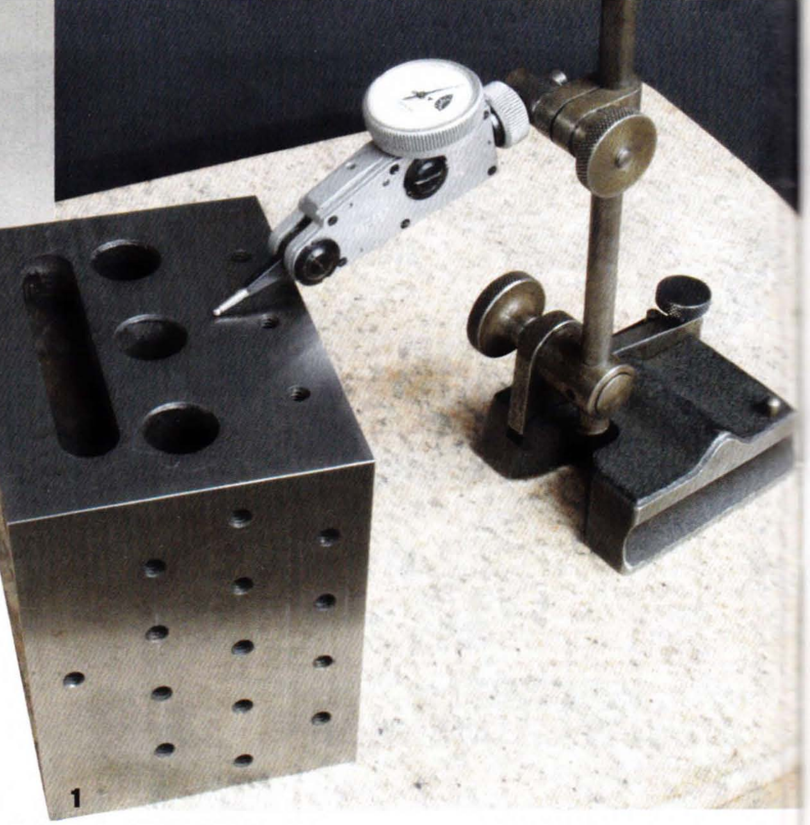
SCRAPING for the Home Shop

Part One

BY MICHAEL WARD

A how-to guide for those home shop practitioners wanting to expand their capabilities using this most basic and versatile technique.



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Enjoyment of workshop activities often means improving workmanship – challenging our accuracy and abilities. One fateful day (fateful for me, given the years of work involved after the light bulb flickered and I had a thought to write an article on scraping) I was carefully checking a toolmaker's block I'd been grinding. With a 10ths indicator and surface plate, I was checking the block for parallelism and squareness, as you can see in Photo 1. This is challenging work simply because 1/10,000th of an inch is awfully small and seems elusive while bumbling about with comparatively massive tools.

I noticed a variance in readings that I didn't understand. After some initial head scratching, I realized that applying pressure on the base of the surface gauge moved the indicator's needle, suggesting that the base was rocking, or otherwise not in solid contact with the surface plate. The first step was to check cleanliness; the presence of dirt or a chip could be the culprit. After a quick cleaning, the rocking persisted.

This nice old surface gauge wasn't as sure footed as it should be and it was causing the inconsistent readings. Correcting this problem, getting the bottom of the gauge flat to a very high degree of accuracy, is tricky business unless the practitioner has added scraping to his repertoire. Even with a surface grinder it's not a straightforward job, given the awkward shape of the base and lack of a convenient surface to hold it by. Rectifying this error to the highest standards, to as high a standard or better than careful surface grinding can do, is a quick and routine task for someone equipped for scraping.

This article will take us through the knowledge and tools required to handle many tasks around the shop and hopefully show that scraping is a versatile addition to home shop benchcraft. This isn't an account from a grizzled veteran of hand-fit machine tool manufacturing; I've not scraped as a vocation and I know many who are more experienced in the subject. However, I forged ahead, believing this simple goal was achievable with my modest home shop learnings: to remove the mystery of scraping and get anyone so inclined confident and proficient at scraping in the home shop.

THE HOME SHOP FOCUS

Scraping is a time consuming endeavor, often focused on fixing items or making precision items that could otherwise be readily purchased. For example, a commercial shop has expensive precision angle plates and surface grinders to get things square or parallel, or will buy new because making it or fixing it has a real cost to them in terms of overhead. In our home shops, the time is spent because we enjoy making things and the consideration isn't about covering overheads, but rather toward reducing total disbursements and improving capabilities and accuracy. Of course, the techniques care not whether they're applied in our garages or an industrial unit, but this piece is written for, and oriented to, us home shop types.

Let's start with what these ramblings will cover: The basic tools and techniques required will be explored, as well as details on making both steel and carbide scrapers. We'll build a rotary lap to easily put on the keen edge that is so critical to scraping. We'll also walk through a number of practical projects including:

- Cleaning up a casting – creating a datum surface.
- The ultimate woodworking plane sole.
- A shaper block – scraping for parallelism.
- Scraping in a machine vise – scraping for parallelism and squareness.
- A toolmaker's cube – high precision work and squareness without a reference square.
- V-blocks and scraping angles.

There are also two machine tool scraping projects that should cover the basics of V-ways and dovetails. The dovetail piece focuses on a mini-mill; an item present in so many shops and, by all accounts, often in need of bearing surface improvement.

This is an extensive piece with lots of photographs. I hope that does not try the patience of non-scrapers too much. Barbeque grill style assembly instructions aren't for me; I enjoy excursions into different shop subject matter, believing it greatly enhances sharing of knowledge and learning (for both of us – as these forays often force confirming research on my part). There are a lot of techniques and information on fundamentals that hopefully will be of interest to non-scrapers – and maybe even convert a few of you.

Digital photography has made it so convenient to include photographs of various shop practices. What once was endless prose is now easily brought to life with pictures. This makes learning faster and more interesting, which is good. The downside, for the author at least, is that everything must be done in real-time, creating a considerable project burden; I scraped and photographed these projects for you and this article, so you're stuck with a lot of photographs!

SCRAPING'S A BASIC WORKSHOP SKILL

Anybody can scrape. Many skilled machinists and tool and die makers are aware of scraping's capabilities, but modern shop realities mostly preclude their learning and practicing it. Lesser shop beings erroneously conclude, "Wow, if old Joe reveres scraping potential but can't do it, it must be the stuff of wizards."

There seems to be some mystery and intrigue surrounding the subject. Occasionally, I hear it referred to as an art and often with reverence as if it's the exclusive purview of grizzled old scraping hands, blackened head to toe in cast iron dust. This has always struck me as nonsense and is one of the reasons why I wanted to write this article; it's not an art. It's a workshop technique that is not too difficult and one with countless home shop applications.

In its basic application, scraping is not much more cerebrally demanding than, say, tapping or laying out a hole. I say cerebral, as scraping is more physically demanding; it will take more effort and time. However, it's not unpleasant work. On bigger jobs, until fatigue sets in, it's sort of relaxing shop time, in a meditative sort of way. Very Zen like.

That doesn't mean it is all easy; machine tool reconditioning especially can be one of, if not the most, challenging and complex undertakings we'd take on. It is complex because a multitude of surfaces have to be brought into precise relationships with one another; however, the underlying act of scraping each surface flat is relatively simple.

Machine tool reconditioning is the granddaddy of scraping complexity, but by the time we're finished here, you will have a good sense of how it is done and we'll have looked in detail at some machine tool scraping of V-ways and dovetails. Many will never recondition a machine tool but the same techniques apply to any bearing surface (i.e., dovetails) you might make. This creates a dramatic rise in your abilities to make beautifully fitting and working bearing surfaces in other projects. After all, these mechanical elements appear in all sorts of projects other than machine tools.

Regarding machine tool reconditioning, this is but an introductory glimpse. There is enough meat on the bone here to get the enthusiast started. For those looking for more thorough and advanced coverage, consider obtaining the tome of machine tool scraping; Edward F. Connelly's book "Machine Tool Reconditioning." This article does not attempt to replicate the extensive coverage Connelly gives, a task I'm unqualified for in any event.

SCRAPING – WHAT IS IT?

Scraping is a technique that can be done using hand tools to remove material from a workpiece in a precise manner, such that the workpiece ends up matching a master or reference to a very high degree of accuracy. As the reference, such as a surface plate, is very accurate, the workpiece ends up almost as flat. Also, the depth of cut when scraping is extremely small; it can be less than a 1/10th of a thousandth of an inch (.0001") with finish work, so the highs and lows on the work aren't very far apart. The scraped surface is brought, by comparison, to the same flatness as the reference and the highs and lows on the scraped surface will have less than .0001" or so variance.

There are lots of interesting tricks and techniques that we can deploy to manipulate this simple premise so that entire machine tools can be made with incredible accuracy. However, at its heart it is a simple process of hand machining a workpiece to closely match a reference such as the surface plate.

What makes scraping so accurate and versatile is that unlike other processes, such as various forms of abrading like grinding or lapping, the material removal is very localized; the process directs and lets us remove material from specific spots on the work. This is done by comparing the work against something we know is very flat, like a surface plate. We apply to the surface plate a thin layer of marking medium, what we call blue, which is sort of like a blue oil paint that doesn't dry. We then place the object to be scraped onto the blued area of the plate and move it back a forth a bit. When you lift it up, it will have blue on it where it contacted the plate.

This is valuable information! It tells us the locations that were the highest and thus made contact with the blue. These will need to be lowered to bring the surface of the work closer to a single plane. We take a scraper, a hand tool that takes a very light cut, and scrape away a small amount of material where the work shows the blue. As a scraper removes such a very small amount of material, we are gently and gradually bringing things into the same plane of the reference. We go through multiple iterations of placing the work on the surface plate to mark it with blue and then scraping

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away the areas that show blue. As the depth of cut is so small, the difference between the highs and lows of the work are extremely small, meaning we can replicate the flatness of the surface plate to a very high degree of accuracy over a large area. Shout *"Hooray!"*, as getting larger areas very flat is not trivial!

That's a statement to ponder; getting things really flat is not trivial. In fact, it is very difficult. In discussions with those new to or unfamiliar with scraping, I often think this point has not registered, but it is a cornerstone of why scraping is so valuable. Even armed with a grinder, as you shall soon see, getting surfaces very flat can be a real challenge, whereas scraping readily affords a way to get surfaces as flat as your surface plate with only hand tools.

All of the work herein is based on comparing to a known reference; a surface plate for example. You may be interested to know that perfectly flat reference surfaces and squares can also be created without any reference. This can done using three plates or three squares, A, B, and C. Joseph Whitworth invented the three plate scraping process in the nineteenth century.

The process is simple but time consuming. Start by defining A as the reference. Scrape B and C to match it. Then, select B as the reference and scrape A and C to match. Then, select C as the reference, etc. Continue this process until A, B, and C match perfectly, then all three will be perfectly flat. You must work with square shapes and there is a requirement to rotate the plates as well.

While interesting to know, unless you are on a deserted island it strikes me as masochistic to take on original generation when surface plates are readily available...and who doesn't already have several lifetimes of projects stacked up? Then again, that's my view; we all approach things differently and if original generation attracts, have at it and make that wonderful engineer Sir Whitworth proud.

Photo 2 shows a homemade scraper forged from an old file, while Photo 3 shows two models of the Anderson Scraper, each with steel scraper blades mounted and with carbide blades also shown. Photo 4 shows some smaller bench scrapers used in conjunction with an angle gauge I made. More on these later.

One of the interesting features of a scraped surface is how perfectly smooth it feels to the touch, yet how rough and jagged it looks to the eye (Photo 5). I like showing the un-initiated a freshly scraped surface and watching the amazement when the super smooth feel under hand betrays the eye's expectation. The first time you scrape a surface I'll bet you'll feel the same.

While each movement of the scraper might only take off .0001" or so of material, it does so at a

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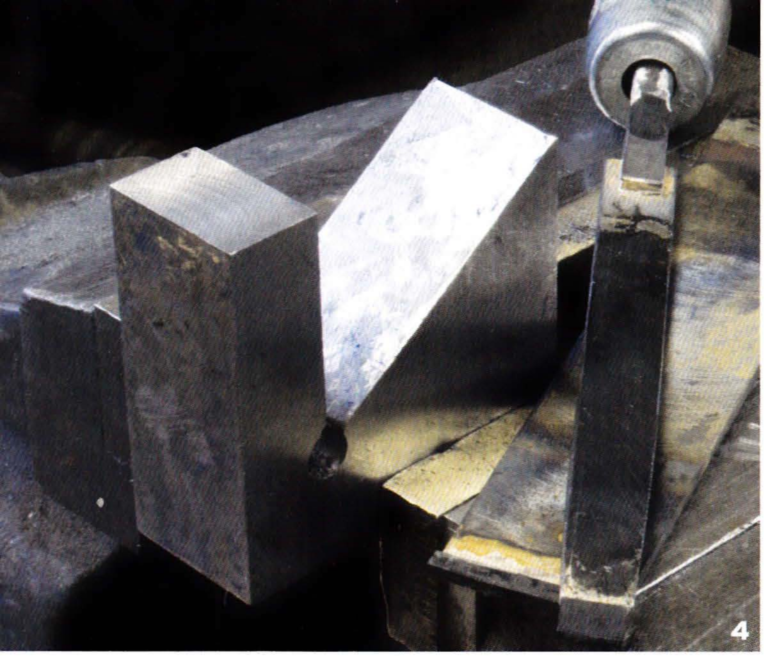

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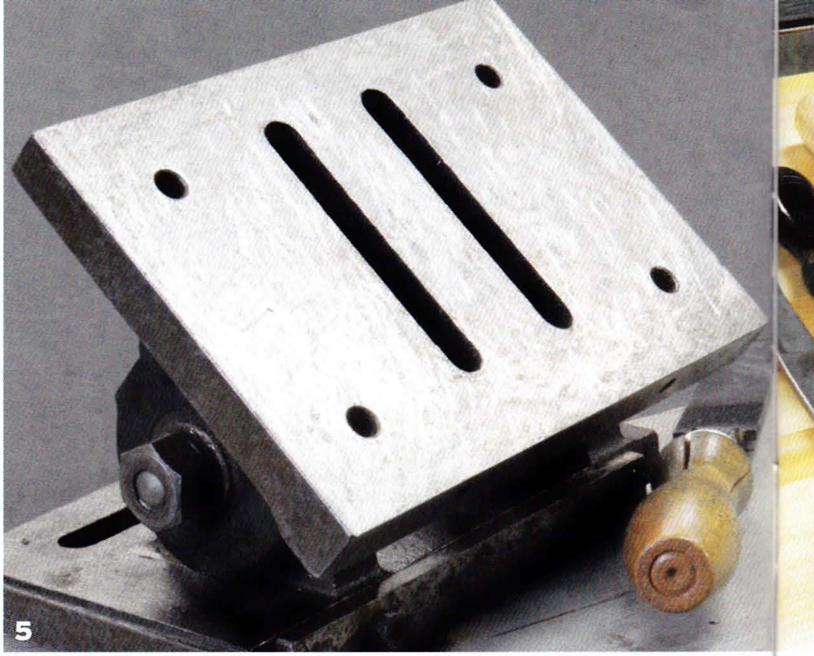

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different angle and it's the interesting reflective qualities of the resulting surface that give a scraped surface its dazzling appearance.

