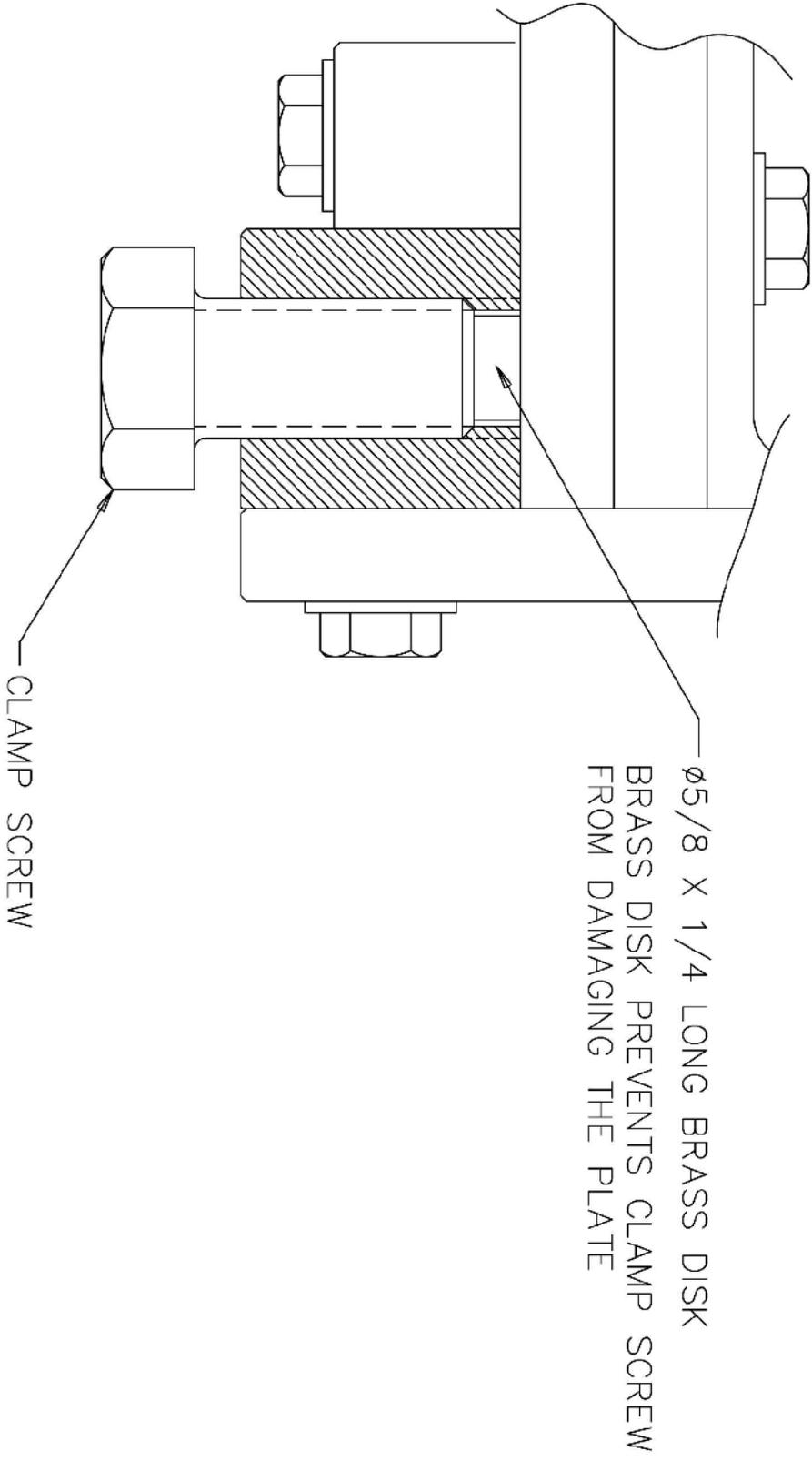
Later I replaced that clamp with this one so that the contact surfaces were only made with smoother and more accurate pieces of three quarter and one inch cold rolled key stock.



The drawings on the next two pages show the current clamp mechanism. By properly adjusting the top and bottom 3/4" clamp bolts (putting a little more pressure on the bottom clamp bolt than on the top) and adding a little pressure with the jack, the vertical slide can be raised in increments of .0001" (by light taps!) and the table does not move when the clamp bolts are tightened!







Step 13, The vertical slide turntable and cross slide

Bigger is better so try for a two foot square table.

The removable machine table top can be a wonderful tool itself. Unlike a store bought tool, you can (with good conscience!) drill and mount holding fixtures and adapters for the cross feed table. When it looks like a swiss cheese, just call it "versatile".

When you mount the top plate to the vertical slide block you probably need to use both transfer punches and transfer screws to properly mark all of the holes.

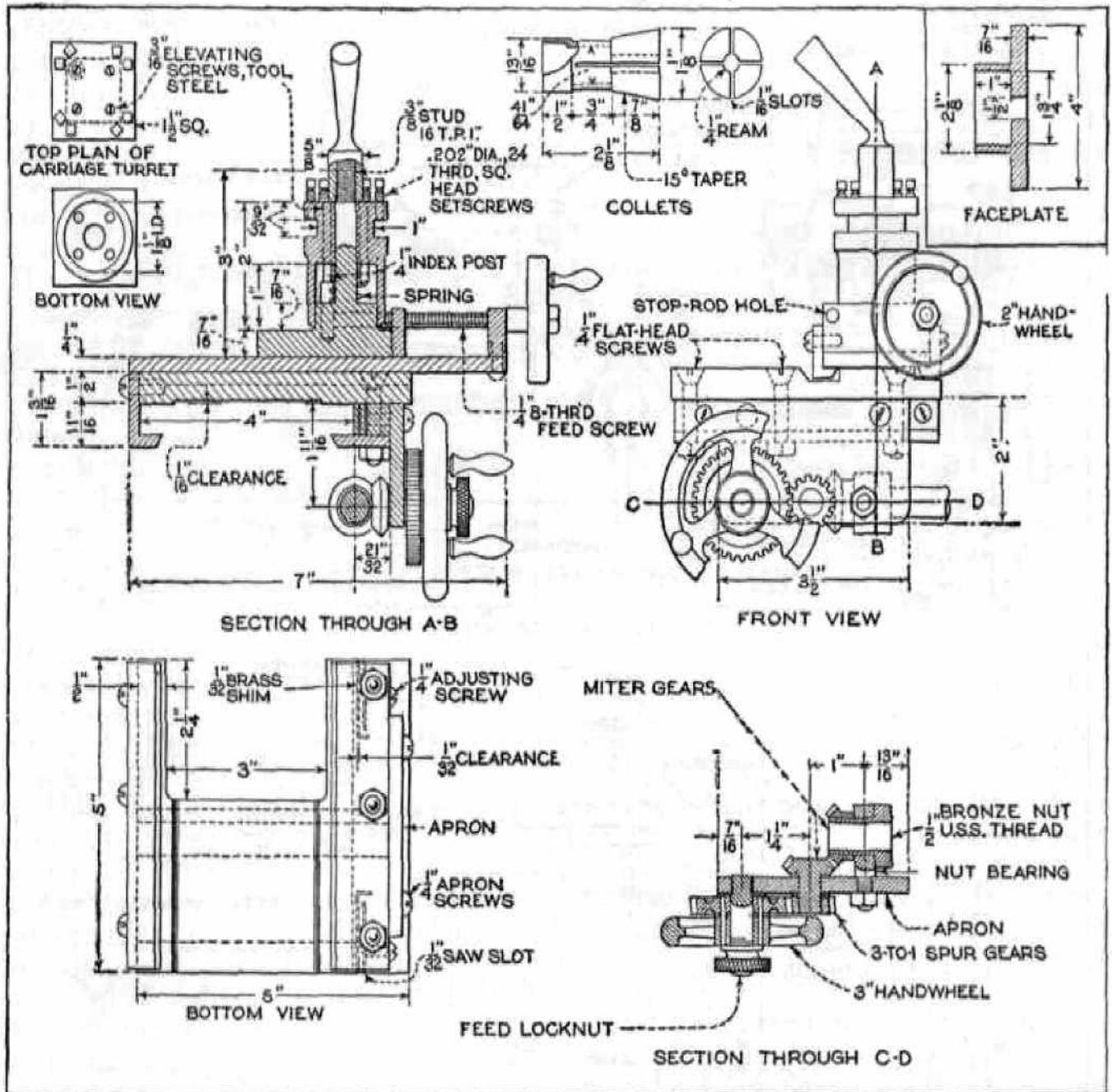
Be sure that there is a 3/4" hole in the center of the plate that will let you turn a commercial cross slide 360 degrees. A "Romig" bed and cross slide will probably be too long to turn. Drill at least two more holes for alternate slide positions. I chose one that was even with the first hole and 6" toward the left as you face the machine and also one closer to the chuck so that the tool post would be close to the center of the cross slide for heavy cuts. Don't forget clearance room for the nuts. Be certain that a cutting tool can cut from the center of the spindle to the edge of the largest faceplate that you are going to use.

This is the smallest of the common commercially available cross slide tables. \$70 in the US but might be many times that much in other countries