EQUIPMENT

The basic equipment for scraping something flat consists of a scraper, a reference surface (often a surface plate), and a marking medium (Prussian blue or other medium) used to visually highlight a comparison between the two.

We're going to use scraping to get the base of the surface gauge perfectly flat, or as close to perfectly flat as possible. For many shop applications getting something flat is all that is required.

THE SCRAPER

Photo 6 shows my box of scraping tools that resides on a shelf under my bench. The end of the scraper is a precision cutting edge and needs to be protected against nicks (Photo 7). A folded over piece of cardboard and some duct tape works well.

Why so many? Some are explained by the short and long handles (the short are more comfortable for bench work) and there are some specialty ones made of thin carbide for reaching into tight dovetail corners. There is also one or two ground with a flat end for getting into square corners. However, the bulk of them are simply there because it's handy to have lots of sharp ones at hand. They don't cost much to make and I like being able to sharpen several at a time. It's easy to zone out while scraping, but if you find yourself all of sudden not having fun, reach for a freshly lapped tool. Scraping with a dull blade is not very satisfying. Having a sharp scraper is important and they require frequent sharpening, especially when doing fine, finishing work.

Photo 8 shows a variety of straight scrapers, including commercial models from Moore & Wright and Anderson Brothers, as well as a variety of homemade ones, both in carbon steel and carbide.

THE SCRAPER EDGE

Photo 7 shows the end of a carbon, or tool steel, scraper and Photo 9 shows the end of a lapped carbide scraper. The materials used for scrapers are either steel (tool steel or high carbon) or carbide. Carbide is preferable as the scraper's edge lasts longer, but maintaining a carbide edge requires more supporting equipment (to be covered in some detail in a later part). Steel scrapers, such as those made from old files, are easier to obtain and require less to sharpen; however, they won't hold an edge as long.

I went for years using steel scrapers with good results, so it is not essential to have carbide scrapers. On the other hand, carbide is preferable and in my opinion worth the trouble and expense. If you go

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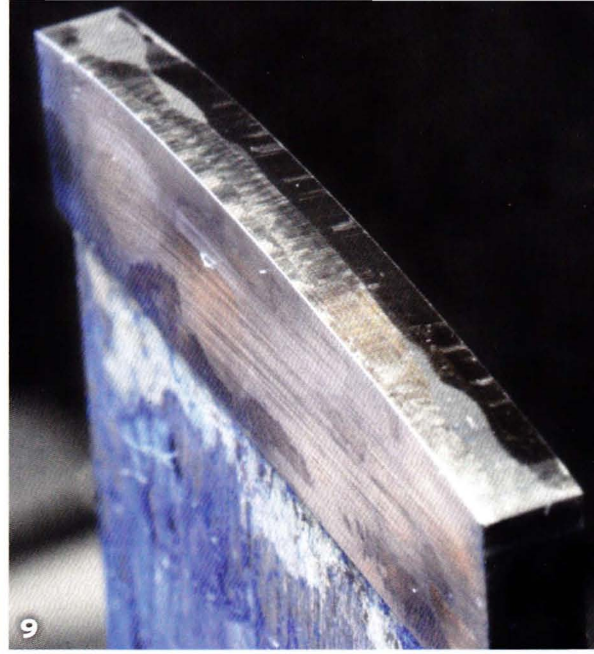

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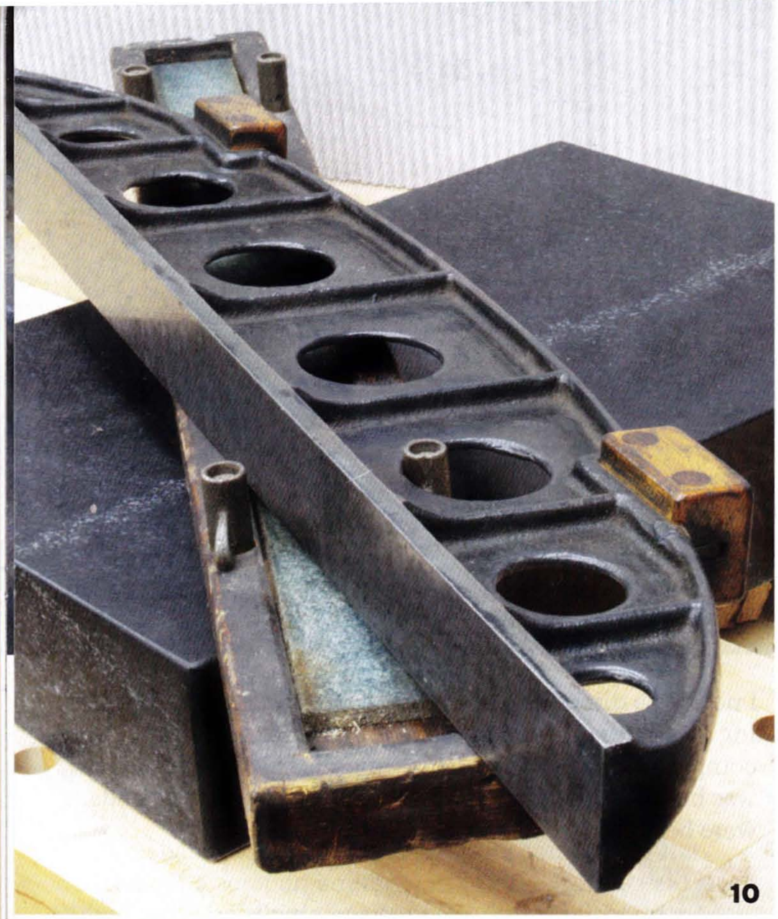
carbide, it requires different sharpening equipment but, truth be told, once you equip yourself with a carbide scraper you won't use the steel one again.

REFERENCES

The most basic reference is the surface plate. It is flat, wear resistant, and takes the blue well. Interestingly, scraping is one home shop activity that might actually challenge the accuracy of your surface plate. Recently, I noticed a different pattern on a large workpiece, depending on whether I used my Starrett plate or my cheap composite plate. During finishing, the middle of the work was being marked on the import plate, whereas the ends were being marked on the Starrett plate!

PORTABLE REFERENCES

An important application of scraping is creating high quality ways or bearing surfaces on machines, whether for



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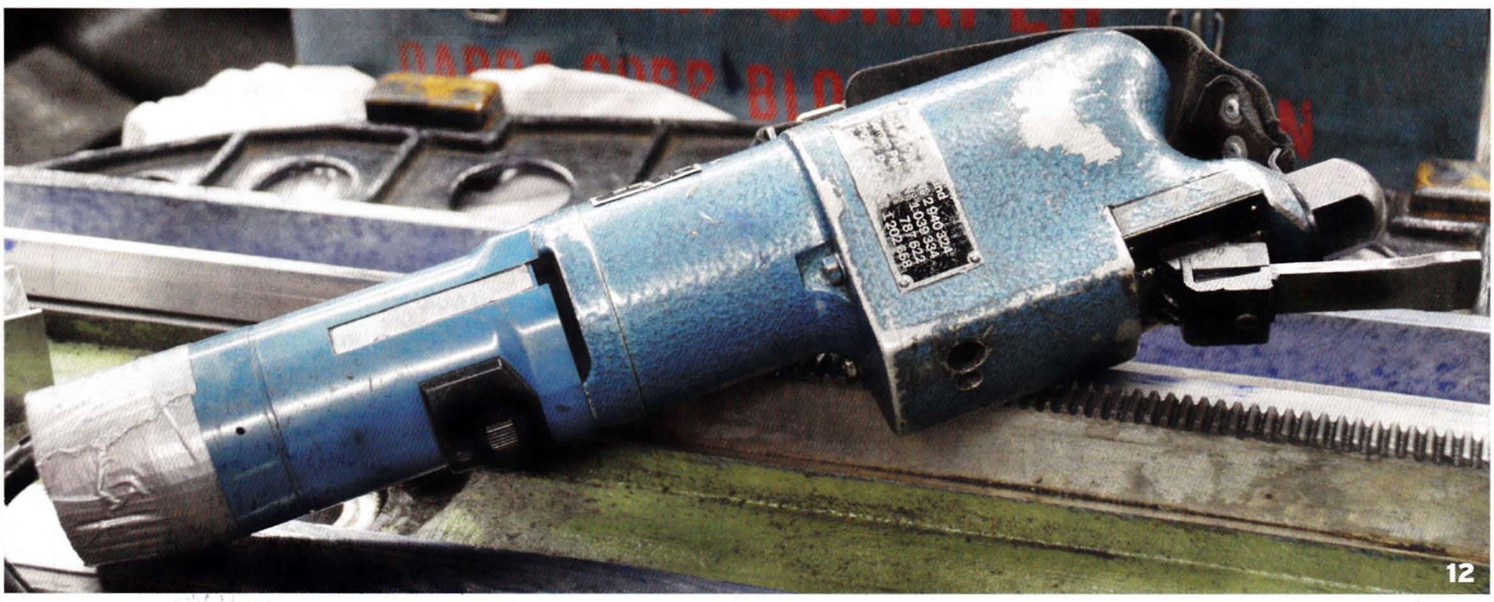

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restoration or original construction. This makes sense, as scraping is a method to make surfaces flat to a high standard and that is exactly what the various bearing surfaces of a machine tool require. A very high standard of work is possible over large areas and hand scraping is still considered one of the finest ways to finish a machine bearing surface. Even though a visible bearing surface on a high class machine might be ground, its mating surface, which you can't see, could well be scraped.

Obviously, it would be difficult to heft your Bridgeport column up onto the surface plate, and the surface plate would not work on a lathe bed's Vs. To scrape these larger stationary or unusually shaped items, there are various portable references or straight edges available. Photo 10 shows a beautifully made Moore & Wright 30" camelback. Its working surface is finished, via scraping, to the highest levels of precision. As a reference, blue is applied to the camel back and then it is put in contact with the lathe bed, leaving blue marks on the lathe bed indicating high spots. Or blue can be applied to the lathe bed and the camelback used to rub away the blue on the high spots.

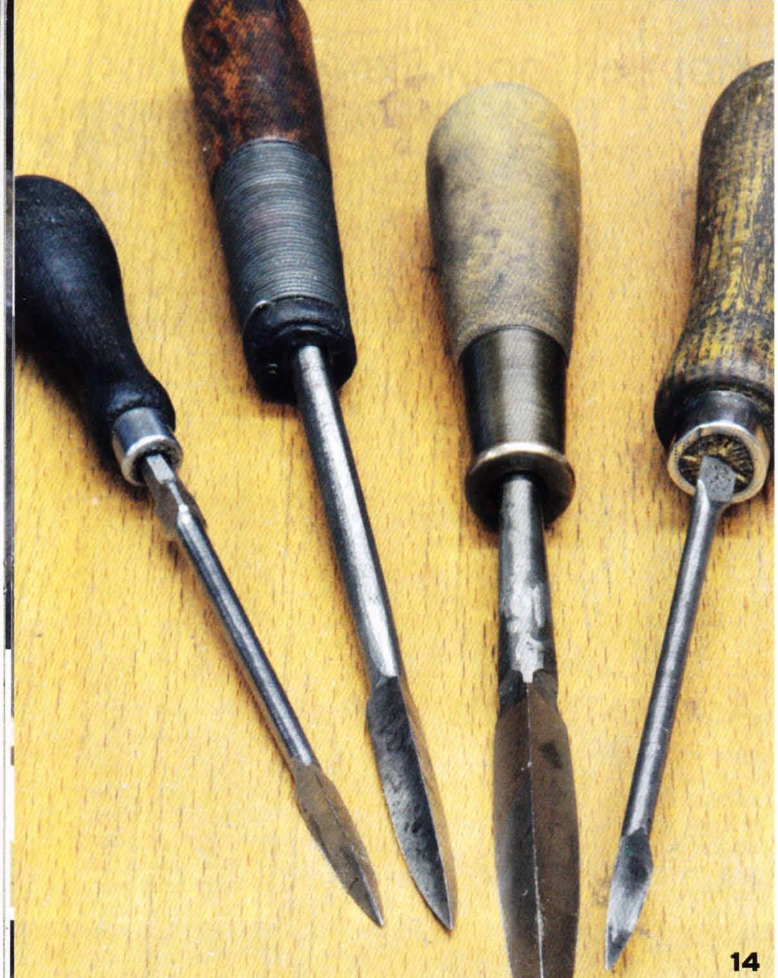
Another important element of machine tool designs are dovetails. To scrape the two surfaces of a dovetail requires a reference surface that can fit into the acutely angled dovetail surfaces, such as those shown in Photo

11. Incidentally, achieving a particular angle often isn't important; what is important is the two surfaces are perfectly flat, which results in the angle being constant between them. More on that subject later.

After you've done a bit scraping, you'll come to appreciate a wonderful invention – the power scraper (Photo 12). They are expensive, but if your objective in learning scraping is to deal with larger bearing surfaces such as full sized machine tool ways, picking up one of these used would be a real time, arm, and back saver. Do your homework though. Disappointingly, a popular manufacturer does not support earlier models. You would not want to acquire one only to find out you were left in the lurch on parts. Keep in mind also that, except for in experienced hands, its aggressive action makes it more of a roughing tool, with finishing still best done by hand.

Don't pine over the power scraper too much; I think power scrapers are somewhat analogous to hydraulic log splitters. You'll split a lot more wood over the course of a day, but you'll be just as tired. Given the weight of the power scraper, it's still work using it, although it does remove a lot more material.

To cover the subject of scrapers completely, Photo 13 shows bearing scrapers. The bearing scrapers are used in the same manner as flat scrapers, in that they are used to remove high spots revealed by a spotting media. They are used on the curved surfaces of plain bearings to get a very good fit between bearing and shaft. If you've ever made an engine with a tight fit on a journal bearing, these are the tools needed to



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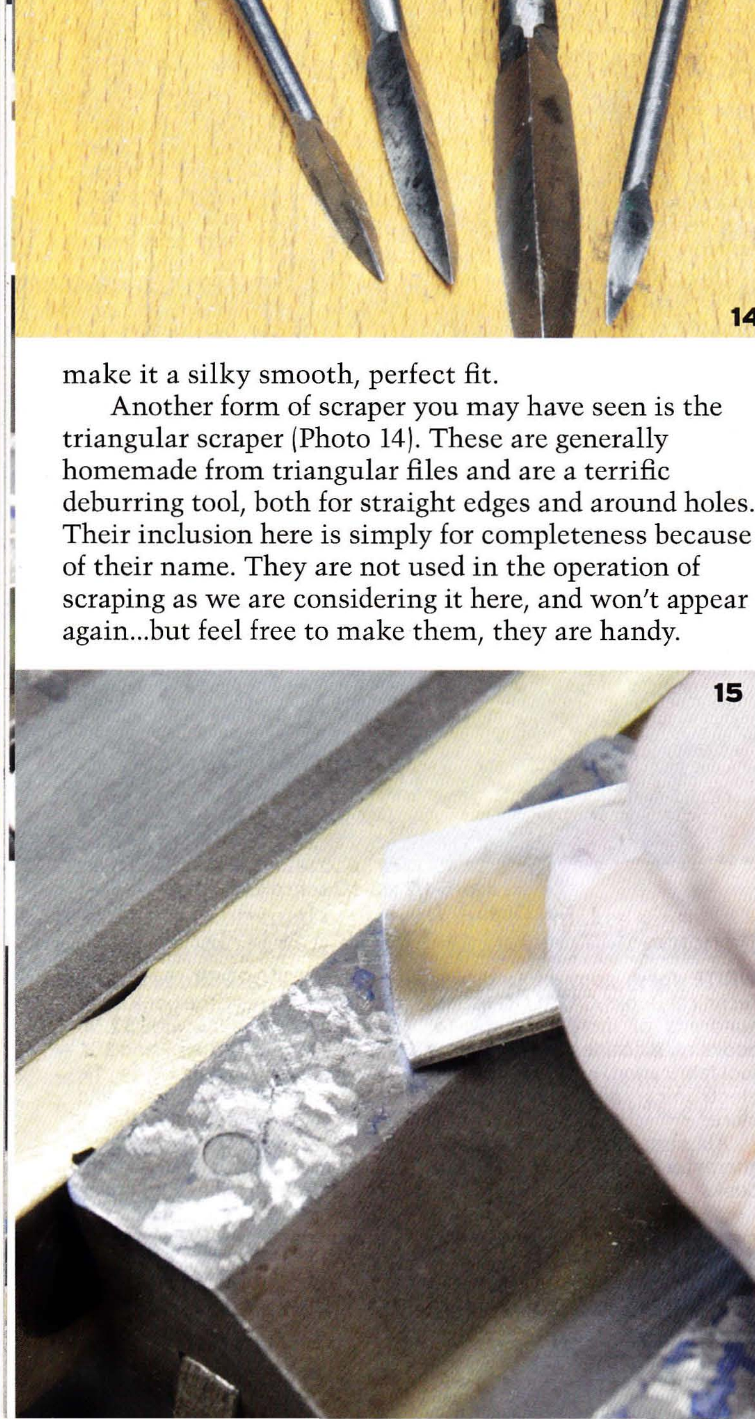
make it a silky smooth, perfect fit.

Another form of scraper you may have seen is the triangular scraper (Photo 14). These are generally homemade from triangular files and are a terrific deburring tool, both for straight edges and around holes. Their inclusion here is simply for completeness because of their name. They are not used in the operation of scraping as we are considering it here, and won't appear again...but feel free to make them, they are handy.



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THE SURFACE GAUGE PROJECT

What to scrape? Assuming you aren't sitting there with a surface gauge in need of a tune up (Photo 15), you'll want some material to scrape as part of the learning (if you do have a surface gauge, make sure it isn't one of the hardened or case hardened models!). Almost any material will work. Cast iron is best, but you can practice on aluminum as well – steel will do in a pinch but it's the least fun to work with in my opinion.

Scraping is precision work – we are machining to small tolerances here. That means cleanliness is important. Wipe off the surface plate! A bare hand is actually very sensitive at detecting contaminants, so run your hand over the plate and make sure it's clean.

Next, spread some blue on your surface plate. There are several ways to do this; the simplest and most effective in my experience is with a piece of felt. This leaves about the right thickness of blue and the felt will also wipe away contaminants. Another option is a piece of foam rubber packaging, although I prefer the felt.

Many advocate using fingers for applying the blue, which has the advantage of touch. Shop time is often sporadic for me; I'll squeeze an hour in before running off to a kid's sporting event or some time at night with an important meeting scheduled the next morning. My life's non-workshop realities are such that it's often not possible to go about with blue hands and fingernails. I frequently wear disposable rubber latex gloves (available from the drug store) and will sometimes spread the blue using gloved fingers or a latex glove stretched across the

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fingers. I find this works particularly well when you want a very thick coat of blue for initial roughing (more on that to follow).

Forrest Addy, a guy who knows a thing or two about scraping, advocates the use of a brayer (a printer's tool; a rubber roller for use with ink). I've also used with some success a rubber squeegee like those used for silk screening. It is essentially a thick, straight piece of rubber mounted in a handle. What is quite nice about the squeegee is that it can be drawn across the surface plate from time to time and will clear off any small chips or dirt that may have contaminated the blued surface. What I don't like about it is the edge of the rubber tends to break down or becomes rounded over; however, this may be sharpened by freezing and then filing.

So there are several options for getting the blue spread. Mostly though, I use felt (Photo 16) or if I want a heavy coating, I smear it on with my fingers and then maybe squeegee it smooth. While it is important to get an even coating of blue, the importance of evenness becomes greater as we move from roughing to finishing and hence from thick coats of blue to thin. A thin coat, where its thickness matters more, I find is easily achieved with the felt.

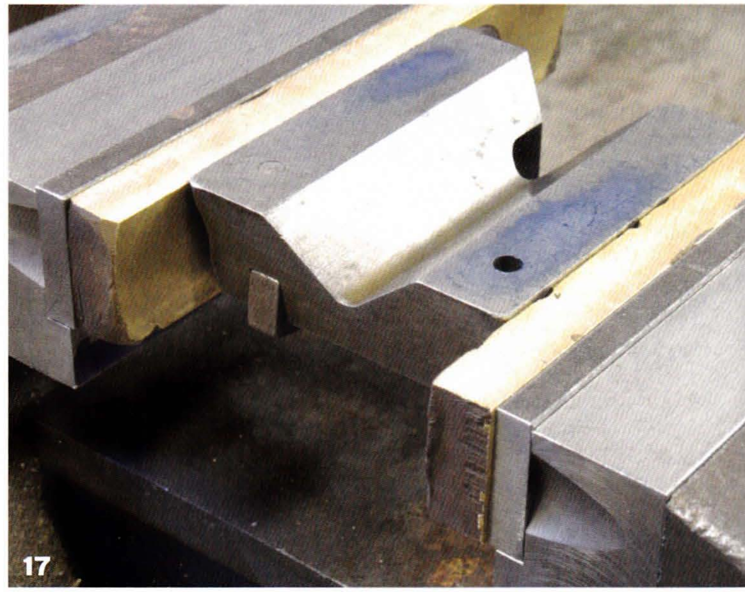
HOW THICK TO SPREAD IT?

When spinning scraping or fishing yarns, as thick as you're able, but I'm talking about the blue. Actually, it is almost true that the blue indicates where the work was sitting on the reference. In fact, if you picture what is going on at a magnified level, there are a few points of work in contact with the surface plate. These points have sunk through the layer of Prussian blue to make contact with the plate. What gets blued is any part of the work up to the thickness of the blue.

This is an important concept. The thicker the layer of blue on the plate, the more of the work that will be blued when the work is brought into contact. When starting a job, you are usually doing roughing, heavier cuts. You want to remove more material from a larger area, so having a little thicker layer is beneficial. As you finish, you want to be more and more localized in where you are removing material, so you want a thinner layer. With final finishing, you are actually trying to identify and remove those bearing points that have squished all the way through the blue to the plate and, as a result, have very little on them, but are surrounded by a small island of faint blue.

Be cautious with roughing – take too much and you'll be scraping down to a new low that you've made rather than that which originally existed.

There's no perfect, quantitative way to tell you how thick to spread it. Spread with a piece of felt, you want to cover the reference surface but have it thin enough that you can still see features of the reference through the blue (Photo 16). In starting, less is more as you develop a sense for what is required. Start with a thin layer and try it. It is an iterative process and as you go back to the surface plate to again blue the area you just scraped, you will notice the layer of blue is getting thinner. With a little experience, you develop a sense of how much blue you need for initial roughing cuts through to finishing. This is maybe the most trying aspect when scraping, especially for beginners; doing iteration after iteration of finishing scraping when really there should be wholesale removal of material via roughing. It's not that daunting though; the knowledge of using thicker for roughing and thinner for finishing and a little experience will soon make you quite comfortable with the whole process.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SCRAPING THE SURFACE GAUGE

Photo 17 shows the base of the surface gauge freshly spotted before beginning to scrape.

For my first bluing, I started with a thin layer, as I wanted to see what was going on with the base of the surface gauge. As can be seen, the area of contact is not good and this fact produced the wobble I noticed with the indicator. This is a typical pattern when starting; broad areas of contact but concentrated in regions. The blue was applied fairly thin as this initial spotting was just to see what was going on. Also, while there was wobble, I didn't expect the bottom to be so bad that heavy coats of blue and roughing would be required.

TECHNIQUES

While a scraper is the simplest of hand tools and it is quite simple to get a good result, there are a few points worth understanding. I'm going to leave descriptions of sharpening and the scraper's edge until we are making our scraper, but let's have a look at scraping technique and the thickness of blue.

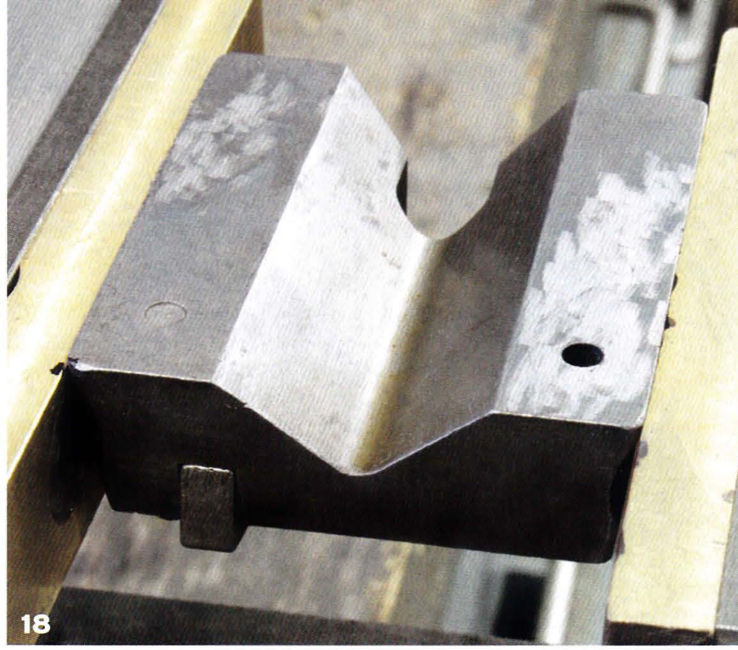
We can loosely categorize scraping as roughing and finishing. Think of roughing as hitting all regions or areas with at least some bearing points, or points of contact, and finish scraping as directed towards removing just the highest of the spots to increase the total number of bearing points.

Length of stroke has an effect on the depth of cut and the accuracy of the scraped surface. Generally, longer strokes are used in the initial roughing stages. Long strokes remove more material and throw up more burrs, but are a more expedient way of quickly bringing things into line. Shoveling it off, with the air black with cast iron dust, is the legend of the scraping hand but I've never been so animated as to turn the air black. The point being, the power and length of a stroke definitely change as the work transitions from initial roughing to finishing.

So we scrape. Bring the scraper to bear, at around a 20-30° angle. Gently push it forward, concentrating contact where there is blue. It will remove a tiny amount of material, less than a tenth of a thousandth of an inch on a light cut.

Scrape until the blue areas are no more. We then deburr (more on that in a minute) and return to the surface plate and again apply the work to the blued surface.

Photo 18 shows the first round of scraping and Photo 19 shows how the piece marks up after the first round. Our first round of scraping has created clearly visible low spots and the blue shows new high spots requiring attention.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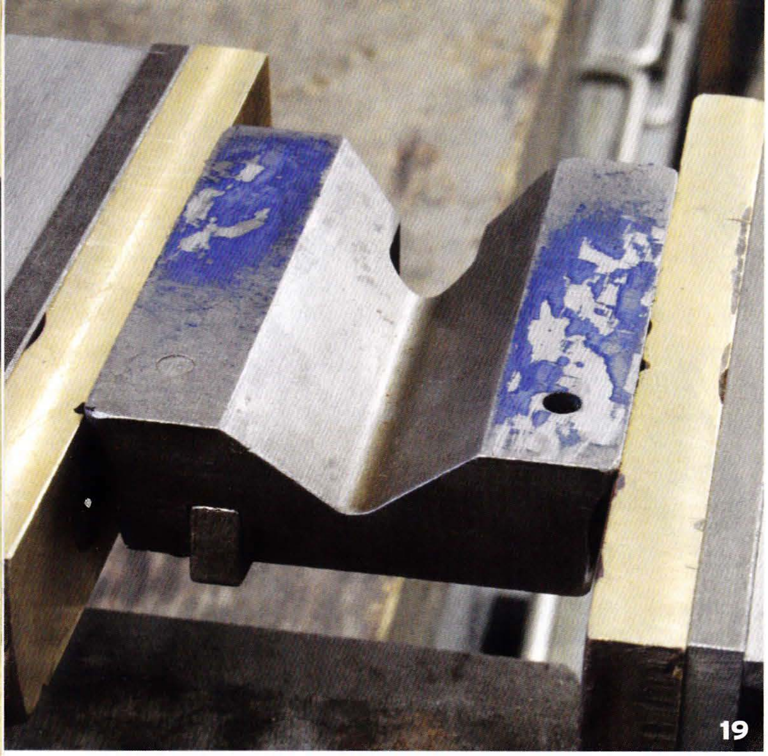