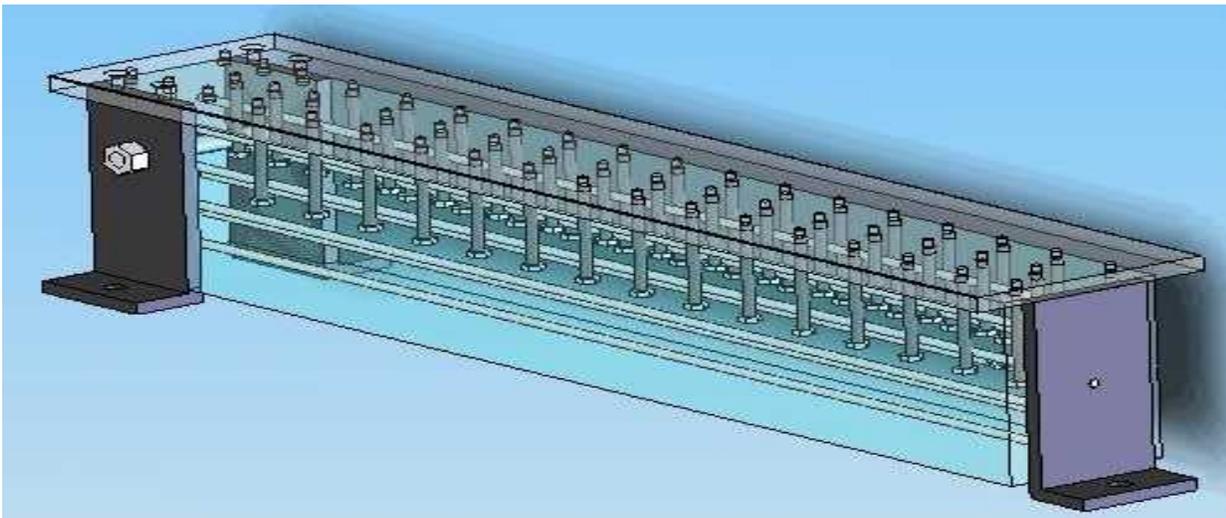
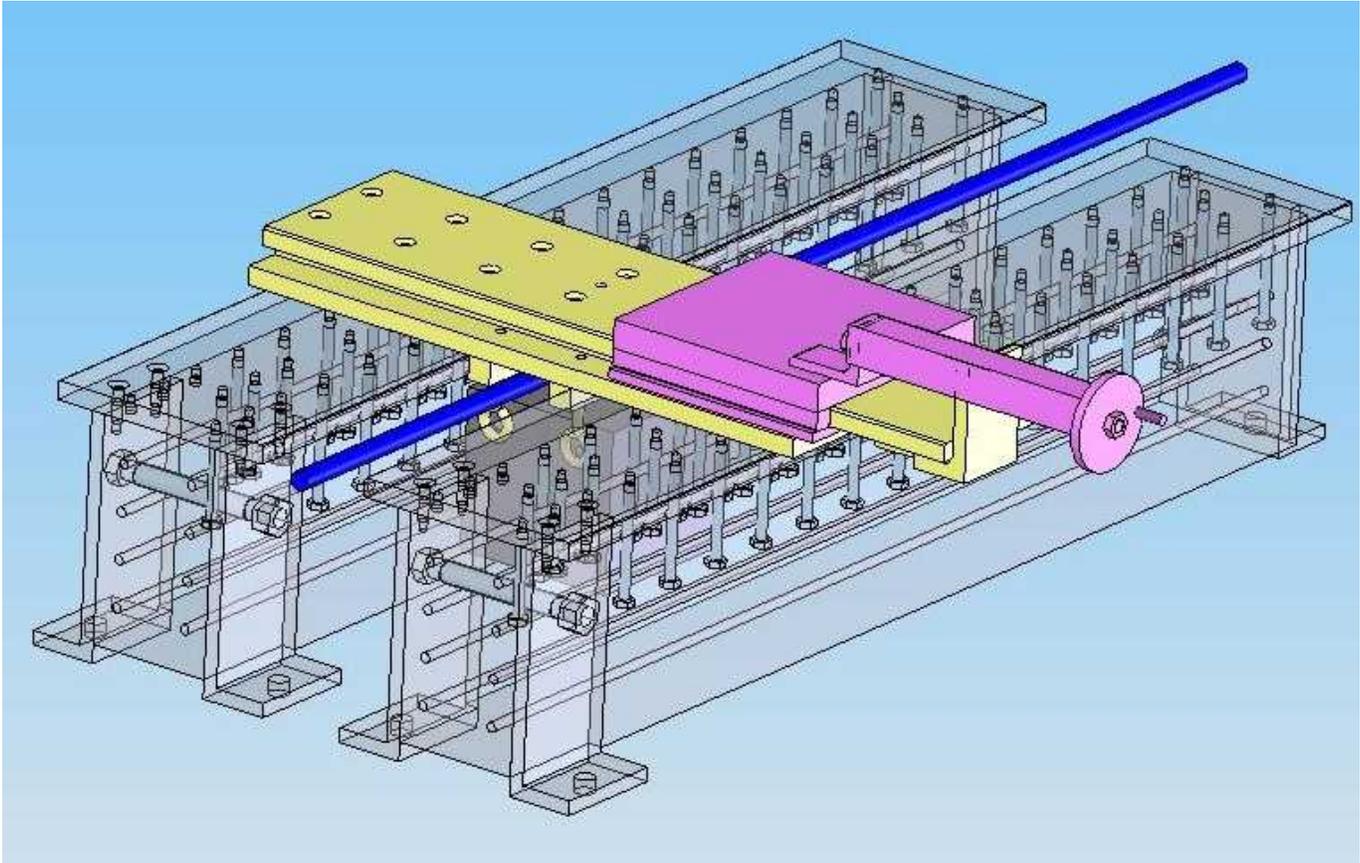
If you use a "store bought" cross slide then mount it on a turntable. The turntable can serve as a lathe compound. If you make the turntable 11.46 inches in diameter then a 36" length of 1/4" tape measure will give you 360 degree graduations at one and a quarter degrees each! **Be sure to check for clearance for bottom cross feed knob. You may have to add a spacer for clearance.**

Building your own cross slide



The original "Romig" turret lathe cross slide (above). Our version (below) clamps the carriage down with a weight along with screwed together pieces of key stock while this much earlier design used pieces of angle iron. What you should do depends on the tools and material that you have available. There is nothing wrong with mixing and matching ideas!

A MultiMachine exclusive! A twin bed version of the 1950's "Romig" "Popular Mechanics" turret lathe bed. Our design spans 120 years, starting with a "weighted carriage" design from 1825. It can be built anywhere cement and steel bar stock is available. The components could even be cut from vehicle frames. It can be built as a single bed version weighing 25 lbs or a dual bed version weighing 40 times that much!

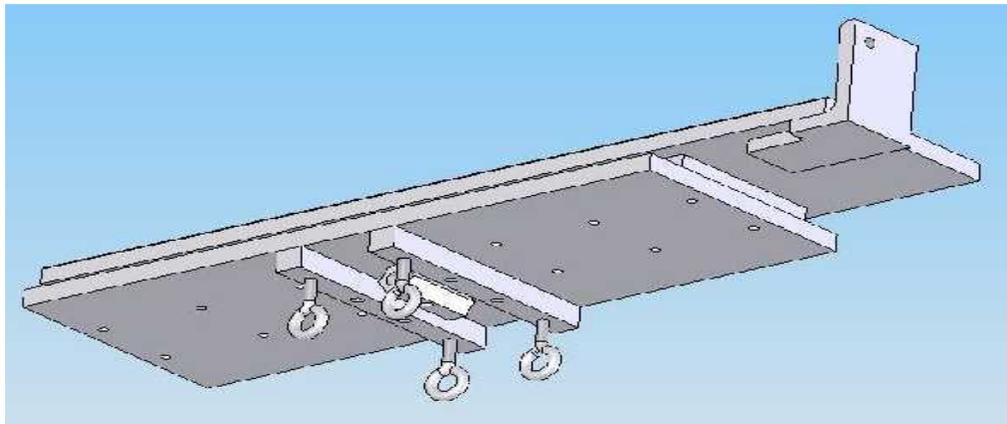


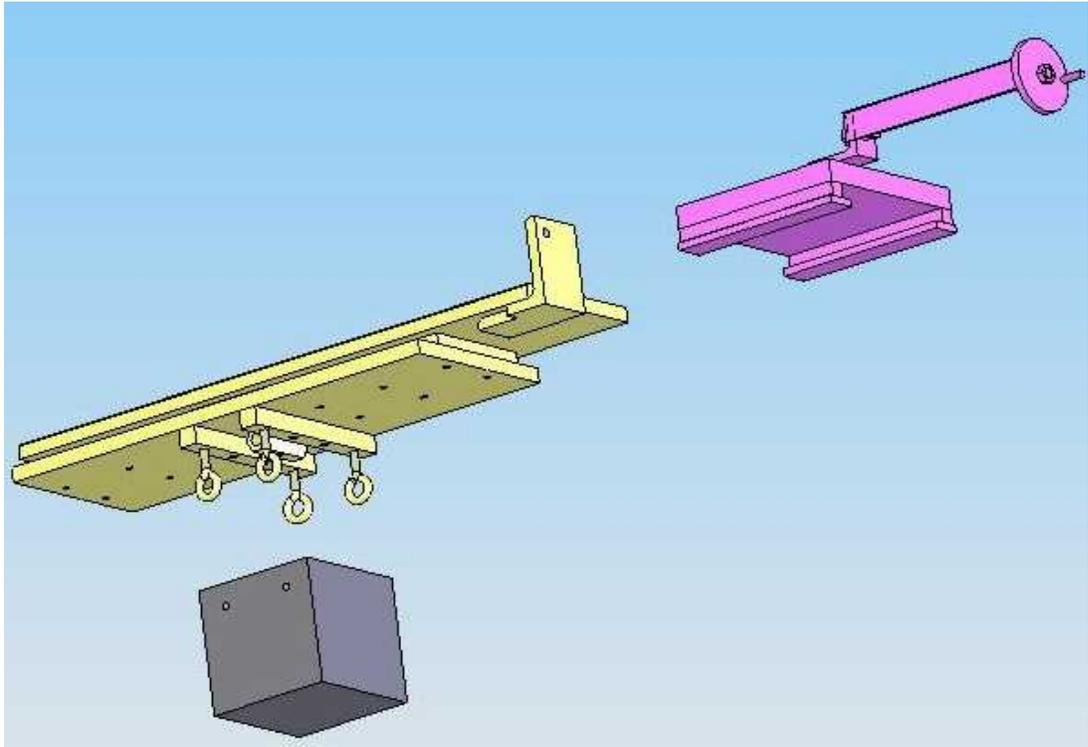
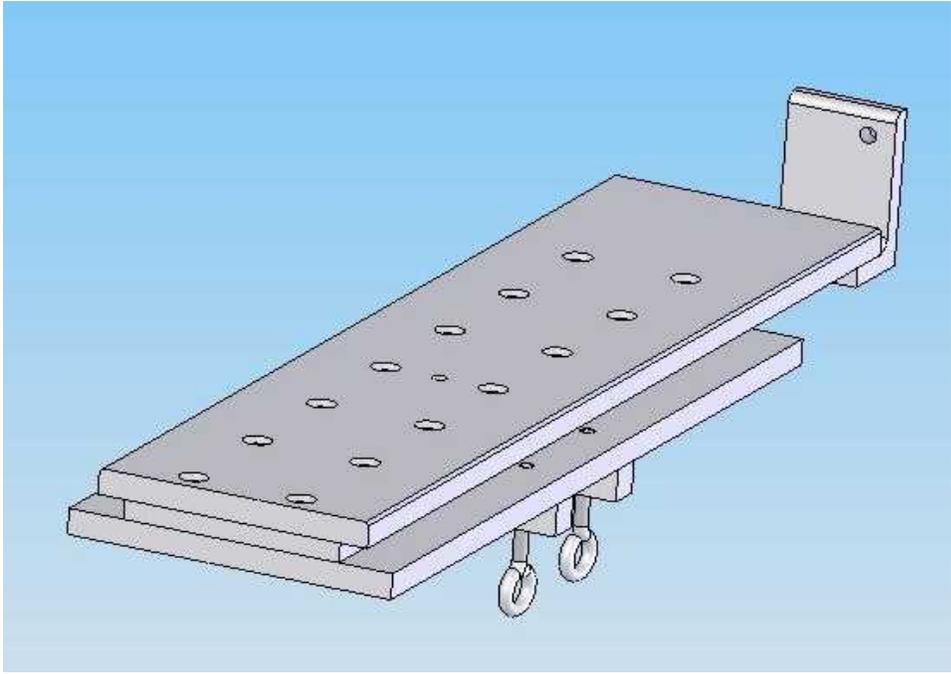
This was taken from the Popular Mechanics magazine article:

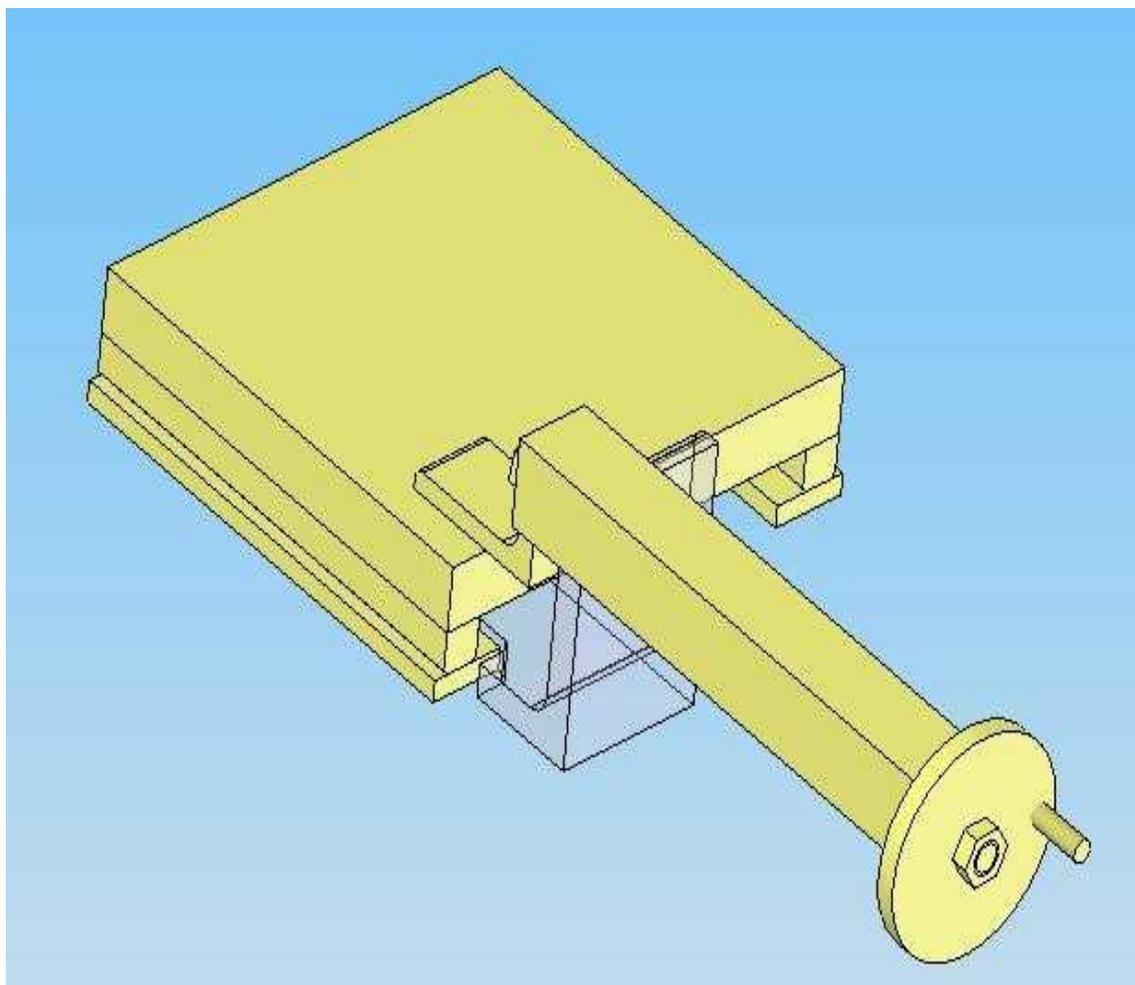
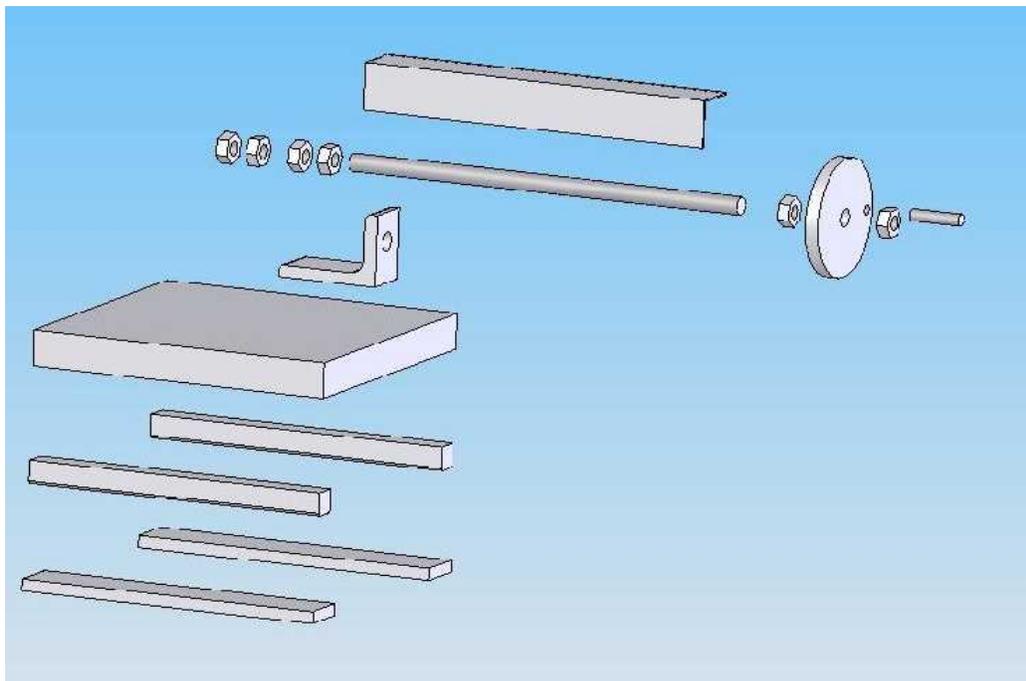
“The construction of the bed is somewhat of a novelty, although it has been thoroughly tried out by the writer in this and other machines, and found to be very satisfactory. This method of making the bed eliminates the hardest work of making a small lathe, as it does away with the bed casting and the necessary machining. A piece of $\frac{1}{2}$ by 4-in. cold-rolled steel, 30 in. long, is used for the shears. This is first drilled and tapped for a number of $\frac{3}{16}$ -in. stove bolts, of varying lengths, which are used to anchor the shears to the cement, also drilled and countersunk for the leg screws and for the $\frac{1}{2}$ -in. headstock bolts. It is next carefully straightened and scraped to a true surface on top and sides, testing the width throughout with a micrometer, and using a knife-edge straightedge on the surfaces; these must be as true and straight as it is possible to make them, as upon their truth depends the accuracy of the lathe. When trued, all surfaces should either be frosted or polished.

The shear anchor bolts should now be screwed home, the pipes, leg and rear leadscrew-bearing bolts placed in position, and a wooden form made to fit closely around shears and legs, in which to pour the cement. The cement used is a mixture of one part Portland cement to three parts clean, sharp sand, mixed with just enough water to enable a handful of the mixture to be picked up and squeezed and to leave the impression of the fingers in it. This cement is tamped down firmly in the form, poking it around the screws and into the corners with an ice pick, or some similar tool. When the concrete has set thoroughly, the boards are removed and the cement thoroughly wetted twice a day for about a week; this will temper the cement, and is a very important part of the work. The resulting bed is as strong as anyone could wish. Reinforcing rods may be laid down in the cement, as it is being placed, or wires twisted throughout the bolts, adding further to the strength of the bed.

The main member of the carriage is made of cold-rolled steel, $\frac{1}{2}$ by 5 by $5\frac{1}{4}$ in. in size, machined as shown in the carriage-detail drawing. A piece of $\frac{1}{4}$ by 2-in. cold-rolled steel, 7 in. long, is fastened to the top of the main member by $\frac{3}{16}$ -in. screws; on this piece the cross slide runs. The cross slide is also made of steel, machined as shown, and is fitted with a turret tool post. The cross slide is held to its ways by means of angle pieces, as shown in the front view of the carriage.” **Your machine will use different dimensions but this is a good explanation of cement and steel construction.**







Step 14, The overarm

These 3/8" clamp bolts are ridiculous, I kept forgetting to order nice ones from ENCO.



Top view of a set of clamps made from an old piece of one inch key stock.

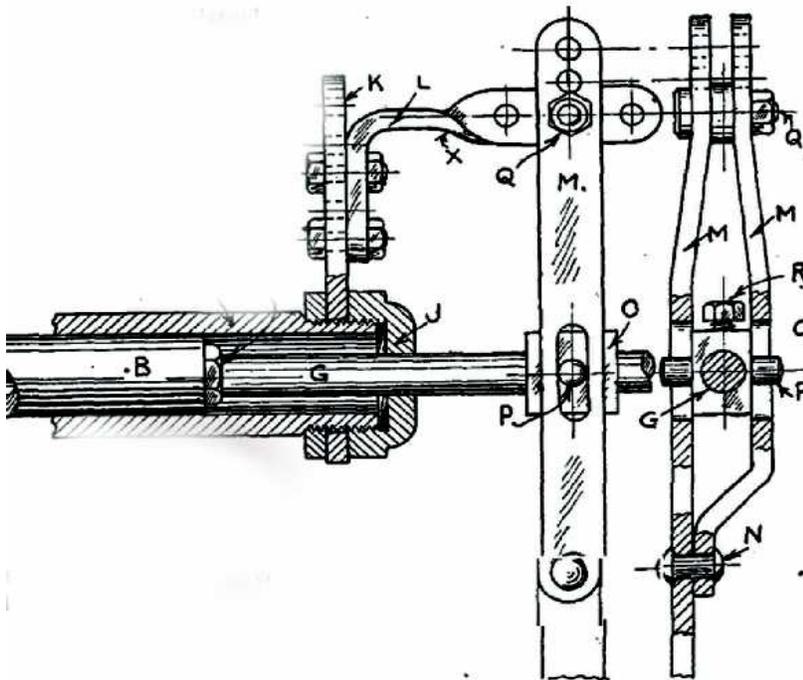
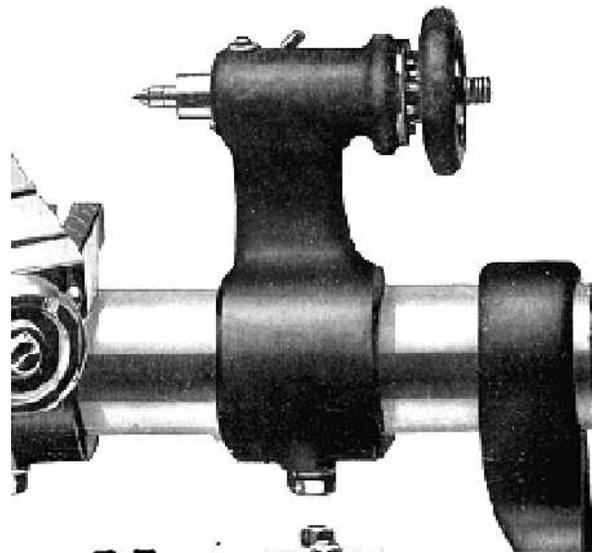


This first "tailstock" was made from an old piece of service station jack that had a 7/8" flange bearing added. For alignment purposes, it was step drilled with bits held in the lathe chuck. It has worked very well for the last three years.