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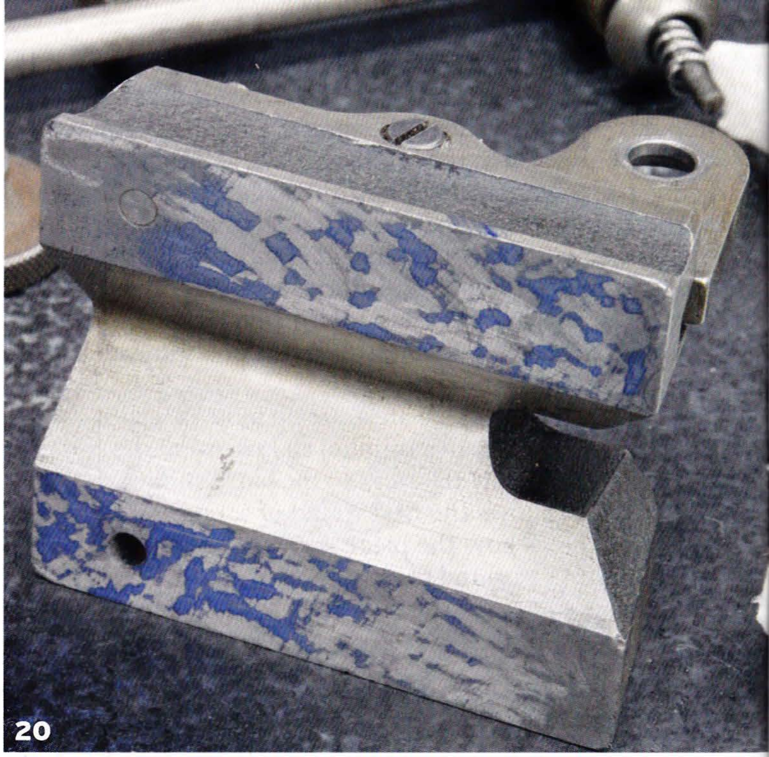

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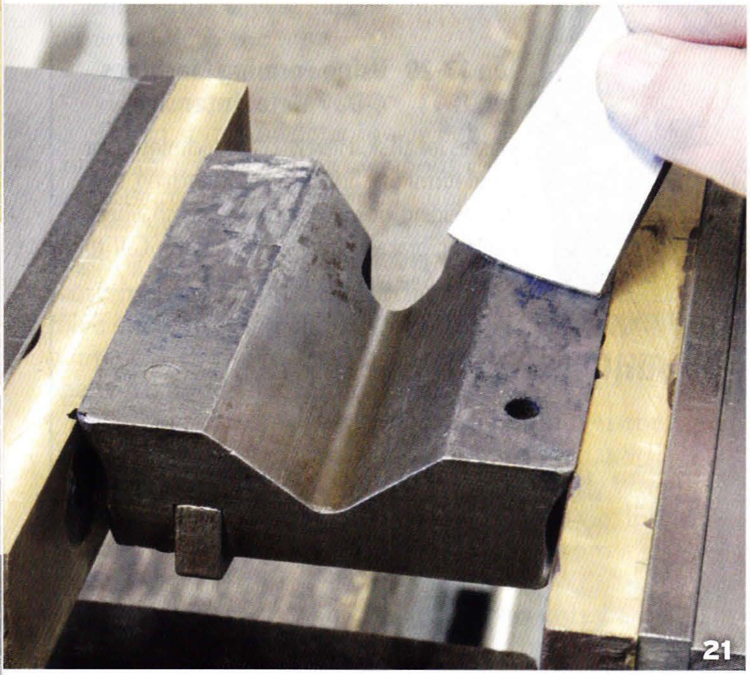

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In Photo 20 you can see how my earlier scraping lowered the previous high areas, creating a series of spots high enough to come in contact with the blue over most, but not quite all, of the surface. We are almost done rough scraping, and want to ease up a little. Heavy scraping creates new lows, so just like cruising down a country road toward a stop sign, take your foot off the gas and coast well ahead of the stop.

Photo 21 shows the work in progress. The scraper angle is maybe a bit steeper than normal as I balance the camera remote control and scraper for this "action" shot.

BURRS, FILES, AND STONES

Around the edges of the shallow, localized cut made by scraping, tiny burrs are thrown up. After each round of scraping, we want to remove these. Otherwise they would interfere with a proper marking and will also break off during spotting, leaving the marking medium contaminated with tiny chips.

There are two common ways for dealing with these burrs. One method uses a modified piece of a file and the other a stone. In either case, the idea is to quickly and lightly run the deburring tool over the work to knock off any burrs.

THE MODIFIED FILE DEBURRER

We want a short, say, 3" or 4" long section of a file from which to make our deburring tool. My sense is that a double-cut file works best, and we don't want the pitch of the teeth too coarse. Having said that, what file is used is not overly critical. So, select an old file that will yield a section around the size shown in Photo 22.

Break the file off so you have your short section. To break the file, grind a groove around the file on the bench grinder. Wrap the file in a cloth and hold one end

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in the bench vise. Administer a blow to the other end and you will have two pieces of file. Please wear eye protection and use the cloth for this operation; when breaking hardened steel in this manner there is a real risk of sharp shards of metal flying about.

To complete the file deburring tool, we need to abrade the sharp points of the teeth off using first a coarse stone followed by a fine. The coarse one removes material quickly and the fine makes it so the bottom of the tool is smooth enough that it won't scratch our work. The idea is that the bottom of the file is stoned flat so it's not going to cut, but any protruding burrs or pips will get caught between the teeth and will be sheared off.

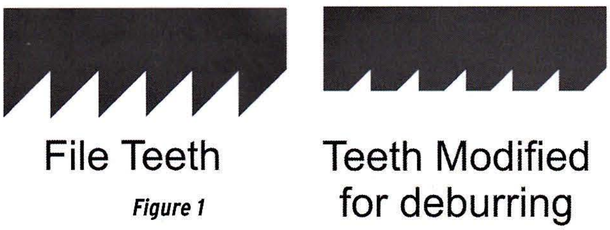


Figure 1

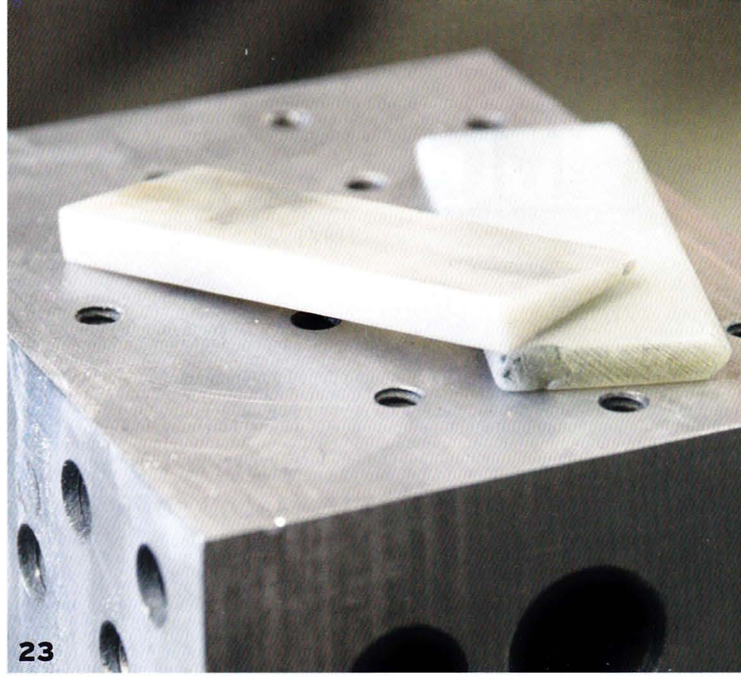
Figure 1 illustrates what we're trying to achieve. With the teeth stoned down to a profile as shown on the right, the file will skate over the work, yet burrs will protrude up between the teeth and be knocked off.

Never satisfied with one tool when two will do, I've ended up making a few file deburrers over the years. One, shown in Photo 22, has fairly fine teeth and is very well stoned. It is made from a half round file and that has proven advantageous when deburring in tight areas such as dovetails. The other two are from a slightly coarser file with one side well stoned and the other less so. This creates fine, medium, and coarse tools, where the coarse one is typically knocking off high spots more than burrs. The medium and coarse versions don't see finishing work as they tend to leave scratches, but they are handy during roughing.

DEBURRING WITH A STONE

The action is fairly obvious; we run a stone over the surface, which will abrade protruding burrs. What does take some thought though is what stone to use. Different types of stones and different grades of grit determine the removal rates. We want to be careful that we are using a stone that removes material so slowly that it's not materially affecting the surface and has just enough action to remove the burrs and slightly polish the tops of the high spots. We do not want to use something whose cut is aggressive enough that it's abrading the scraped surface in general, or will leave the surface full of scratches; we're trying to deburr here, not alter the geometry.

A more aggressive fine oil stone is okay for rouging but when it comes to finishing, the stones to use are hard Arkansas stones (Photo 23). I believe Arkansas stones are about as fine a grit a stone as you can get; their action is more like polishing than other stones you might have used. They are very hard, don't seem to wear, and remove material at a very slow rate, leaving a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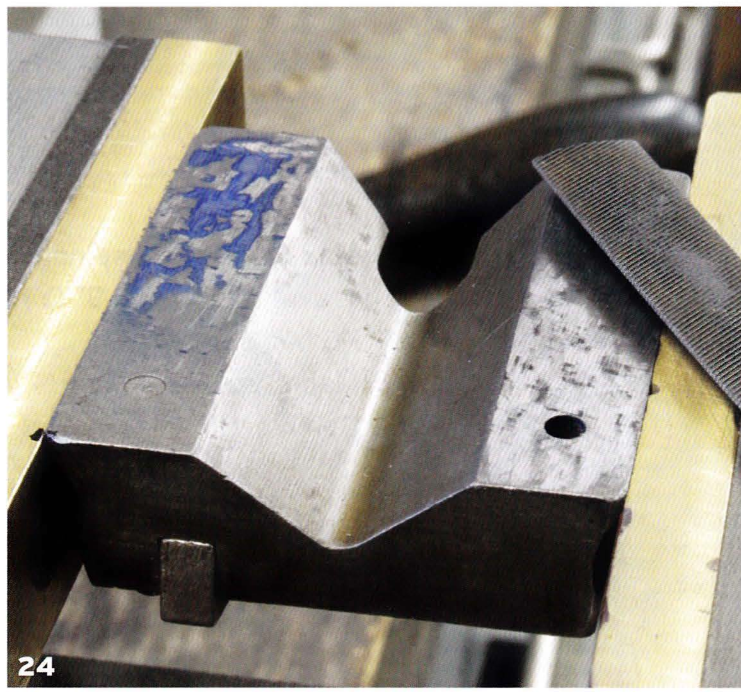
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bright, polished surface. You could work the surface with an Arkansas stone for some time and do little more than polish the high spots. This is good, as it will address burrs but not materially affect the surface.

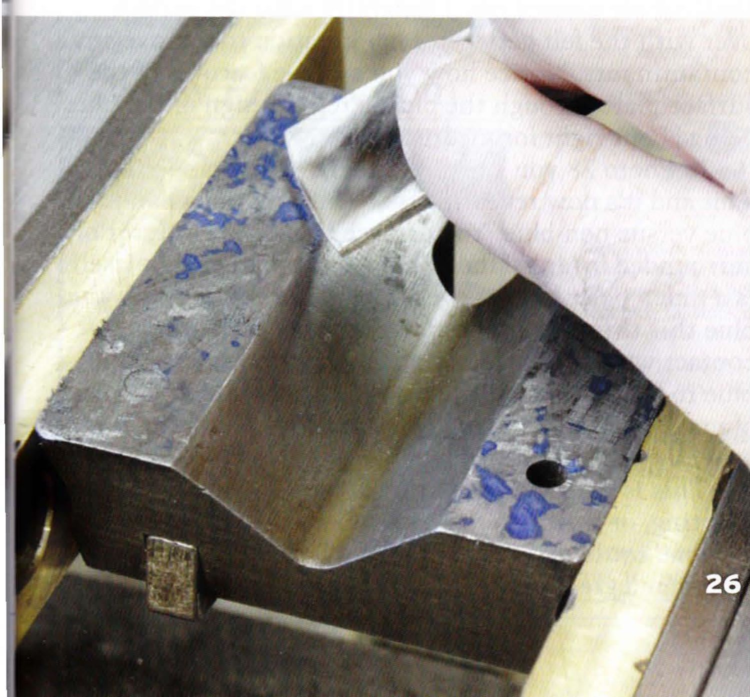
You will find proponents of both deburring methods. I think the file technique is preferred for heavy and medium scraping, while a hard Arkansas stone with a bit of kerosene or WD-40 is just right for fine finish scraping. If you do all your deburring with a stone, on heavy scraping you might want to use something with a slightly more aggressive cut than the hard Arkansas stone.

DIRECTION

You may notice, when you are beginning to scrape, occasionally you get undesirable patterns of lines that are chatter marks. This can be avoided by scraping in different directions, as well as by using very sharp scrapers. It is beneficial to scrape at a different angle with each iteration of spotting and scraping. The other thing to be aware of is the direction you are scraping when you approach an edge. Edges are weaker and are prone to chatter marks, allowing the cutting tool go deeper than intended. It is best to scrape toward the edge on a diagonal to avoid this.

You can see in Photo 24 we are still rough scraping, since we have large areas that are not making contact with the blue or the surface plate. It stands to reason that, regardless of how thick the blue is spread on the surface plate, we have to keep rough scraping until we start to see the entire surface starting to come into the same plane. This means starting to see markings over the entire surface as in Photo 25. In Photo 26 there are no untouched regions and scraping starts to move from rough to finish work.

As this project was small and already close to flat, it was quick and easy to blue and scrape without much more thought than to remember to scrape from a different direction each time. And for the most part, that's all you need to do. However, on larger surfaces, especially where there is a greater difference between



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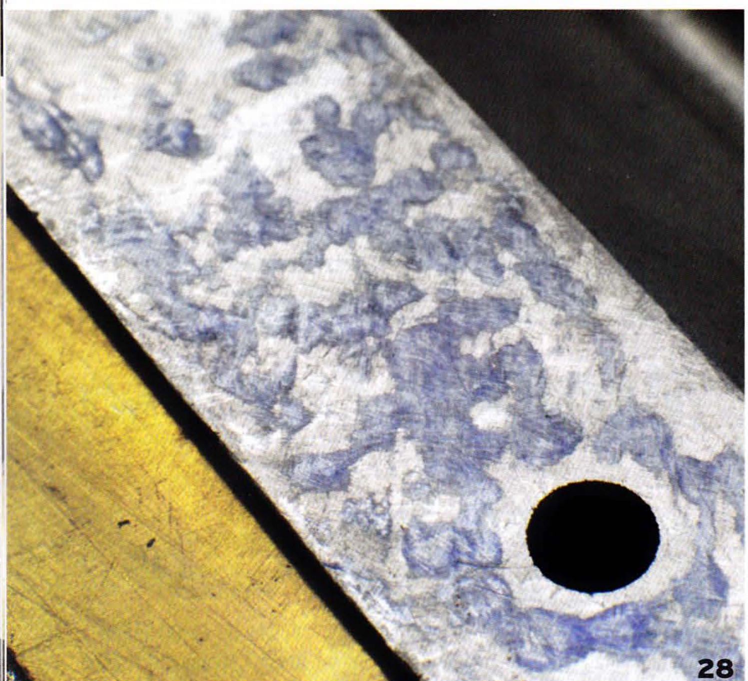
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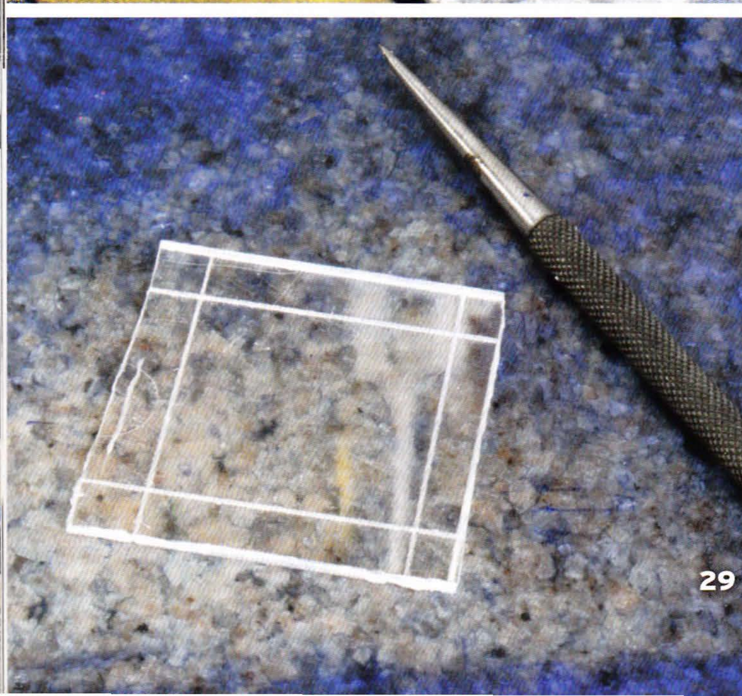
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high and low regions, work will progress much more efficiently if scraping is done less haphazardly. It's not required for small items like this but be aware of it. Essentially, each roughing iteration should be done as two diagonal passes perpendicular to each other. More on this later.

After each iteration, the surface of the work will have minute chips on it that will stick to the blue. After a few passes with the deburring tool, always wipe the surface down with a paper towel or rag so it is clean when it goes back to the blue on the surface plate.

When are you finished? The short answer is when you have enough bearing points for the type of work at hand. With scraping, we are not trying to get the entire surface perfectly into the same plane; we are trying to get enough of the surface into the same plane. As we progress with scraping, we will end up with numerous points that make contact with the surface plate. These are the bearing points. What determines the extent of the scraping job is the number of the bearing points per square inch, and that the concentration is consistent over the entire surface.

In other words, our scraped surface might be flat over some area to within .0001-.0002". However, the slight variance in the surface means it will only be a series of points that are exactly (exact used in the sense of our ability to detect or measure it) in the same plane.

As rough scraping progresses into finer and finer finish scraping, we need to be aware of two subjective elements of scraping. First, as mentioned earlier, about how thick the blue should be, and secondly, as the work becomes finer, high spots become finer and there are some subtle changes in how the marking medium identifies them.

The general idea is that a thicker layer of blue is used on the reference early on for rough scraping, as we want to remove material from broad areas. As we progress, it is allowed to thin until we're hardly picking up any blue in the final stages. Photo 27 shows a medium-fine coat of blue on the surface plate. The blue will naturally thin as repetitive cycles of spotting are carried out. I generally wipe the surface over with the felt between each iteration to remove any contaminants. Notice how you can see features of the surface plate through the blue, a telltale sign of the blue being about right for medium to fine work.

In Photo 28 you can see I'm letting the blue thin a bit and it's now revealing more information than just blue versus non-blue. You can see high spots are sort of surrounded by an island of blue, but the high spot itself is a much paler blue or even silvery grey color. With the blue this thin, the highest areas of the work are in contact with the surface plate and tend to squeeze the blue to the sides, resulting in the pattern shown in the photo. The final pointing work involves removing the grey islands surrounded by blue.

This is when the finish work occurs; when you are pointing, or trying to remove the individual high spots.

One could miss several meals if this progression to a finer and greater number of high spots was allowed to continue, but we'll take our cue from the pros. Professional scrapers work toward a standard expressed in points per inch, with finer tolerance work requiring more points per square inch. Work is subject to inspection, whereby inspectors use a magnifier device with an optical grid that allows the counting of bearing points. A homemade device is easily made as shown in Photos 29 and 30. It's as simple as taking a piece of CD case and scribing lines to form a 1" square.

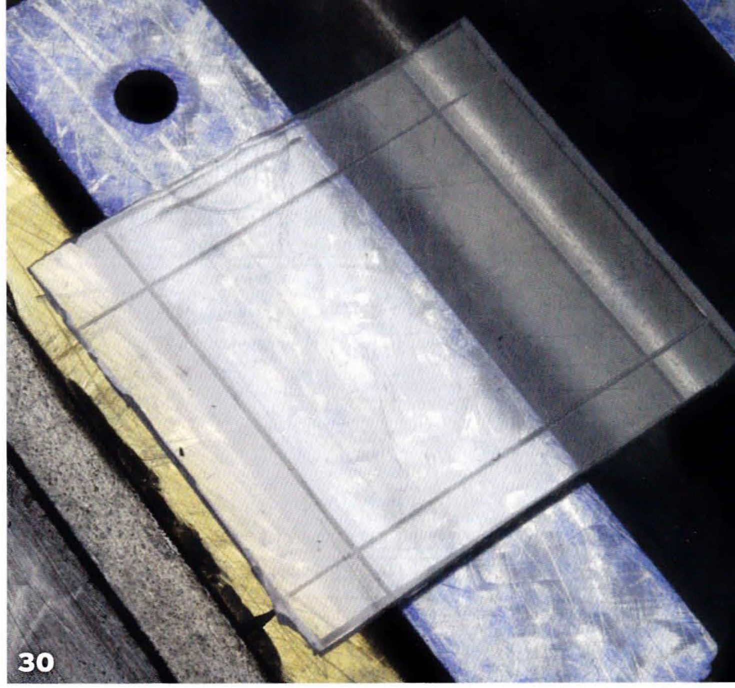
Fortunately, we home shop types are our own inspectors. However, let's look at Connelly's point per inch guidelines. In his treatise on scraping he suggests:

- Stationary Surfaces: 1-5 bearing spots per square inch.
- Sliding Bearings: 5-10.
- Precision Sliding Bearings: 10-20.
- Gauges, Surface Plates: 30-35.

I present this information just to give you a sense of it. Common sense must be applied and we are our own inspectors. There's no need to count spots if you don't want to, but it conveys the idea that finer work requires more bearing points per square inch.

Connelly also notes the following correlation between the size of the cut and the number of bearing points per inch:

- 1/4" sq – 8-12
- 3/16" sq – 18-22
- 1/8" × 1/8" – 30-35



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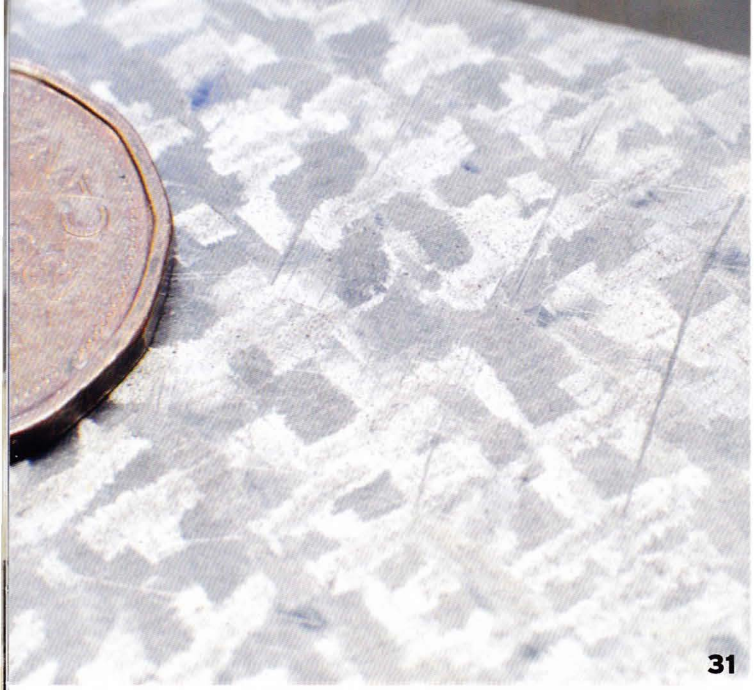
SCRAPING PATTERNS

Photo 31 shows the surface of a Starrett master precision level. You'll notice how regular the pattern is, almost like a checkerboard, versus the hodgepodge look of my scraping examples. For the seasoned professional able to lay down a pattern like this, Connelly's notations on the sizes of cuts make sense. In fact, in the trade, or so I'm told, scrapers could be identified by their



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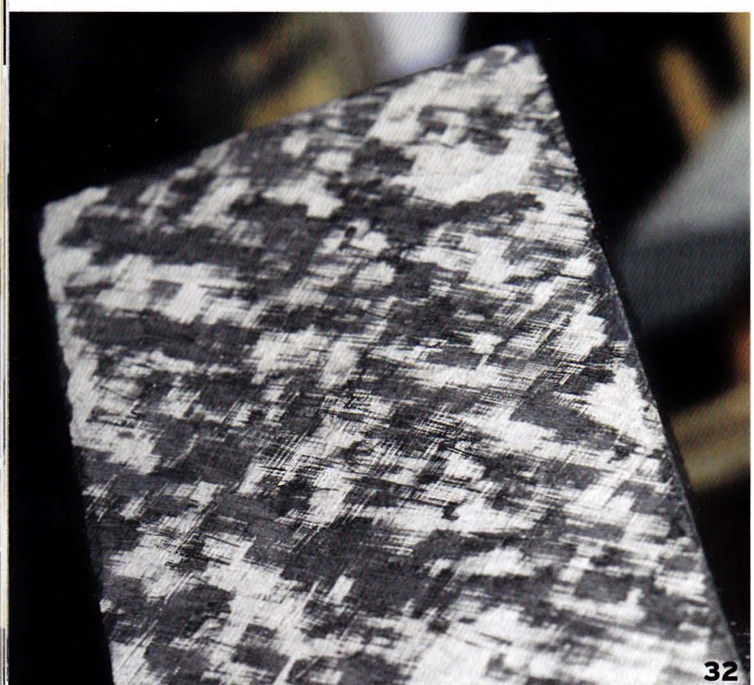

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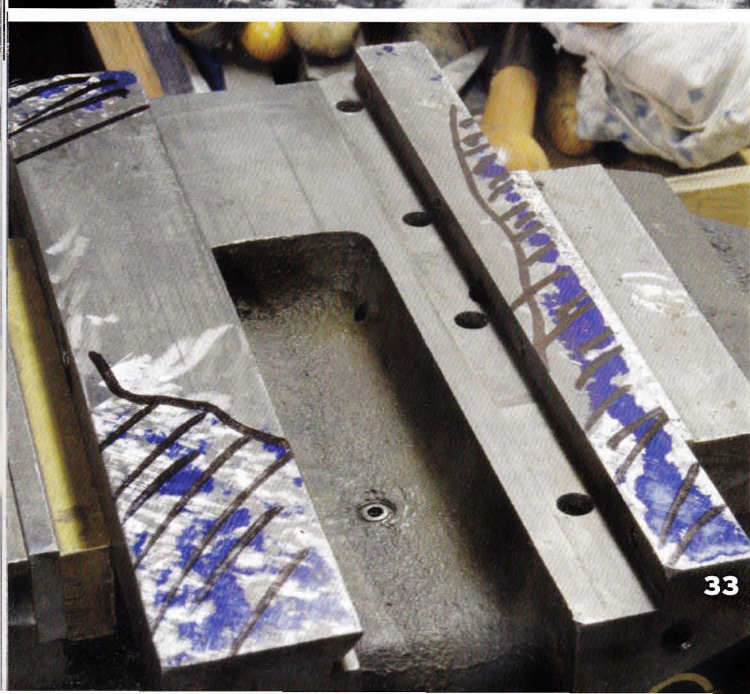

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work much like telegraph operators recognized one another from their touch on the key.

Failing to lay down this pattern does not mean our results are any less functional though. I'm able to produce a similar pattern using a power scraper but generally finish the job with hand scraping where the pattern becomes more random. What counts is the percentage of bearing surface, the number of bearing points per square inch, and that the points are evenly distributed.

Photo 32 shows the top half of a lathe compound dovetail that needed some heavy roughing. This was done with the Biax power scraper and you can see that it more closely approximates the Starrett level pattern. This is achieved by making one pass at a diagonal to the way and then making a second pass perpendicular to the first. I will finish this by hand, so the neat, Starrett-like pattern in the photo only makes brief appearances and is obliterated by the time I've finish-scraped.

With the surface gauge project, it was both a small area and fairly flat to start with; it didn't require much more than to spot on the surface plate and scrape where you see blue. However, when larger areas require scraping and lots of it, there is an advantage in using more methodology about where to scrape. To rough bigger areas, that is, to bring the work so that all regions are making some contact, we want to make rough passes in two directions (Photo 32) and to lay this down wholesale across zones, as opposed to just scraping the blue.

For example, in Photo 33 you can see I've spotted the top of the lathe compound using a fairly thick coat of blue. Still, only a small percentage of its surface is in contact. Rather than painstakingly scraping the blue, I'll scrape in zones. I'll do two passes of heavy scraping, one in each direction, of the areas outlined in black marker. I know wholesale removal of material is required, as we're not yet close to having all areas making contact. The advantage here is that it's much quicker to lay down rows of scraping across a zone than the more tedious targeting of the complex pattern of blue areas.

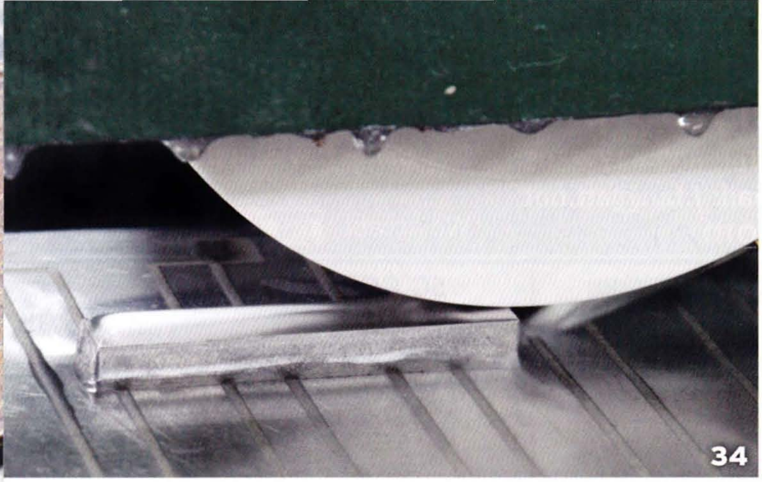
In the end, either will get you there, but when faced with a job that is both a large area and quite a distance between highs and lows (a thousandth is a lot in scraping parlance), it's quicker to use this approach.