This photo is of an old Drummond round bed lathe tail stock. If it were turned up side down, it would be a great design for a MultiMachine. It was kept in alignment with a “V” shaped key on the bottom of the round bed.

Casting one like this out of ZA-12 would be great.

If you build a “Romig” type bed then add a conventional lathe type tailstock to it. It could be similar to this but would need a flat bottom that would match the “Romig” bed.



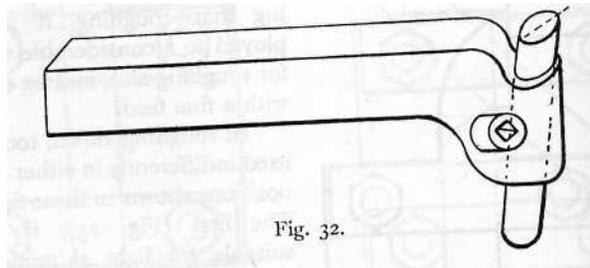
A great lever tailstock that was designed to speed up production in WW 2.

The next few pages cover three tools/techniques that will complete your MultiMachine.

- (1) A “broken bit” cutting tool system that can save hundreds of dollars in tool expense. Even though the included pictures show only round bits, the bits can be ground into conventional cutting tool shapes.**
- (2) An accurate homemade lathe chuck.**
- (3) A very old but accurate way of cutting threads. The MultiMachine Yahoo newsgroup will have plans for a CNC lead screw when one becomes available.**

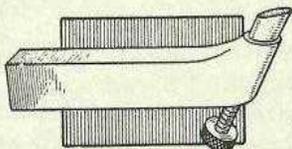
Step 15, Building your own “Broken bit” (tangential) cutting tools

A lathe is not very useful without cutting tools. This very old idea is great because most toolboxes contain the essential ingredient, broken or worn out drill bits! This type of tool works especially well with a MultiMachine since the vertical slide can be raised and lowered to adjust tool height. This makes the adjusters and offset ends that are shown in the next pictures unnecessary.



Converting Broken Drills into Lathe Tools

Broken twist-drill shanks make excellent lathe tools, particularly if the drill happens to be of high-speed steel. A holder for such pieces of broken drill is made as illustrated. A set-screw is placed in the underside of the cutter to be used as an adjustment. This permits using up all but a very small scrap of the steel. Of course the drill shank must be thoroughly hardened for this use.



This is from a 1925 “Popular Mechanics” book.

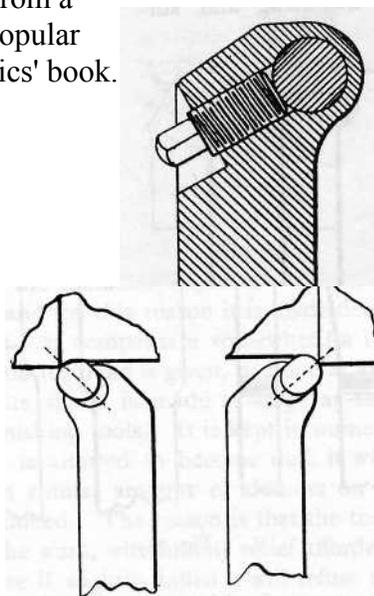
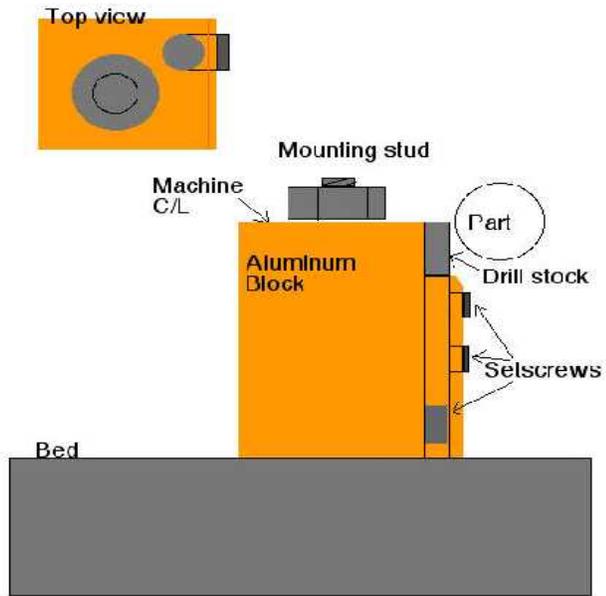


Fig. 33.



A modernized design by Jeff Hansen

A partially completed chuck made from an old engine flywheel



Step 16, Building your own lathe chuck

Accurate Lathe Chuck

Letters on Practical Subjects

MACHINERY MAGAZINE - OCTOBER 26, 1916

The jaws of the average lathe chuck seldom have a bearing for their full length on the piece of work which they are holding, and therefore cannot be depended upon to hold work perfectly square. They may work fairly well while new if they have been perfectly fitted, but they soon wear, and the looseness between the jaws and the chuck body allows them to become bell-

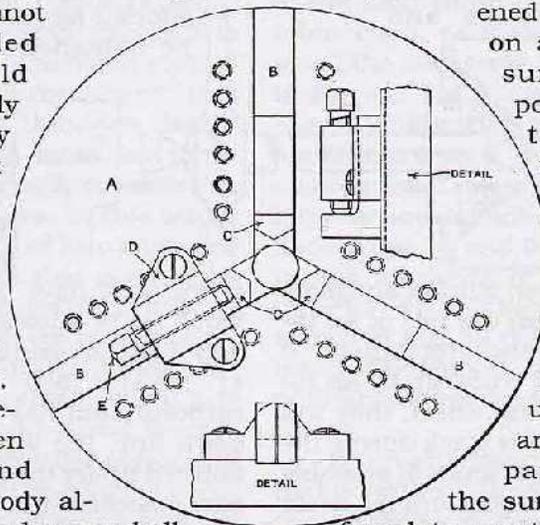
mouthed when tightened on a piece of work. The need of a chuck which could be easily kept true led to the design shown in the accompanying illustration, which shows a set of auxiliary jaws fitted to a bench lathe faceplate. *A* is the faceplate in which have been cut the shallow grooves *B* that the jaws *C* slide in. *D* is the strap which holds the jaws in place and carries the adjusting screw *E*. The strap is held to the faceplate by screws that enter tapped holes, as indicated, spaced to allow for shifting the strap to different positions as shown.

The illustration is clear enough to show the principle, but it is well to note that the chuck jaws and strap are hard-

ened and ground on all wearing surfaces or points of contact, while the grooves in the faceplate are either scraped or ground on the surface grinder until they are perfectly parallel with

the surface of the faceplate, as strap *D* must bind sufficiently on the jaws so that when the screws are drawn tight the jaws will be a tight sliding fit. Special jaws for holding odd shaped or thin pieces can be easily made up, while any wear on the jaw faces can be remedied by regrinding on a surface grinder. While designed originally for use on a bench lathe faceplate for holding pieces that had to be turned, bored or ground accurately, there is no reason why the same principle cannot be applied to heavier work. It would prove cheaper and more accurate than the regular chucks on a large variety of work.

D. B.



Step 17, How to cut threads (90 years ago)

Scientific American Supplement April 16, 1910

HOW TO CUT THREADS

WITHOUT A SCREW-CUTTING LATHE OR THREAD-CHASING TOOL.

by John Bergstrom.

The ordinary way to cut a thread by hand is to use a thread-chasing tool, with the number of teeth per inch wanted. The difficulty in chasing a thread is in the starting. It takes a great deal of practice, and even then a "drunken" thread may be the result.

The accompanying illustrations show how this can be done in a very simple way and yet give an absolutely true thread.

If a number of screws are to be cut the best way to proceed is as follows: Take thin piece of tubing that will just fit over the bar or bolt to be threaded. In one end drill a small hole, into which fasten the end of a spring brass wire, preferably by soldering. Then wind the wire around the tube half a dozen or more turns. Now take a thread gage. Select the number of threads per inch wanted and place it lengthwise of the tube, bringing one turn of wire in each notch, after which pull the free end of the wire and keep it tight. Solder the coils to the tube, using only the corner of the soldering iron; then move the gage one-third of a turn around the tube and repeat the soldering, and finally move the gage again an equal distance and solder.

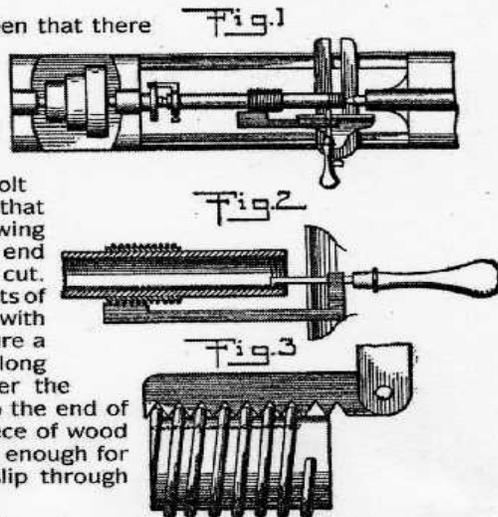
It will now be seen that there is a perfect thread or spiral around the tube, which we will call the master thread. This master thread must be slipped on the bar or bolt

to be threaded, so that it will not turn, allowing enough room at the end for the threads to be cut. The cutting tool consists of an ordinary hand tool, with only one point. Procure a small piece of wood, long enough to reach over the master thread and to the end of the bolt. Into this piece of wood drill a hole just large enough for the cutting tool to slip through and fit snugly.

In operation the cutting tool is held in the right hand, in the usual way. Then with the left thumb press the piece of wood against the master screw and start up the lathe. The master screw will feed the cutting tool the right pitch. As soon as a good start is obtained the tool will feed itself without the aid of the master screw.

When the thread is finished the master screw may be removed and slipped over another bolt to be threaded. The spiral may be wound right or left, according to the direction wanted. Any number of threads may thus be formed. That is to say if a triple or quadruple thread is wanted, it is only necessary to wind three or four wires around the master thread and proceed as before described. This arrangement is also very handy in starting a thread when the ordinary chaser is used, as it will always insure a straight thread. It is not necessary to nick or mark the wooden block, as it readily takes the impression of the thread from the master screw.

Fig. 1 illustrates a plan view of an ordinary lathe, ready to cut a thread. Fig. 2 shows how internal threads may be cut and Fig. 3 shows the master thread.



How to build a really big MultiMachine (or even a “free” metal working factory) by using just common hand tools and vehicle parts!

First though we need some kind of a metal lathe to build a really cheap MultiMachine.

And before that, we need some kind of a drill so let's start from the very beginning, assuming the builder has no money, no electricity and no power drill.

Our “re-discovery” of the “ratchet” drill may be the most important part of the MultiMachine project.

It began with the request from an engineering professor in Kenya for a drill that would drill large holes in steel and aluminum plates that were being used to build and repair agricultural implements. We found a technique that is now almost forgotten but in the period between the middle 1800's and the early 1900's was how most holes were drilled! You did not drill a hole, you ratcheted one! This kind of drill simply breaks down the drilling process into 2 separate parts and changes the usual moderate pressure and high drilling speed to putting great pressure on the drill bit and then turning the bit very slowly by “armstrong” (your strong arm!) power. More work? Sure but can the normal power drill make a 1" hole in a file?



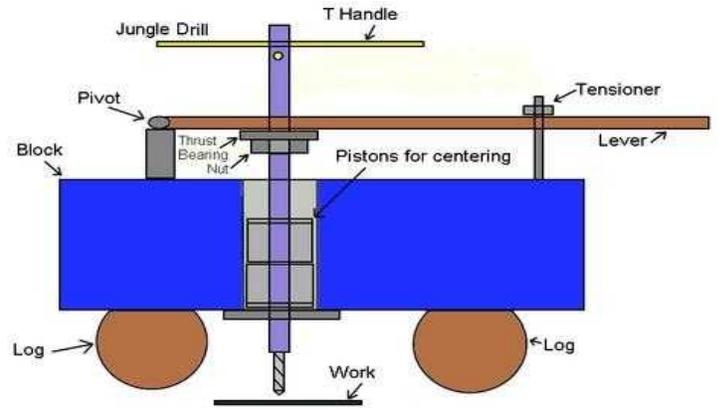
This particular drill was a ratchet drill made by the Cole Tool Company. The power of this type of tool lies in the feed screw that can be tightened down by hand, exerting extreme pressure on the drill point. Materials such as spring, stainless and tool steel can be drilled with by using ordinary high speed steel or masonry carbide type drill bits. The Cole Drill is still useful for drilling large holes in hardened steel or workpieces that are too large for the drill press.

A ratchet drill can be built in many different ways by using the throwout bearing and lever from a manual shift car or truck instead of a harder to build feed screw. The drill bit can be turned with some kind of a handle or a socket wrench ratchet.



One half inch capacity drill chucks are often available for under ten dollars. These are commonly threaded 1/2" x 20tpi so a threading die this size should be part of your tool kit along with good quality taps and drills for 1/4", 3/8" and 1/2". In Metric areas use their metric equivalents. In the USA, ENCO "USA" made “screw machine” bits are low cost and very good quality.

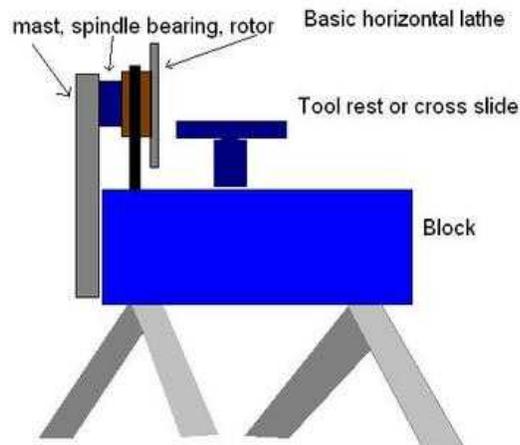
"Cole" type drills may require a very small amount of welding (total bead length is less than 4") but this can be done using a simple temporary welder that can be made by connecting two or three vehicle batteries in series (negative on one battery to positive on the next). The drill spindle assembly can also be made well in advance and the chuck just screwed on to complete construction.



By mixing and matching the ideas above you have many ways to drill the holes needed for a "temporary" lathe and as I said earlier such a lathe will allow you to build almost anything. Why the "temporary" name for a machine that would be useful for years? I had to call it something at first and this name just "stuck"

Once you have the drill the next step is to build the "temporary" lathe.

The reason we need the temporary lathe is for the machining of bushings, spacers, adapters, pulleys. These machined parts that can easily be made from zinc and aluminum alloy lets the builder save most of the money that would be needed to build a regular MultiMachine. These easily cast and machined parts make a much larger machine quite easy and inexpensive (almost free!) to build. A roller bearing with a 5.5"ID could cost thousands of dollars while one made from homemade alloys could cost almost nothing.



A really simple "temporary" lathe, use a hub from a front wheel drive car. The cutting tool can be as simple as a large allen wrench (good steel) ground to the proper shape and attached to a long handle. Blacksmiths used this technique on iron and steel for many years and using it on zinc/aluminum alloy will be much easier. This is another very good reason to learn the basics of tool grinding.

A conventional cross slide will be even easier to work with. If you need too, build a "Romig" type bed and cross slide, or for a faster and easier job, buy a cross slide table from ENCO for \$69 to \$130. If you already have a drill press cross feed vise, perhaps you could lap (use an abrasive paste to gently grind together) the parts together to get a smoother and tighter fit. It may not be rigid enough for machining steel but it may work well on aluminum alloy. If things go wrong, just remelt the aluminum and do it again!

How to build a heavier duty "temporary" lathe

(1) Disassemble a junked engine that came from a manual shift car or truck, remove pistons and rods but leave the crank and flywheel in place. Check the main bearing clearances and add shims to fix any excess play. Remember not to block the oil holes that you need to drill in the main bearing caps. Lubricate with oil through these holes or drill or tap for grease fittings. Drill and tap holes in flywheel for "old time" faceplate clamps (page 11). If you later get a 3 or 4 jaw chuck, then machine the mating grooves in the flywheel/faceplate and just bolt it on. If the only engines blocks you can find have thin automatic transmission type flywheels, you may still be able to machine aluminum or drill holes in steel. Just work gently on the aluminum and make an adapter for a drill chuck that will bolt to the end of the crankshaft. Be on the lookout for a regular flywheel and replace the automatic transmission flywheel if you want to use the machine for heavier work .

(2) Cut one or two (depending on frame width) 4' to 7' long straight pieces of truck frame (or a piece of eight inch wide channel iron) and use the head gasket as a hole guide so that the rail pieces/channel iron can be bolted to the head surface.

(3) Turn block with the bolted on frame pieces upside down so that at least two feet of protruding frame section can be used as a lathe bed.

(4) Bolt on the Romig steel and cement bed or what ever you use for a cross slide, so that top is about 2 or 3 inches below the center of the flywheel. The bed should be offset and located as close to the left edge of the flywheel as possible. Before you permanently attach the cross slide, mount a lathe tool holder and be sure the cutting tool can cut from the center of the flywheel to the outer edge.

(5) Running the lathe with a simple motor and crankshaft mounted pulley arrangement may result in too high a spindle (crankshaft) speed. One way to slow the spindle down is by using the built in reduction of the ring and pinion gears. Gut and cut the starter motor frame (shown below) to convert to flat belt drive and use a timing belt pulley on the motor end. Make a set of aluminum alloy pulleys to get other speeds once the lathe is running.

(6) Use frame parts or angle iron and threaded rod to build an electric motor, bicycle drive or small gasoline engine motor mount. Don't forget that the drive pulleys have to line up so that the bolts that hold the starter together don't interfere with the flat belt. The belt could be a cut to size and glued together serpentine or timing belt.



(7) The tool holder can be a simple steel or aluminum cube with a boring bar hole in one side and a square notch cut in the other. If you have studied cutting tool shapes, you probably think of plenty of cutting tool holders that you can build with just a hacksaw and file.



The big “free” MultiMachine

The non-roller bearing "free" machine may be much larger than the MultiMachine that has just been described. It will probably use removable cylinders (picture on right) that will eliminate the need for machining in the engine and regular machine shops. These cylinders (wet sleeves) are usually found in large truck, industrial and military engines.



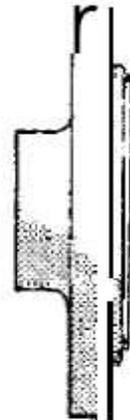
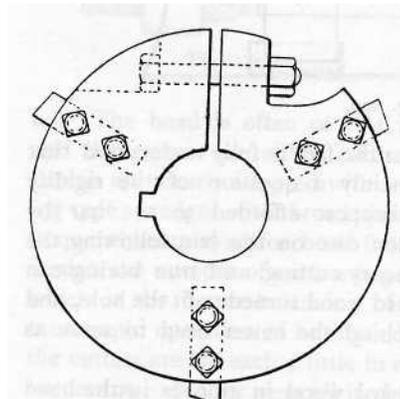
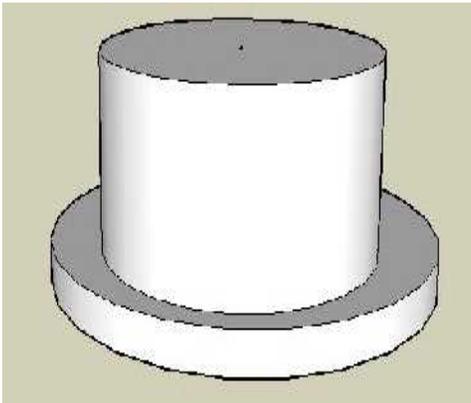
These cylinders can have aluminum alloy liners cast into them and then machined to the right size with the temporary lathe. Sounds like a big job? Sure, but you can make a machine can have the capacity of a machine tool that would cost over a hundred thousand dollars in the USA and several times that elsewhere.

(1) Use a zinc/aluminum alloy as close to ZA-12 as possible or as a second choice, aluminum from an overhead cam cylinder head that does not use separate cam bushings. The assumption here is that the engine manufacturer has chosen a good aluminum bearing material for the head. Heat the cylinder head in a charcoal fire until it is near the melting point and use a big hammer to break it into small pieces. Cast the metal into round sections that can be used for spindle bushings, a thrust bushing and whatever pulleys are necessary for a big MultiMachine.