WHAT ABOUT SURFACE GRINDING?

Anecdotal evidence and logic suggests few commercial machinists know how to scrape compared to those who know how to grind. This is to be expected; it's time consuming, hence expensive, and very often when they do very accurate work it's in hardened materials. Hardened materials require grinding, which is where professional machinists go when they think high precision. I think this has rubbed off on amateurs to the point that some seem to hold the view, "If I wanted high precisions I'd get/use a grinder."

Of course, the obvious answer to the question of why scrape a surface is that only a small number of home shops will have a grinder. However, there are

(Continued on page 32)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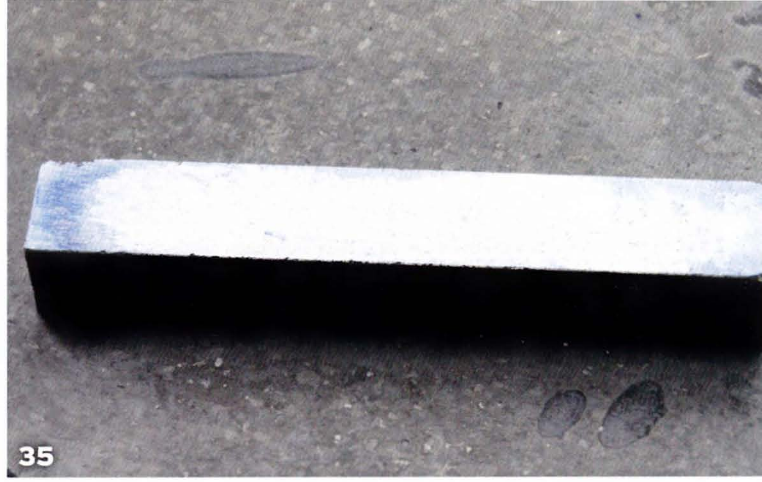
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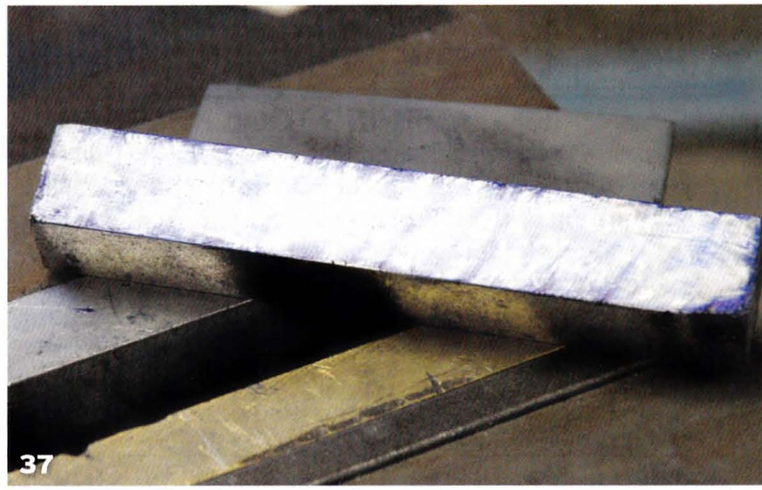
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a number of considerations that might make scraping the best technique for a job, even when grinding is available. Scraping can be as accurate as, or even more so, than grinding. It can also be used to get parts flat, parallel, and square when a grinder might not be available or when setups might be difficult or impossible, given the shape and size of the work. How many grinders, commercial or home, can handle the dovetail ways on a vertical mill or a lathe bed? They're out there at commercial machine tool rebuilders, but not at the corner job shop.

Where scraping has another real advantage over machine tool processes is it doesn't distort the work while it's being held. Given that it's most unlikely the work is going to be perfectly flat before machining, how then does one hold the work without the act of holding it causing it to distort?

Even magnetic chucks used on surface grinders exert plenty enough force to temporarily deform the parts. When the force is removed, the parts spring back to their original shape and the momentarily flat, freshly machined face now takes on the piece's original curves.

In case there were a few guffaws on that last bit – the claim of magnetic chucks distorting the work – let's do an experiment. Photo 34 shows a 2-1/2" long piece of cast iron, maybe 1/2" square, having two opposing sides ground on my surface grinder. Getting this part flat and square should be simplicity itself, especially with a grinder, right?

Photo 35 shows the results when this beautifully ground piece is checked on the surface plate using blue. A check with a tenths indicator shows a difference of .0003" over its length. Not bad for rough work, but hardly a vote of confidence in the surface grinder being king of the fine work.

What happened? The work was not flat to start with, so when held down by the magnetic chuck, the force was strong enough to pull some of the curve out of the work. That small curvature is temporarily removed as the work is flattened and pulled against the chuck and is challenging to get rid of. I don't think the warping resulted from the machining; that it changed shape from heat or removal of stress in the surface layer. I used cast iron, which is less likely to move and, as you'll see later on, I was able to get perfect grinding results after scraping one side.

Now I should point out, lest you think all surface grinding work is for barbarians, there are surface grinding techniques to deal with this. You can carefully map a part with an indicator and shim it so it's fully supported. This will get the ground side flat, but is obviously a lot of work with many possible sources of error. Accuracy is impeded by the resolution you have with available shims – hard to do to a tenth. It's possible to map the surface in detail with a tenths indicator and then replicate this perfectly with the magnet on by adjusting shims, but it's not quick or pleasant work. Another dodge is to turn off the mag chuck and finish grind the work using only the residual magnetism, which exerts a smaller clamping force (and of course has much lower workholding ability). A similar approach involves more sophisticated electric magnet chucks where the power can be dialed down to finish. However, these techniques mitigate but do not eliminate the mag chuck's distorting affects. Ask a grinder to get a long, spindly part flat to a tenth and listen for the groans, whereas it's easily done with scraping.

Not that it's a competition between the two; my belief is our abilities go up with the more techniques we have available and the better we understand the strengths and weaknesses of each. It's just offered to show those inexperienced with grinding that it's not a silver bullet and can be quite tricky in certain situations. The most skilled craftsmen, in my opinion, are the ones that seek the broadest base of knowledge so they can mix and match the best techniques to suit the task at hand.

The alternative I like to use for slender or thin pieces is to scrape one side as shown in Photo 36. As there is no significant force applied to the work while spotting for scraping, the results highlighted by the blue show its true shape without distortion from clamping forces. Getting one surface truly flat in the absence of clamping forces creates a solid datum surface that will fully support the work against the surface of a mag chuck, grinding vise jaw, or other workholding surface.

Cycle through the scraping iterations until you develop enough bearing points to have confidence that the work is not going to be warped by the magnetic chuck. Photo 37 shows the piece pointed to a fairly high density of bearing spots. Wanting an effective demonstration, I probably went overboard on the required bearing points per square inch; you just need enough so the part is well supported over its length.

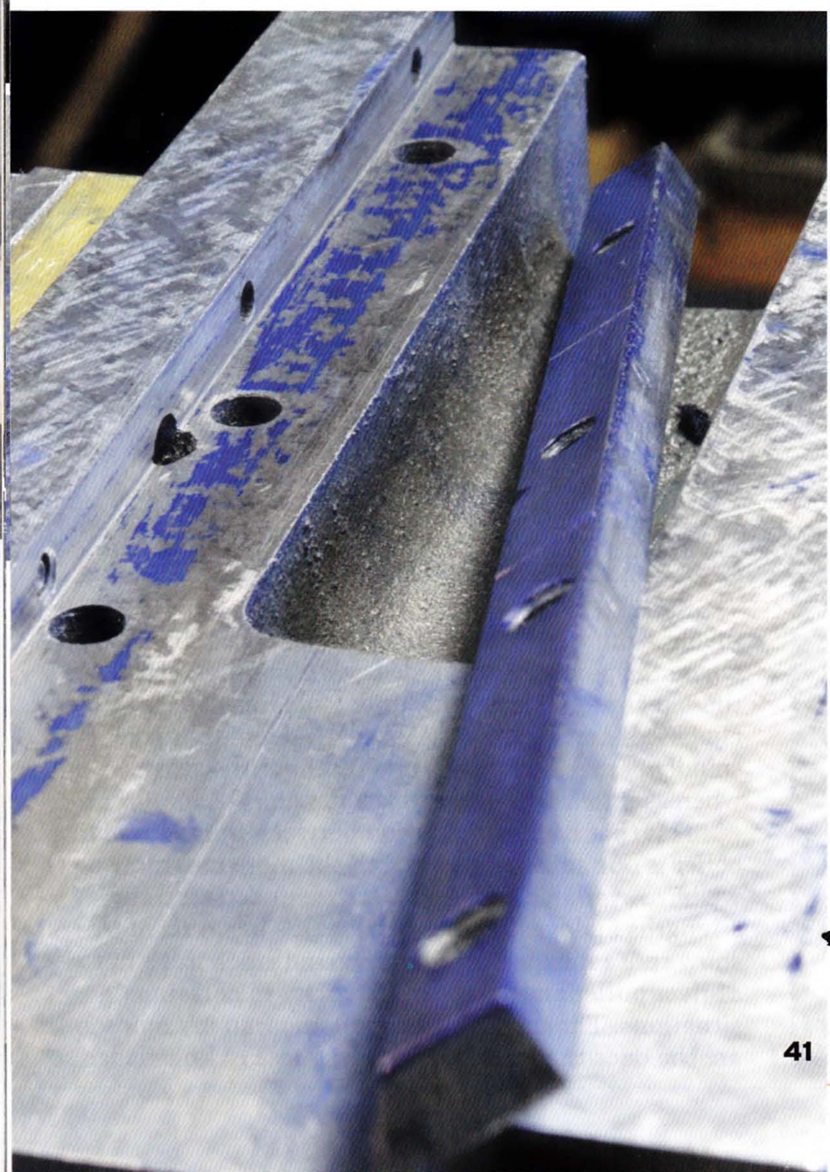
This photo also shows an alternate spotting technique. Here, blue was applied to the work and the work rubbed on a clean area of the surface plate. Like a photographic negative, the results are reversed, with the high areas showing as bright spots.

I sometimes find this approach easier to see, especially when doing fine work. It's also been explained to me it was a common approach on very large jobs; such as when a 15', multi-ton straightedge is lowered by crane to spot a giant machine tool bed. They would blue the bed and use the reference to rub the blue off the high points.

The next step in the experiment is to place the scraped surface on the chuck and regrind the top. Photo 38 is a test to check the flatness of this freshly ground piece. We know the scraped surface is very flat, so how parallel is the top surface? It's perfect; a Swiss tenths test indicator doesn't move over its length.

The patient home shop practitioner should keep in mind that techniques such as scraping, and in the case of hardened or cylindrical parts, lapping, are very basic techniques that can be used to create work of the highest class, the absence of fancy grinding equipment notwithstanding. That alone should earn scraping a special spot in the hearts and minds of home shop machinists.

Here's a practical example of some scraping; Photo 39 shows the gib for my lathe compound. Even with a surface grinder, this is a very difficult part to get flat to a high degree of accuracy. I pulled this gib and began checking it with shims. It was bowed more than .003" in the center. This really matters, as the angled surface that is a bearing has to be scraped flat. If the overall shape is bowed, the bearing surface that was scraped flat will not remain so when the bowed gib is bolted in place (general arrangement of the gib is shown in Photo 40)! Both the gib and the surface it bolts to must be perfectly flat, or else the bearing surface will be distorted when the gib is bolted in.



So, with the gib bowed .003", what to do? .003" is a lot to remove via scraping, even though the surface is small. Files are one option. What I did was set it up on the surface grinder and used shims to maintain the bowed shape measured on the surface plate. This was, in essence, roughing work; after grinding I checked (what I'm doing in Photo 39) and the blue pattern shows things are still far from flat. However, it's much closer; I'm only out .0005" now, so I have saved a lot of scraping.

Getting this gib flat to tenths is an example of the type of work that is trivial with scraping but darn near impossible with grinding.

We'll get more into machine scraping in due course; however, to complete the story, Photo 41 shows the gib being fit to the casting. The now flat top of the gib is used to spot and scrape the surface it bolts to. Everything matters! Fundamental to a machine's accuracy is that all the bearing surfaces are perfectly flat and perfectly mated; any condition otherwise means the surfaces are only partially in contact, which means when a load is applied things will flex to the detriment of accuracy and rigidity.

In the next issue, we will learn what to look for when purchasing a scraper and how to make one, so we can put some of this scraping theory to practice.

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PHOTOS AND DRAWINGS BY AUTHOR

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SCRAPING for the Home Shop

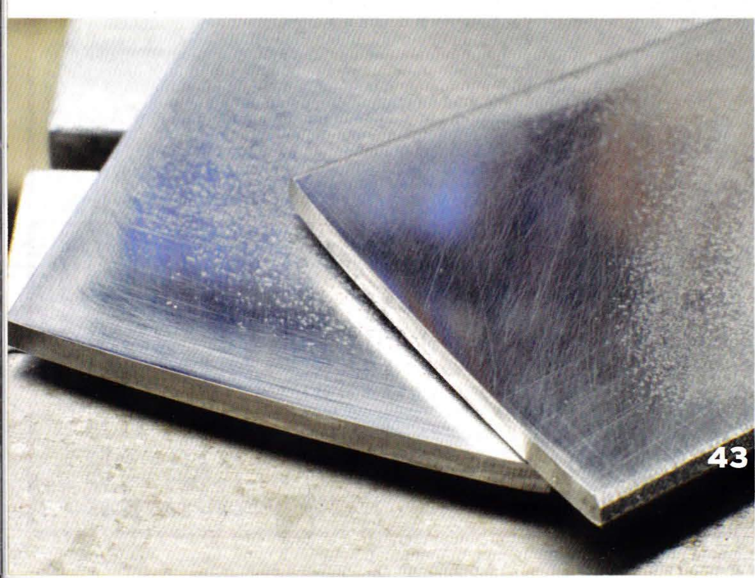
Part Two

BY MICHAEL WARD

ACQUIRING A SCRAPER

With the first installment of this series behind us, and full of enthusiasm and anxious to try out this new knowledge of scraping, we're landlocked without a scraper.

I was introduced to scraping by a kind and skilled British trained tool and die maker. I'm sure our North American scraping brethren are every bit as skilled, but the old world lore, from the land of Maudsley, Whitworth, and Stephenson, complete with tales and accent added to the fun. Dave was one of those gentlemen who would remain silent until his help was sought, and then he'd drop everything to make sure you got what you needed. His favored scraper was homemade from an old file. We're going to go down the path of making a scraper from a file, making a carbide scraper, and also look at some purchased options. A lot of thought will go into how to put a great edge on a scraper, as that is one of the most important and basic aspects of successful scraping.