Except for the steel spindle, simple castings replace each of these parts!



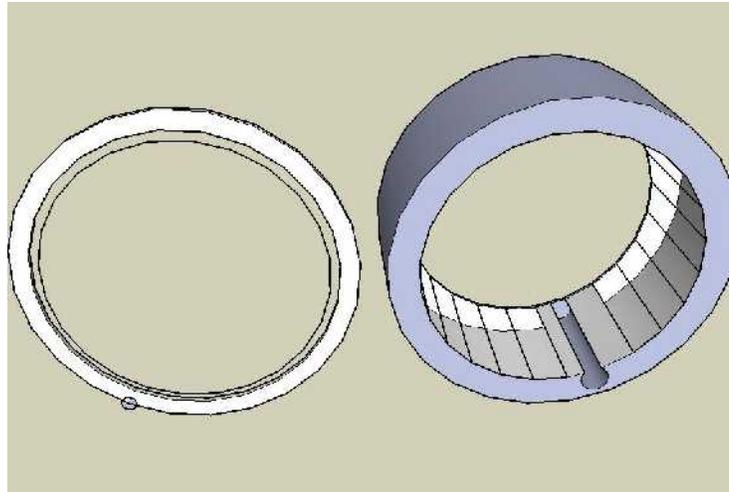
Important! Try to find a large piece of scrap iron or steel to use for the chuck backplate. Many industrial machines use iron castings that look something like this. It would not be difficult to weld up something like this but it may be difficult to machine to size if machinable welding rods are not used.



Find one that can be bored to fit the spindle and still have room to drill two cross bolt holes in the hub to use for clamp bolts. Remember the flycutter picture?(above) Use clamp bolts like these in a long hub.

The spindle bushings should be as long as possible. They may have to be cast and machined in two separate sections. This will make the machining job much easier but could make spindle lubrication more difficult if oil has to pass through one spindle bushing to get to the next one. A solution to this problem would be to have separate oil lines for each bushing section.

Most oil leakage could be stopped by a steel and leather seal fitted to the outer ends of the bushings. A hole could be drilled in the metal part of the homemade seal and a piece of copper tubing oil line soldered in so that it could pass through the seal and line up with the bushing oil groove.



(2) Get the pieces of pipe for the overarm and spindle. For a low cost spindle, try a piece of heavy drive shaft tubing. Since this and most other pipe is not truly round, try to get a light cut taken off (machined on a lathe) whatever pieces of pipe that you are going to use. If you don't have any way to smooth the pipes, remember that the word “lathe” came from “lath”, a thin springy piece of wood used long ago as a way to make a workpiece turn. Just mount the pipe between two wooden supports (trees?), attach a rope to a spring or springy overhead limb, wrap the rope around the pipe a few times and tie the end to some kind of a foot pedal and “pump” away. Polish the pipe with emery cloth as it spins back and forth! Primitive? Sure, but some of the finest woodwork was once done this way.

The rest of the machine could be a much scaled up up version of a regular MultiMachine.

A final word. Using accurately made engine blocks as building blocks and also boring the cylinders to fit the spindle bearings and the overarm means that the core of the machine is accurate. The business end of the spindle is machined in place so that it is also accurate. The cross slide can be done wrong but since it is a “bolt on” module, it can be adjusted or even replaced

Pipe size, metric bearing and Morse Taper specifications
(In the US, try the bearing books at NAPA)

3/4"

[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
3/4	1.050	5	.065	.68	.920
3/4	1.050	10	.083	.86	.884
3/4	1.050	40	.113	1.13	.824
3/4	1.050	80	.154	1.48	.742
3/4	1.050	160	.218	1.94	.612
3/4	1.050	XXHY	.308	2.44	.434

1"

[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
1	1.315	5	.065	.87	1.185
1	1.315		.072	.96	1.171
1	1.315		.083	1.09	1.149
1	1.315		.095	1.24	1.125
1	1.315	10	.109	1.41	1.097
1	1.315		.125	1.59	1.065
1	1.315	40	.133	1.68	1.049
1	1.315	80	.179	2.17	.957
1	1.315	160	.250	2.85	.815
1	1.315	XXHY	.358	3.660	.599

1-1/4"

[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
1 1/4	1.660	5	.065	1.11	1.530
1 1/4	1.660		.072	1.22	1.516
1 1/4	1.660		.083	1.40	1.494
1 1/4	1.660		.095	1.59	1.470
1 1/4	1.660	10	.109	1.81	1.442
1 1/4	1.660		.125	2.05	1.410
1 1/4	1.660	40	.140	2.27	1.380
1 1/4	1.660	80	.191	3.00	1.278
1 1/4	1.660	160	.250	3.77	1.160
1 1/4	1.660	XXHY	.382	5.22	.896

1-1/2"

[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
1 1/2	1.900	5	.065	1.28	1.774
1 1/2	1.900		.083	1.61	1.734
1 1/2	1.900		.095	1.83	1.710
1 1/2	1.900	10	.109	2.09	1.682
1 1/2	1.900		.125	2.37	1.650
1 1/2	1.900	40	.145	2.72	1.610
1 1/2	1.900	80	.200	3.63	1.500
1 1/2	1.900	160	.281	4.86	1.338
1 1/2	1.900	XXHY	.400	6.41	1.100

2"

2-1/2"

[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
2	2.375	5	.065	1.61	2.245
2	2.375		.078	1.91	2.219
2	2.375		.083	2.03	2.209
2	2.375		.095	2.31	2.185
2	2.375	10	.109	2.64	2.157
2	2.375		.125	3.00	2.125
2	2.375		.134	3.21	2.107
2	2.375		.141	3.36	2.093
2	2.375	40	.154	3.66	2.067
2	2.375		.172	4.050	2.031
2	2.375		.188	4.39	1.999
2	2.375	80	.218	5.03	1.939
2	2.375		.281	6.28	1.813
2	2.375	160	.343	7.45	1.687
2	2.375	XXHY	.436	9.04	1.50

[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
2 1/2	2.875		.078	2.33	2.719
2 1/2	2.875	5	.083	2.48	2.709
2 1/2	2.875		.094	2.79	2.687
2 1/2	2.875		.109	3.22	2.657
2 1/2	2.875	10	.120	3.53	2.635
2 1/2	2.875		.125	3.67	2.625
2 1/2	2.875		.141	4.12	2.593
2 1/2	2.875		.154	4.48	2.567
2 1/2	2.875		.156	4.53	2.563
2 1/2	2.875		.172	4.97	2.531
2 1/2	2.875		.188	5.40	2.499
2 1/2	2.875	40	.203	5.80	2.469
2 1/2	2.875		.216	6.13	2.443
2 1/2	2.875		.250	7.01	2.375
2 1/2	2.875	80	.276	7.67	2.323
2 1/2	2.875	160	.375	10.02	2.125
2 1/2	2.875	XXHY	.552	13.71	1.771

3"

[Return to Chart options](#)

3-1/2"

[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
3	3.500	5	.078	2.85	3.344
3	3.500		.083	3.03	3.334
3	3.500		.095	3.45	3.310
3	3.500		.109	3.95	3.282
3	3.500	10	.120	4.34	3.260
3	3.500		.125	4.51	3.250
3	3.500		.141	5.06	3.218
3	3.500		.156	5.57	3.188
3	3.500		.172	6.11	3.156
3	3.500		.188	6.65	3.124
3	3.500	40	.216	7.58	3.068
3	3.500		.250	8.68	3.000
3	3.500		.281	9.66	2.938
3	3.500	80	.300	10.26	2.900
3	3.500	160	.437	14.31	2.624
3	3.500	XXHY	.600	18.58	2.300

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
3-1/2	4.000	5	.083	3.48	3.834
3-1/2	4.000		.094	3.92	3.812
3-1/2	4.000		.109	4.53	3.782
3-1/2	4.000	10	.120	4.98	3.760
3-1/2	4.000		.125	5.17	3.750
3-1/2	4.000		.141	5.81	3.718
3-1/2	4.000		.156	6.40	3.688
3-1/2	4.000		.172	7.03	3.656
3-1/2	4.000		.188	7.65	3.624
3-1/2	4.000	40	.226	9.12	3.548
3-1/2	4.000		.250	10.01	3.500
3-1/2	4.000		.281	11.16	3.438
3-1/2	4.000	80	.318	12.52	3.364
3-1/2	4.000	XXHY	.636	22.87	2.728

4"
[Return to Chart options](#)

5"
[Return to Chart options](#)

NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
4	4.500	5	.083	3.92	4.334
4	4.500		.094	4.42	4.312
4	4.500		.109	5.11	4.282
4	4.500	10	.120	5.62	4.260
4	4.500		.125	5.84	4.250
4	4.500		.141	6.56	4.218
4	4.500		.156	7.24	4.188
4	4.500		.172	7.95	4.156
4	4.500		.188	8.66	4.124
4	4.500		.203	9.32	4.094
4	4.500		.219	10.01	4.062
4	4.500	40	.237	10.80	4.026
4	4.500		.250	11.35	4.000
4	4.500	60	.281	12.67	3.938
4	4.500		.312	13.96	3.876
4	4.500	80	.337	15.00	3.826
4	4.500	120	.438	19.02	3.624
4	4.500	160	.531	22.53	3.438
4	4.500	XXHY	.674	27.57	3.152

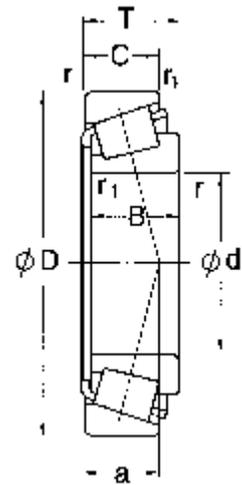
NPS	O.D.	Sch #	Wall	Wt/Ft	I.D.
5	5.563		.083	4.86	5.397
5	5.563		.094	5.49	5.375
5	5.563	5	.109	6.36	5.345
5	5.563		.125	7.26	5.313
5	5.563	10	.134	7.78	5.295
5	5.563		.141	8.16	5.281
5	5.563		.156	9.01	5.251
5	5.563		.188	10.80	5.187
5	5.563		.219	12.50	5.125
5	5.563	40	.258	14.63	5.047
5	5.563		.281	15.85	5.001
5	5.563		.312	17.50	4.939
5	5.563		.344	19.17	4.875
5	5.563	80	.375	20.80	4.813
5	5.563	120	.500	27.06	4.563
5	5.563	160	.625	32.99	4.313
5	5.563	XXHY	.750	38.59	4.063