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PURCHASE

There is a very nice line of scrapers made in America by A&W Precision, Inc., who make the Anderson line of scrapers. There's a fair bit of nostalgia here, as the product dates back almost 100 years. Photo 42 shows the two main styles they produce. They are both very nice scrapers but I particularly like the lightness of the upper one in the photo, which is made from tubing.

The blades on these scrapers are detachable. Photo 43 shows two blades of high speed steel that I have just sharpened. In reflecting on the photo, there are too many scratches to call it good, but it's close. There is not much advantage in a high speed blade over carbon steel in actual scraping; both take and hold a great edge, but HSS will hold the edge at high temperatures when grinding the blade. Hence, when the breast is initially ground, you have less worry that the grinding will draw the temper. Photo 44 shows the ends and blade mounting mechanism, as well as the alternate carbide tipped blades.

As you'll see when we get into putting an edge on, much more equipment is required to sharpen and maintain a carbide edge tool, which is the biggest consideration when deciding on a carbide vs. steel blade.

MAKE A CARBON STEEL SCRAPER

Photo 45 shows the classic scraper made from forging and heat treating an old file. While the edge won't hold as long as carbide, they are simpler to sharpen and are capable of doing great work...and bashing away at red hot metal always makes for entertaining shop time.

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I've included instructions on making the steel blade scraper, as it's an interesting project and learning how to make carbon or tool steel tools and harden and temper them is a useful working shop skill. It makes scraping accessible to all; who doesn't have a suitable old file candidate kicking around? For someone wanting to get their feet wet, it avoids the cost of a commercial scraper or diamond wheels for carbide, etc.

There is one area where the forged scraper can be just the thing. Getting into dovetails can be tricky, constricted work. While I've made various small carbide scrapers to address this, I have a beautifully tapered forged scraper about 1/2" wide that is the perfect shape for dovetails. Just a thought, even if you are going the carbide route, don't completely ignore what the forged scraper can do.

I've also been told that many commercial scrapers use steel scrapers, as much of their work is out and about, far away from the bench mounted lapping machine necessary to put the edge on carbide. Also, steel is more easily scraped with steel than carbide. All evidence shows that while carbide is very nice and in my opinion preferred, steel scrapers aren't in the buggy whip category and deserve coverage.

For a general scraper, we want to start with a quality file 12"–14" long. Something with fine, i.e., small teeth is preferable, as it will have a better core thickness and require less grinding.

Work starts at the grinding wheel (Photo 46). I left one of the grey wheels of disagreeable quality that came with my grinder on one side for this type of roughing work. Using care to keep your hands away from the wheel, grind most of the teeth off on the two sides and two edges and, of course, wear safety glasses.

Toward the end to be forged, remove all of the teeth by grinding. Any tiny valleys left between teeth will act as stress risers and they will encourage cracking when we heat treat the file – as you will see.

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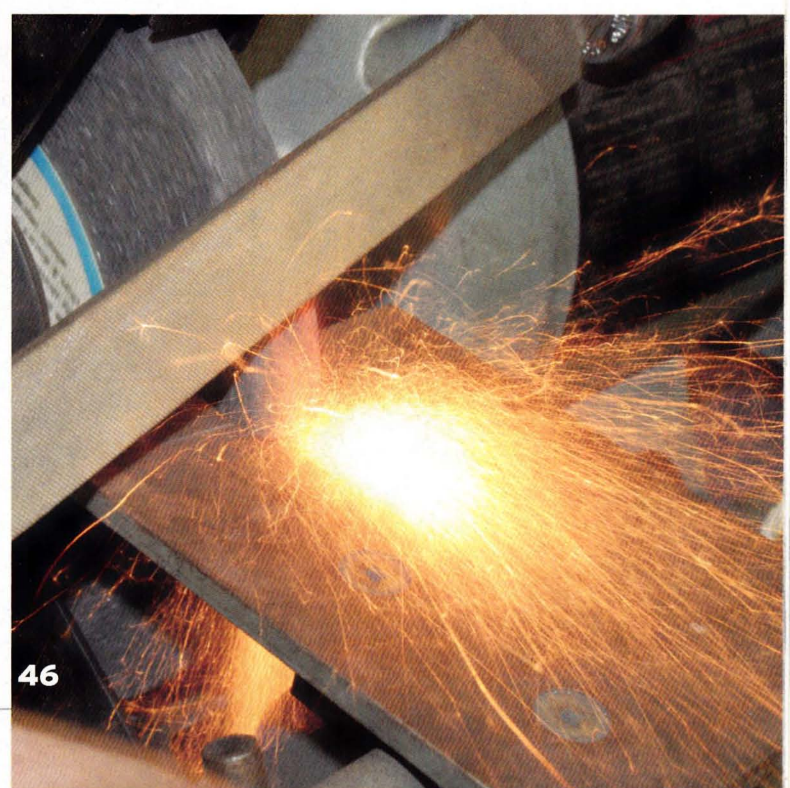

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The file will look rough at this point and uncomfortable to handle, with lots of burrs and sharp edges remaining. Spend a few minutes with a coarse stone and the file will be much more pleasant to handle.

Speaking of handles, it is essential that a good-quality handle is used on our scraper. In Photo 47 you can see the handle that came off the file and the one I replaced it with. This file must've snuck its way into my shop; I think it silly not to use good file handles as they're so inexpensive. I recommend extending that thinking to your files as well as your scrapers; make sure each has a well-fitting, comfortable handle.

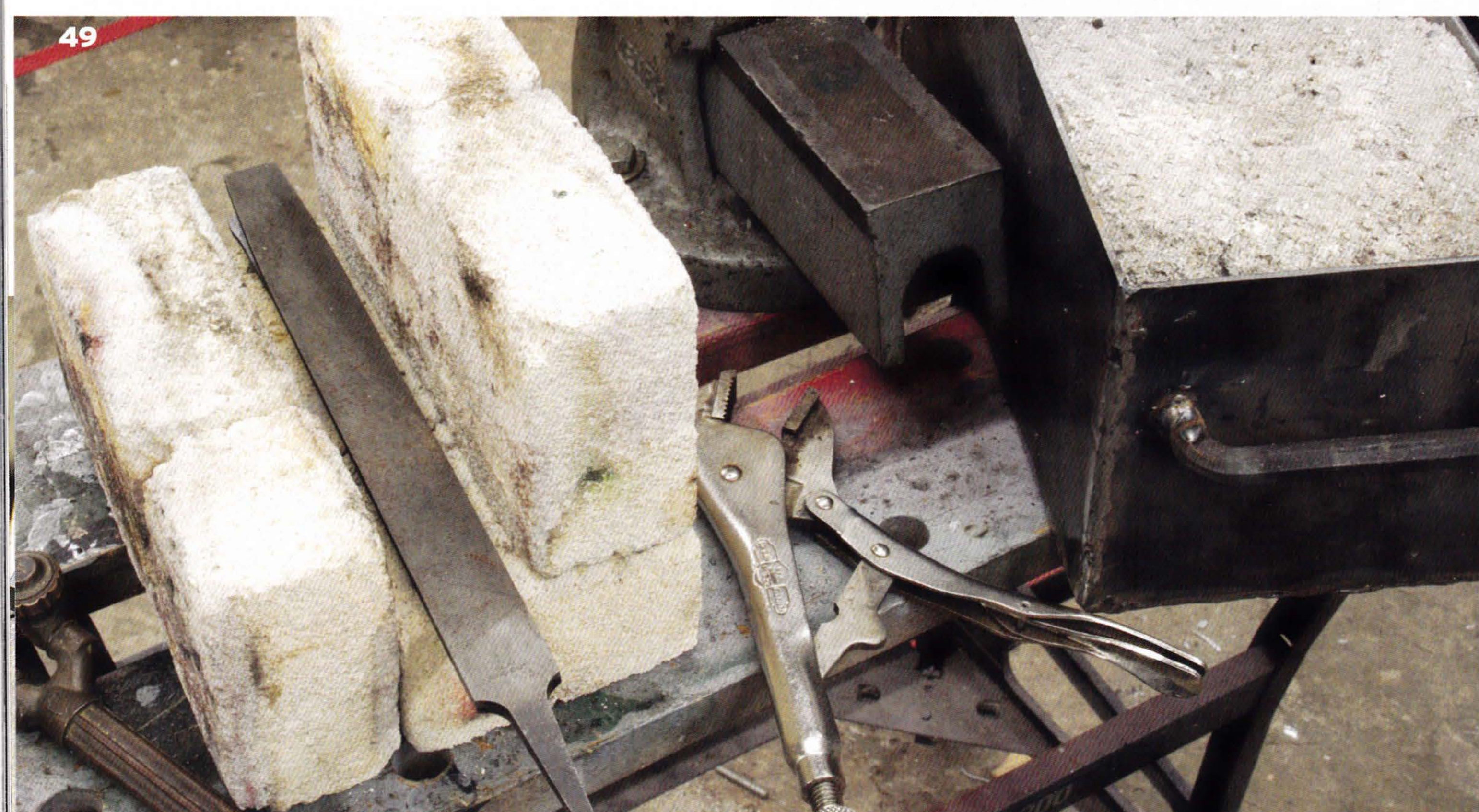
The handle shown in the photo is made by Lutz, costs only a few dollars, is hardwood, and has a screw thread insert into which the tang is screwed and securely gripped.

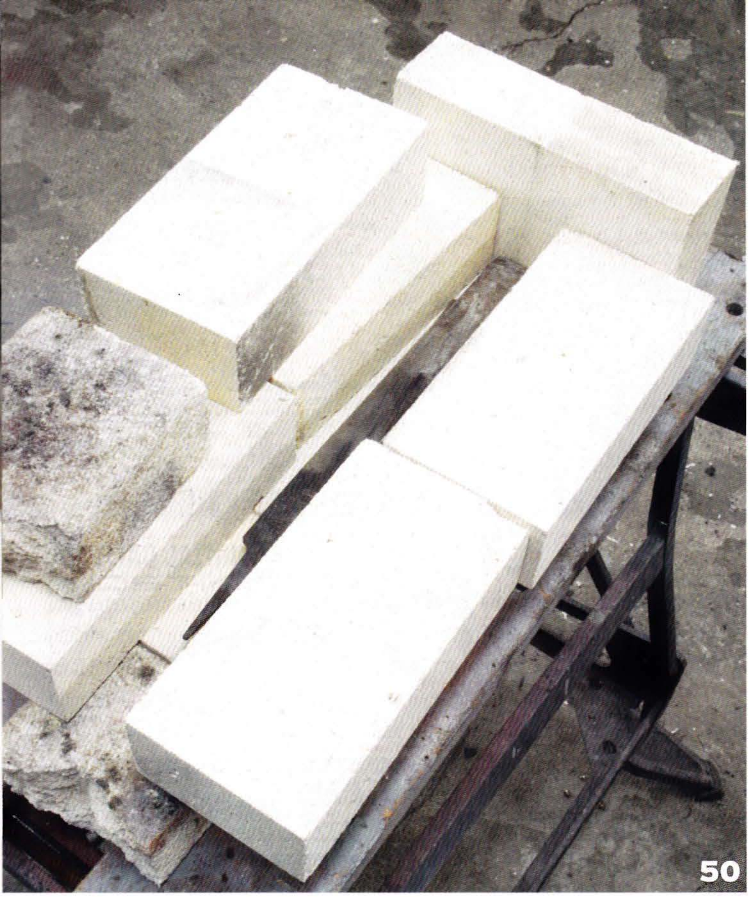
If you examine the Anderson scrapers pictured earlier, the handles are more bulbous than your typical file handle. They look more like a doorknob or an enlarged version of what you might see on an old woodworking scriber. This is the correct and traditional style of a handle, given that much of the work of a traditional scraper was heavy scraping on large castings where the entire body was put into the stroke. Indeed, rubber pads that fit the handle can be purchased for use between the hip and handle.

The handle on the Anderson scraper is definitely easier to get behind and preferable. Feel free to turn up this style, especially if you have a lot of heavy work to do. I find that my shop use of scraping is commonly lighter duty benchwork and a good-sized file handle suffices.

To end up with a forged scraper, we're going to first anneal the files, then forge to shape, anneal again, then harden, and finally temper.

I am not absolutely sure whether the first annealing is required; however, I have included it as it was reported to me that we are better off forging a piece with less internal stresses than are likely to be present in a hardened file. *(Continued on page 54)*

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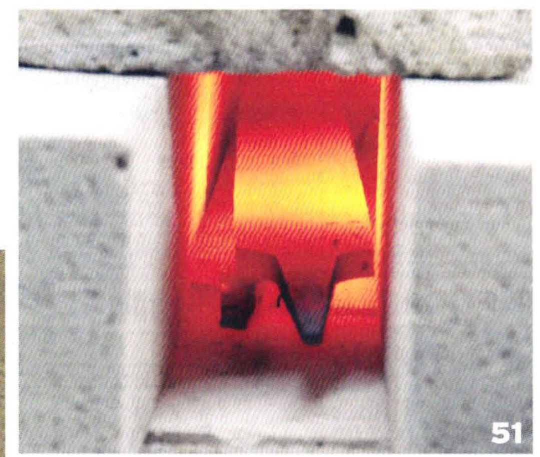
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ANNEALING

Photo 48 shows the file ready for annealing, with the teeth ground off and the handle installed for a trial fit.

Photo 49 shows the Phase I setup for annealing. Insulated fire bricks and a box with a lid, full of fireplace ash, are perfect for annealing.

Annealing, or softening, works by taking steel up past its critical temperature to a cherry red, about 1500° F, and then allowing the work to cool very slowly. When placing the red hot steel in the ash, the ash acts as an excellent non-combustible insulator, facilitating the slow cooling required. That the steel is slowly cooled instead of being quenched is the difference between annealing and hardening.

The torch is played back and forth until the files are red hot. The challenge I had with the setup in Photo 49 was that there was too much open and exposed area to contain the heat. It was hard to hold the heat well enough to get an even red throughout the file and I felt I was wasting expensive welding gas. Hopefully, by showing my tribulations as well as successes, your ventures will have fewer potholes along the way.

Off to the insulated fire brick (IFB) store for supplies and Phase II emerges (Photo 50). IFBs can be purchased at suppliers to foundry/forge businesses or may be easier to find at pottery supply places. Mine came from a discouraged potter and the online classifieds.

If you are not familiar, IFBs are not the heavy, dense fire bricks you'd use on a wood stove or fireplace job. They are very light, foam-like bricks. They are so light that they can be cut with a handsaw (use a hacksaw and you won't feel as bad about dulling a blade) and they do a wonderful job of reflecting heat back rather than absorbing it.

Just like the best block work you did as a child, a base and walls were made with a trench in the middle. Extra blocks…errr bricks…are ready to stack on top as a ceiling.

Photo 51 shows the Phase II setup in action. Faster and more even heating results from more fully enclosing the files.