Morse taper specifications

Morse Taper	Taper	Gauge Line Diameter	Minor Diameter	Taper Length	Angle
0	19.212:1	0.3561" (9.045mm)	0.252"	2.00"	1°29'27"
1	20.047:1	0.4750" (12.065mm)	0.369"	2.126"	1°25'43"
2	20.020:1	0.700" (17.780mm)	0.572"	2.562"	1°25'50"
3	19.922:1	0.938" (23.825mm)	0.778"	3.188"	1°26'16"
4	19.254:1	1.231" (31.267mm)	1.020"	4.064"	1°29'15"
5	19.002:1	1.748" (44.399mm)	1.475"	5.188"	1°20'26"
6	19.180:1	2.494" (63.348mm)	2.116"	7.252"	1°29'36"
7	19.231:1	3.270" (83.058mm)	2.750"	10.00"	1°29'25"

Metric bearing specifications

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METRIC SERIES

Bearing No.	d	D	B	C	T	r _{min}	r _{1min}
30203	17	40	12	11	13.25	1.0	0.3
30204	20	47	14	12	15.25	1.0	0.3
30205	25	52	15	13	16.25	1.0	0.3
30206	30	62	16	14	17.25	1.0	0.3
30207	35	72	17	15	18.25	1.5	0.6
30208	40	80	18	16	19.25	1.5	0.6
30209	45	85	19	16	20.75	1.5	0.6
30210	50	90	20	17	21.75	1.5	0.6
30211	55	100	21	18	22.75	1.5	0.6
30212	60	110	22	19	23.75	1.5	0.6
30302	15	42	13	11	14.25	1.0	0.3

30303	17	47	14	12	15.25	1.0	0.3
30304	20	52	15	13	16.25	1.5	0.6
30305	25	62	17	15	18.25	1.5	0.6
30306	30	72	19	16	20.75	1.5	0.6
30307	35	80	21	18	22.75	1.5	0.6
30308	40	90	23	20	25.25	1.5	0.6
30309	45	100	25	22	27.25	1.5	0.6
30310	50	110	27	23	29.25	2.0	0.6
32204	20	47			19.25	1.0	0.3
32205	25	52	18	15	19.25	1.0	0.3
32206	30	62	20	17	21.25	1.0	0.3
32207	35	72	23	19	24.25	1.5	0.6
32208	40	80	23	19	24.75	1.5	0.6
32209	45	85	23	19	24.75	1.5	0.6
32303	17	47	19	16	20.25	1.0	0.3
32304	20	52	21	18	22.25	1.5	0.6
32305	25	62	24	20	25.25	1.5	0.6
32306	30	72	27	23	28.75	1.5	0.6
32307	35	80	31	25	32.75	1.5	0.6
32308	40	90	33	27	35.25	1.5	0.6
32309	45	100	36	30	38.25	1.5	0.6
32310	50	110	40	33	42.25	2.0	0.6
32004X	20	42	15	12	15	1.0	0.3
32005X	25	47	15	11.5	15	1.0	0.3
32006X	30	55	16	14	17	1.0	0.3
32007X	35	62	17	15	18	1.0	0.3
32008X	40	68	18	16	19	1.0	0.3
32009X	45	75	19	16	20	1.0	0.3

32010X	50	80	19	16	20	1.0	0.3
32011X	55	90	22	19	23	1.5	0.6
32012X	60	96	22	19	23	1.5	0.6
32013X	65	100	22	19	23	1.5	0.6

Glossary

abrasive wheels -

Wheels of a hard abrasive, such as Carborundum used for grinding.

adapter -

A tool holding device for fitting together various types or sizes of cutting tools or other parts to make them interchangeable on different machines.

alloy -

A metal formed by a mixture of two or more different metals.

angle iron -

An iron or steel structural member that has been cast, rolled, or bent (folded) so that its cross section is L-shaped.

angle plate -

A precision holding fixture made of cast iron, steel, or granite. The two principal faces are at right angles and may be slotted for holding the work or clamping to a table.

annealing -

The controlled heating and cooling of a metal to remove stresses and to make it softer and easier to work with.

arbor -

A shaft or spindle for holding cutting tools; most usually on a milling machine.

assembly -

A unit of fitted parts that make up a mechanism or machine, such as the headstock assemble of a lathe.

backlash -

The lost motion or looseness (play) between the faces of meshing gears or threads.

bar stock -

Metal bars of various lengths, made in flat, hexagon, octagon, round, and square shapes from which parts are machined.

bearing -

Rollers, and balls placed between moving parts to reduce friction and wear.

bed -

One of the principal parts of a machine tool, having accurately machined ways or bearing surfaces for supporting and aligning other parts of the machine.

bevel -

Any surface that is not at right angles to another surface. Also, the name given a tool used for measuring, laying out, or checking the accuracy of work machined at an angle or bevel.

bit, tool (cutter) -

A hardened steel bar or plate that is shaped according to the operation to be performed and the material to be machined.

bore -

To enlarge and finish the surface of a cylindrical hole by the action of a rotating boring bar (cutting tool) or by the action of a stationary tool pressed (fed) against the surface as the part is rotated.

boring bar (cutter bar) -

A combination tool holder and shank.

boring tool -

A cutting tool in which the tool bit, the boring bar and, in some cases, the tool holder are incorporated in one solid piece.

broach -

A long, tapered cutting tool with serrations which, when forced through a hole or across a surface, cuts a desired shape or size.

bronze -

A nonferrous alloy consisting essentially of copper and tin.

carbide tool bits -

Lathe cutting tools to which carbide tip inserts have been brazed, to provide cutting action on harder materials than the high speed cutters are capable of.

carriage -

A principal part of a lathe that carries the cutting tool and consists of the saddle, compound rest, and apron.

case hardening -

A heat treating process, basically carbonizing, that makes the surface layer or case of steel substantially harder than the interior or core.

castigated nut (castle nut) -

A nut with grooves cut entirely across the top face.

casting -

A part made by pouring molten metal into a mold.

center, dead -

A center that does not rotate; commonly found on the tailstock of a lathe. Also, an expression for the exact center of an object.

center drill -

A combined countersink and drill used to prepare work for mounting centers.

center, live -

A center that revolves with the work. Generally, this is the headstock center; however, the ball bearing type tailstock center is also called a live center.

center punch -

A pointed hand tool made of hardened steel and shaped somewhat like a pencil.

chamfer -

The bevel or angular surface cut on the edge or a corner of a machined part.

chasing threads -

Cutting threads in a lathe or screw machine.

chatter -

The vibrations caused between the work and the cutting tool which leave distinctive tool marks on the finished surface that are objectionable.

chip breaker -

A small groove ground back of the cutting edge on the top of a cutting tool to keep the chips short.

chipping -

The process of cutting metal with a cold chisel and hammer.

chisel -

Any one of a variety of small hand cutting tools, generally wedge-shaped.

chuck -

A device on a machine tool to hold the workpiece or a cutting tool.

chuck, independent jaw -

A chuck, each of whose jaws (usually four) is adjusted with a screw action independently of the other jaws.

chuck, universal (self-centering chuck, concentric chuck) -

A chuck whose jaws are so arranged that they are all moved together at the same rate by a special wrench.

clearance -

The distance or angle by which one object or surface clears another.

climb milling -

A method of milling in which the work table moves in the same direction as the direction of rotation of the milling center. Sometimes called down cutting or down milling.

cold-rolled steel -

Steel that has been rolled to accurate size and smooth finish when made. In contrast, hot-rolled steel may have a rough, pitted surface and slag inclusion.

collet -

A precision work holding chuck which centers finished round stock automatically when tightened. Specialized collets are also available in shapes for other than round stock.

compound (rest) -

The part of a lathe set on the carriage that carries the tool post and holder. It is designed to swing in any direction and to provide feed for turning short angles or tapers.

coolant -

A common term given to the numerous cutting fluids or compounds used with cutting tools to increase the tool life and to improve surface finish on the material.

counterbore -

To enlarge the top part of a hole to a specific size, as for the head of a socket-head or cap screw. Also, the tool that is used.

countersink -

To enlarge the top part of a hole at an angle for a flat-head screw. Also, the tool that is used.

cross feed -

The feed that operates across the axis of the workpiece or at right angles to the main or principal feed on a machine.

cutting fluid -

A liquid used to cool and lubricate the cutting to improve the work surface finish.

cutting speed -

The surface speed of the workpiece in a lathe or a rotating cutter, commonly expressed in feet per minute (FPM) and converted to revolutions per minute (RPM) for proper setting on the machine.

cutting tool -

A hardened piece of metal (tool steel) that is machined and ground so that it has the shape and cutting edges appropriate for the operation for which it is to be used.

dead center -

See center, dead.

die -

A tool used to form or stamp out metal parts', also, a tool used to cut external threads.

die stock -

The frame and two handles (bars) which hold the dies (chasers) used for cutting (chasing) external screw threads.

A clamping device (lathe dog) used to drive work being machined between centers. Also, a part projecting on the side of a machine worktable to trip the automatic feed mechanism off or to reverse the travel.

dovetail -

A two-part slide bearing assembly used in machine tool construction for the precise alignment and smooth operation of the movable components of the machine.

dowel -

A pin fitted or keyed in two adjacent parts to accurately align the parts when assembling them.

down feed (climb cutting, climb milling) -

A seldom used method of feeding work into milling cutters. The work is fed in the same direction as the portion of the cutter which comes in contact with it.

drill -

A pointed tool that is rotated to cut holes in material.

drill, center -

A combination drill and countersink-

drill chuck -

A device used to grip drills and attach them to a rotating spindle.

drill, twist -

A commonly used metal-cutting drill, usually made with two flutes running around the body.

drill jig -

A jig which holds parts or units of a structure and, by means of bushings, guides the drill so that the holes are properly located.

drill press -

An upright power-driven machine for drilling holes in metal, wood, or other material.

drill rod -

A high-carbon steel rod accurately ground to size with a smooth finish. It is available in many sizes and is used extensively in tool making.

drill sleeve -

An adapter with an internal and external taper which fits tapered shank tools such as drills or reamers to adapt them to a

larger size machine spindle.

drill socket -

An adapter similar to a sleeve except that it is made to adapt a larger tapered-shank tool to a smaller size spindle.

drill, twist -

A commonly used metal-cutting drill, usually made with two flutes running around the body.

drive fit -

One of several classes of fits in which parts are assembled by pressing or forcing one part into another.

ductility -

The property of a metal that permits it to be drawn, rolled, or hammered without fracturing or breaking.

face -

To machine a flat surface, as in the end of a shaft in the lathe. The operation is known as facing.

face milling -

Milling a large flat surface with a milling cutter that operates in a plane that is at right angles to its axis.

faceplate -

A large circular plate with slots and holes for mounting the workpiece to be machined. It is attached to the headstock of a lathe.

facing -

The process of making a flat or smooth surface (usually the end) on a piece of stock or material.

feed -

The rate of travel of a cutting tool across or into the work-, expressed in inches per minute or in inches per revolution.

feed mechanism -

The mechanism, often automatic, which controls the advancing movement (feed) of the cutting tools used in machines.

fit -

The relation between mating or matching parts, that is, the amount of, or lack of, play between them.

fixture -

A production work-holding device used for machining duplicate workpieces. Although the term is used interchangeably with a jig, a fixture is not designed to guide the cutting tools as the jig does.

flange -

A relatively thin rim around a part.

flute -

The groove in a cutting tool which provides a cutting edge and a space for the chips to escape and permits the cutting fluids to reach the cutting edges.

fly cutter -

A single-point cutter mounted on a bar in a fly cutter holder or a fly cutter arbor- used for special applications for which a milling cutter is not available.

follower rest -

A support for long, slender work turned in the lathe. It is mounted on the carriage, travels close to and with the cutting tool, and keeps the work from springing away.

footstock -

Part of an indexing, attachment which has a center and serves the same purpose as the tail stock of a lathe.

force fit -

A fitting which one part is forced or pressed into another to form a single unit. There are different classes of force fits depending on standard limits between mating parts.

gage, feeler (thickness gage) -

A gage consisting of a group of very thin blades, each of which is accurately ground to a specific thickness.

gage, indicating (dial indicator) -

A gage consisting of a dial, commonly graduated (marked) in thousandths of an inch, to which is fastened an adjustable arm.

gage, screw pitch -

A gage consisting of a group of thin blades. used for checking the number of screw threads per unit of distance, usually per inch, on a screw, bolt, nut, pipe, or fitting.

gib -

A tapered strip of metal placed between the bearing surface of two machine parts to ensure a precision fit and provide an adjustment for wear.

hacksaw -

A metal blade of hardened steel having small, close teeth on one edge. It is held under tension in a U-shaped frame.

half nut -

A lever-operated mechanism that resembles a split nut that can be closed on the lead screw of a lathe when threads are being cut.

handwheel -

Any adjusting or feeding mechanism shaped like a wheel and operated by hand.

hardening -

A heat-treating process for steel which increases its hardness and tensile strength and reduces its ductility.

headstock -

The fixed or stationary end of a lathe or similar machine tool.

heat treatment -

The process of heating and cooling a solid metal or alloy to obtain certain desired properties or characteristics.

hex -

A term used for anything shaped like a hexagon.

high-speed steel -

An alloy steel commonly used for cutting tools because of its ability to remove metal at a much faster rate than carbon steel tools.

hole saw -

A cutting tool used to cut a circular groove into solid material.

honing -

The process of finishing ground surfaces to a high degree of accuracy and smoothness with abrasive blocks applied to the surface under a light controlled pressure. and with a combination of rotary and reciprocating motions.

hot-rolled steel -

Steel which is rolled to finished size. while hot. Identified by a dark oxide scale left on the surface.

idler -

A gear or gears placed between two other gears to transfer motion from one gear to the other gear without changing their speed or ratio.

independent chuck -

A chuck in which each jaw may be moved independently of the others.

indexing -

The process of positioning a workpiece for machining it into equal spaces. dimensions. or angles using an. index or dividing head.

indicator -

A precision instrument which shows variations of thousandths of an inch or less when testing the trueness or alignment of a workpiece, fixture, or machine.

jack, leveling -

Small jacks (usually screw jacks) for leveling and holding work on planer beds and similar places.

Jacobs chuck -

Common term for the drill chuck used in either the headstock spindle or in the tailstock for holding straight-shank drills, taps, reamers, or small diameter workpieces.

jig -

A production work holding device that locates the workpiece and guides the cutting tool (see fixture).

key -

One of the several types of small metal objects designed to fit mating slots in a shaft and the hub of a gear or pulley to provide a positive drive between them: also. the name of the T-handle wrench used on chucks.

key seat -

A recessed groove (slot) machined into a shaft or a part going on the shaft (usually a wheel or gear).

knee -

That part of a column of a knee-type milling machine which carries the saddle and the table and provides the machine with vertical feed adjustments.

knurl -

A decorative gripping surface of straight-line or diagonal design made by uniformly serrated rolls called knurls.

knurling -

The process of finishing a part by scoring (pressing) patterns on the surface of the work.

lap -

A tool made of soft metal and charged With fine abrasives for precision finishing of metal surfaces. Also, to perform the operation using a lap

lard oil -

A cutting oil made from animal fats usually mixed with mineral oils to reduce its cost and improve its qualities.

layout -

To locate and scribe on blank stock the shape and size dimensions required to machine or form the part.

lead screw -

The long, precision screw located in front of the lathe bed geared to the spindle, and used for cutting threads. Also, the table screw on the universal milling machine when geared to the indexing head for helical milling.

lip of a drill -

The sharp cutting edge on the end of a twist drill.

live center -

See center, live.

machine tool -

A power-driven machine designed to bore, cut, drill, or grind metal or other materials.

machining, Finish -

Machining a surface to give it the desired finish.

machinist -

A person who is skilled in the operation of machine tools. He must be able to plan his own procedures and have a knowledge of heat-treating principles.

mild steel -

A term used for low-carbon machine steel.

mill -

A milling machine; also, the act of performing an operation on the milling machine.

milling, climb -

See climb milling, milling, face-See face milling.

Morse taper -

A self-holding standard taper largely used on small cutting tools such as drills, end mills, and reamers, and, on some machines, spindles in which these tools are used.

normalizing -

Process of heating a ferrous metal or alloy to above its critical temperature and cooling in still air to room temperature to relieve Internal stresses.

off center -

Not centered; offset, eccentric, or inaccurate.

oil hardening -

The process of quenching in oil when heat treating alloy steel to bring out certain qualities.

overarm -

The support for the end of a milling cutter which is on the opposite side of the cutter from the spindle and column.

parting -

The operation of cutting off a piece from a part held in the chuck of a lathe.

peen -

To draw, bend, or flatten, also, the formed side of a hammer opposite the face.

pilot hole -

A starting hole for large drills to serve as a guide, reduce the resistance, and aid in maintaining the accuracy of the larger hole. Also called a lead hole.

play -

The looseness of fit (slack) between two pieces press fit-See force fit.

punch, prick -

A solid punch with a sharp point, used to mark centers or other locations on metal.

quench -

To rapidly cool heated metal in water, oil brine, or air in the process of heat treating.

radial -

In a direction directly outward from the center of a circle or sphere or from the axis of a cylinder. The spokes of a wheel, for example, are radial.

ram -

That part of a shaper which moves back and forth and carries the tool head assembly.

running fit -

A class of fit intended for use on machinery with moderate speeds, where accurate location and minimum play are desired.

scraper -

A hardened steel hand tool used to scrape surfaces very smooth by removing minute amounts of metal.

scribe (scribe; scratch awl) -

A steel rod 8 to 12 inches long and about 3/16 inches in diameter. It has a long, slender, hardened steel point on one or both ends.

set screw -

A plain screw used principally for locking adjustable parts in position.

setup -

The preparation of a machine tool to complete a specific operation. It includes mounting the workpiece and necessary tools and fixtures, and selecting the proper speeds, feeds, depth of cut and coolants.

shims -

Very thin sheets of metal made in precise thickness and used between parts to obtain desired fits. Sometimes they are laminated, to be pulled off to the desired depth.

shoulder -

A term for the step made between two machined surfaces.

slitting saw -

A narrow milling cutter designed for cutoff operations or for cutting narrow slots.

slotter -

An attachment which operates with a reciprocating motion. Used for machining internal slots and surfaces.

soft hammer -

A hammer made of brass, copper, lead, or plastic to a non-marring finished surfaces on machines or workpieces.

spindle -

A rotating device widely used in machine tools. such as lathes., milling machines, drill presses, and so forth, to hold the cutting tools or the work, and to give them their rotation.

spindle speed -

The RPM at which a machine is set. See cutting speed.

square, solid (toolmaker's tri square) -

A very accurate try square in which a . steel blade is set firmly into a solid, rectangular-shaped handle so that each edge of the blade makes an angle of exactly 90" with the inner face (side) of the handle.

steady rest -

A support that is clamped to the bed of a lathe used when machining a long workpiece. Sometimes called a center rest.

step block -

A fixture designed like a series step to provide support at various heights required for setups.

stock -

A term for the materials used to make parts in a machine tool. Also, the die stock used for threading dies.

surface grinding -

The process of grinding flat surfaces on a surface grinding machine. With special setups, angular and form surfaces may also be ground.

swing -

The dimension of a lathe determined by the maximum diameter of the work that can be rotated over the ways of the bed.

tailstock -

That part of a machine tool. such as a lathe or cylindrical grinder which supports the end of a workpiece with a center. It may be positioned at any point along the way of the bed, and may be offset from center to machine tapers.

tang -

The flat on the shank of a cutting tool, such as a drill, reamer or end mill, that fits a slot in -the spindle of a machine to keep the tool from slipping. Also, the part of a file that fits into a handle.

tap -

A tool used to cut threads on the inside of a round hole.

taper -

A uniform increase or decrease in the size or diameter of a workpiece.

tapping -

The process of cutting screw threads in a round hole with a tap (an internal thread cutting tool).

T-bolt -

Term for the bolts inserted in the T-slots of a worktable to fasten the workpiece or work-holding device to the table.

tempering -

A heat-treating process to relieve the stresses produced when hardening and to impart certain qualities, such as toughness-, sometimes called "drawing."

template -

A pattern or a guide for laying out or machining to a specific shape or form.

tensile strength -

The property of a metal which resists force applied to pull it apart.

thread -

A helical projection of uniform section on the internal or external surface of cylinder or cone. Also, the operation of cutting a screw thread.

throw -

The crankpin on a crankshaft. Also, the length of the radius of a crank, an eccentric, or a cam.

tool steel -

A general classification for high-carbon steel that can be heat treated to a hardness required for metal cutting tools such as punches, dies, drills, taps, reamers, and so forth.

truing -

The act of centering or aligning a workpiece or cutting tool so that an operation may be performed accurately. Also, correcting the eccentricity or out of round condition when dressing a grinding wheel.

T-slot -

The slots made in the tables of machine tools for the square-head bolts used to clamp the workpiece,, attachments, or work-holding fixtures in position for performing the machining operations.

two-lip end mill -

An end milling cutter designed with teeth that cut to the center so that it may be used to feed into the work like a drill.

Ways -

The flat or V-shaped bearing surfaces on a machining tool that guide and align the parts which they support.

wheel dresser -

A tool or device for dressing or truing a grinding wheel.

work -

A common term for a workpiece or part being machined.

Apology, this came from a unknown engineering site.