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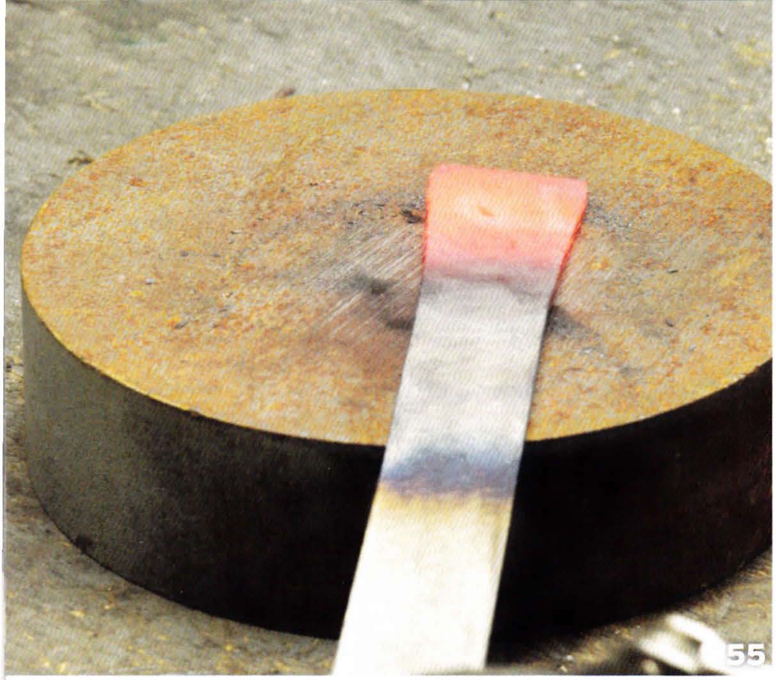
54

The annealing box (Photo 52) is welded up from 1/8" steel with some hinges and filled with fireplace ash. Bury the red hot files and come back the next day.

Photo 53 shows my benchtop forge setup. It's my one minute forge; one minute to set up, that is. To the right is the propane/air torch held in the vise with rubber jaws (now, who was it that was snickering at the suggestion of rubber jaws in my vise jaw article? (July/August 2009.)) with the flame directed toward a simple setup of two insulated fire bricks. To the left you can see my anvil, which consists of a 6" diameter slice of steel.

The torch is turned on and the work left to heat up. Occasionally, I would move the work around to get the entire end up to temperature (Photo 54).

Forging is done on the "anvil" (Photo 55). The anvil was straight off of someone's band saw and therefore has a rough surface, which proved to be a poor choice. The saw texture ended up being transferred to the work. Subsequent to this photograph, I used a piece of cold-rolled steel on top of the anvil and all was well.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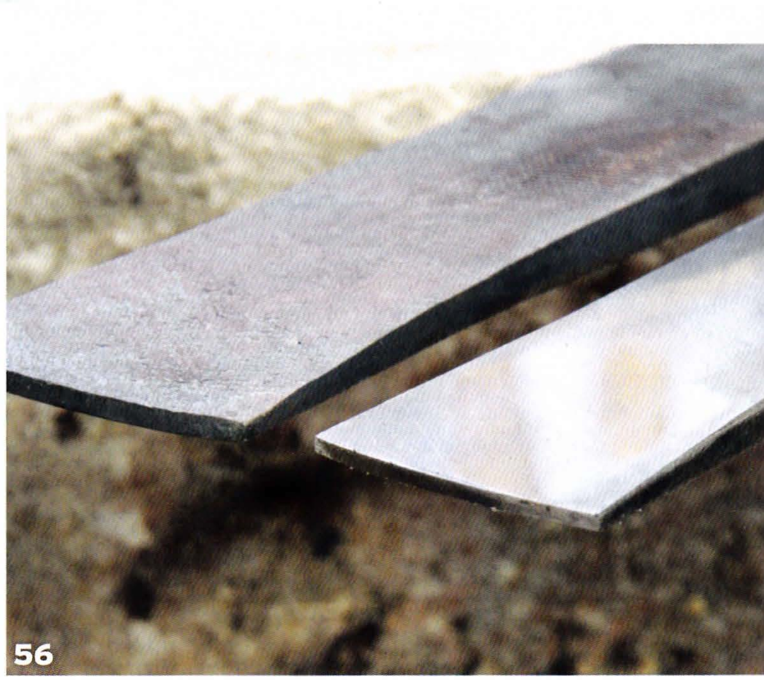
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One day, space permitting, I'll have a real anvil!

Forge away until you start to develop the fantail shape shown in Photo 56. On the left is my forging and on the right is the scraper made by my mentor. I did a little more thinning on it and considered it done. Do exercise some care with the forging operation. Avoid overheating, as pitting can result, and try for a smooth finish. We want to get these faces smooth so the more careful you are here, the less work you will have to do later on.

HEAT TREATING

Heat treating makes for some dramatic images, stabbing red iron into buckets of water with the ensuing plume of steam. Sadly, however, with pieces of red-hot iron in hand and wanting to move quickly, I haven't mastered juggling the camera as well – so you'll have to take my word for it.

I spoke with the engineering department of a large, quality manufacturer of files who still manufactured in North America at the time. The objective was to gain an understanding of the metallurgy so we would know how to heat treat the scraper properly. They were reluctant to divulge their secret alloy and process but did give the guidance that if treated like W1, a water quenching tool steel, we should get a satisfactory result.

I think the files could well be W1. All the scraps of information I've found suggests this; however, all that matters to us is that they are a heat treatable carbon steel that is effectively hardened via a water quench.

THE QUENCH

High carbon or tool steel is interesting stuff. Its finer points might not sustain conversation on the cocktail circuit or around the breakfast table, but for us interested in metalwork there's a lot to learn and understand.

The crystalline structure of steel changes, depending on the alloy mix and also the temperature. In a hunk of steel, there is the element carbon, which is a primary alloying element. If we have enough carbon present, around .08% for a typical tool steel, the steel can easily be hardened via heat treating. In fact, even regular carbon steels can be heat treated, resulting in a small increase in hardness. For example, regular old

(Continued on page 58)

FILES AND CASE HARDENING

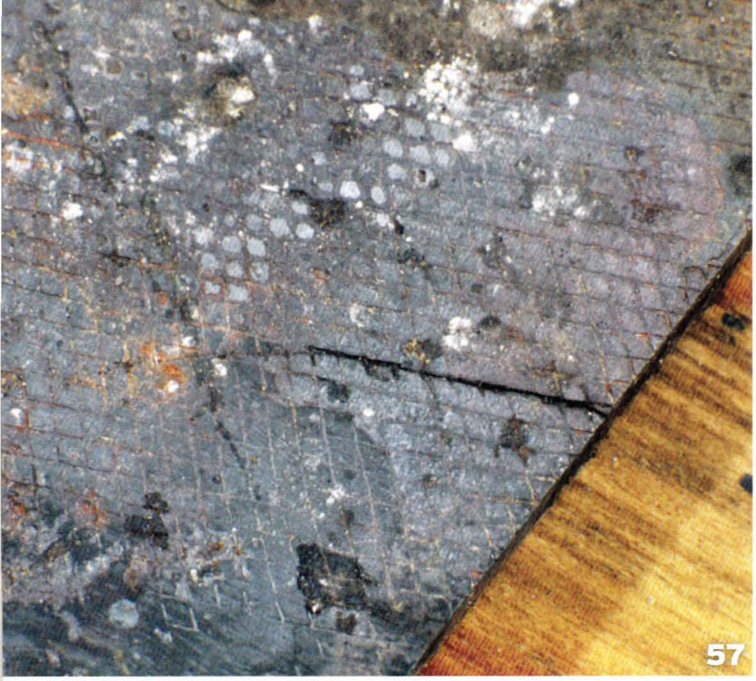
Numerous conversations suggest there's confusion around the term case hardening and how it applies to files. The American Society of Metals defines case hardening as any process that creates an outer layer substantially harder than the interior.

A form of case hardening, used extensively on mild steel, is to submit the work to various processes such as carburizing, nitriding, or others such that the surface layer absorbs carbon sufficient enough that it can be hardened.

Another form of case hardening is done by heating techniques that only bring the outer layer to temperature, such as induction heating. By using a steel that already has enough carbon content to harden throughout and only heat treating the outer layer, the work *is* case hardened. This is what happens with files. Via induction heating, only the outer layer is heat treated. The reason for doing so is that with a soft core, the file is less brittle if, say, dropped on a concrete floor.

Now the confusion comes in that many erroneously think of the term "case hardening" only means one of those processes like carburizing, where stuff is actually added to the outer layer. When they hear files are case hardened, which they are, they assume that only the outer layer of steel is heat treatable. This erroneous assumption, of course, makes it very hard for them to understand why the entire file is in fact heat treatable and can be made into a scraper.

Now if some naysayer says, "You can't make a scraper out of a file, they're case hardened," you can smile and carry on.



Stress Riser

The sharp corner concentrates forces into a very small area

A curve or fillet prevents this concentration of forces

Figure 2

1018 will develop some increase in hardness with a very rapid quench such as with a cold brine; however, the hardness and its depth is insufficient to be of much use.

What happens during heat treating is the crystalline structure of the steel changes to austenite at the critical temperature. The critical temperature varies with carbon content but is close to 724° C, or 1335° F. If the steel is held slightly above this temperature to allow its structure to complete a conversion to austenite, and then rapidly quenched, the crystalline structure is "locked" in a form of hard, tetrahedron shaped crystals known as martensite.

We are going to quench our file/scraper in a bucket of water. Room temperature is fine for the water. You have perhaps heard of oil quenching steel as well. The process is the same; it's just that water gives a faster quench or rate of cooling than oil. It's also a little cleaner, without the obnoxious fumes that result from an oil quench. In any event, the quench medium is dictated by the steel type and all indications are that water is the right quench medium for our old file.

Heat the steel up so that it is bright red in dim light. There is usually a soak time with heat treatment to ensure the crystalline change has taken place throughout the steel. This cross-section is quite thin, so my sense is that a couple of minutes should be adequate. There is no need to have the entire file at temperature; indeed, this might be challenging with by small air-propane forge. Get the business end to temperature and hold it there for say five minutes.

Firmly holding the file with a vise grip, plunge the red hot end into the water and move it about. The thinner the section, and the faster the quench medium, the greater is the chance that there will be some cracking. If you do end up with cracking, you will have to try again with another file. If you are having no luck with this, an oil quench slows things down and might avoid cracking; however, it will not produce the same level of hardness.

WHEN THINGS GO WRONG

With early attempts, I tried to heat treat right after forging. That is, the work was quenched in water from a red color to re-harden the file. This resulted in a couple of failures that are worth looking at.

Photo 57 clearly shows a crack that is following a valley between rows of teeth. The error here was that the teeth were not completely ground off and the remaining valley acted as a stress riser.

What's a stress riser (Figure 2)? It has nothing at all to do with teenagers or the tax man. A stress riser is a feature of the shape that allows stresses to concentrate into a very small area when the structure is subjected to forces. If you imagine the bottom of an "L" shape is fixed, and a force applied to the upright from right to left, hopefully it makes sense that a sharp corner concentrates the stress and more easily leads to failure.

So, if we've allowed the valley between teeth to remain, it will become a stress riser. When we quench, it is a violent operation, creating a lot of forces and movement in the steel. Having a stress riser increases the chances of cracking.

In Photo 58 the break may have followed an earlier stress line from the valley. However, the smaller crack above the break is perpendicular to the edge of the file. What has happened here is that when the piece was quenched, there were a number of internal forces remaining in the metal from forging.

ANOTHER ROUND OF ANNEALING

I consulted with those more familiar with the subject matter – some blacksmiths, who suggested that the forging be annealed again before quenching. The idea is to eliminate or reduce forces present in the metal so that it has a fighting chance to survive the violent quench without the extra challenges of various internal stresses.

This proved quite successful. Simply anneal the files after forging as described previously. After annealing, the worst of the stress should have been removed. A fringe benefit is that the steel is soft enough now to file, allowing you to do a bit of cleaning up on the forging (Photo 59). Once they are hardened only abrasives will touch them.

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TEMPERING

After a quench, the steel will be very hard and brittle. Tempering is a process whereby the steel is warmed slightly and then let down, meaning that is it loses both a tiny bit of hardness and brittleness. Some of the martensite, around the boundaries of the crystal, turns into bainite, which is less brittle than the glass hard and brittle martensite. The application of the tool determines to what temperature it needs to be annealed. For example, a striking tool or punch needs to have a lot of brittleness removed. A scraper, not subject to blows, requires minimal tempering. In fact, I've left some dead hard. It is a good idea to temper the tool though. To do so it needs to be warmed to about 400°F, or a pale yellow color.

Do the warming either in an oven or with a propane torch. If using a torch, heat the work very slowly, as it is

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easy to overshoot and raise the temperature well above the targeted 400° F. Toaster ovens can be very effective for tempering smaller workpieces.

PUTTING ON AN EDGE: STEEL SCRAPERS

Start your edge work by very carefully grinding a slight curve on the end of the scraper. The radius is not critical, about 10"-18" seems right, but it is a matter of personal preference. I say be careful because our carbon steel tool can easily have its temper drawn, or have its hard edge holding ability ruined by the temperatures generated in grinding. Take very light cuts and cool the work frequently. Clean up the sides in a similar fashion.

FINISHING THE TOP AND BOTTOM

When putting an edge on the scraper, the first order of business is to put a very fine finish on the broad top and bottom of the scraper. This is done for the same reason a woodworker first laps flat and smooth the bottom of a chisel before worrying about the edge. A great edge is the intersection of two surfaces; to get a great edge requires that both are very well finished.

In addition, any irregularities on these faces can result in ridges in the work surface. Keep in mind that with finishing work the depth of cut can be less than a tenth of a thousandth, so while scratches and ridges on the surface may be very small, they will have an effect on the feel of the action and the cleanness of the cut. Let's make finishing these broad, flat surfaces the first order of business.

I like to use woodworker's water stones because they cut so quickly. Our woodworking brethren have long known of the advancements in man-made water stones and we'd do well to borrow a page from their book to get a great finish. A mainstay in my shop is a 200×1000 grit water stone kept in a bucket of water. At least I think that is what it is, it might be 200×800, but the point is, it's one of the inexpensive, double-sided water stones commonly available.

After careful forging, annealing, filing smooth, and then hardening the scraper, it goes to the 200 grit water stone. In Photo 60 you can see quite a slurry worked up as I work the business end to shape. Not too many minutes later, after a quick rinse, the end of the scraper is starting to take shape (Photo 61).

I progressed through the 1000 grit side of the water stone and then moved to a 4000 grit water stone. These cut very finely and will leave a mirror finish (Photo 62). Finish both sides of the scraper; a scraper has two cutting edges and we want them both in tip top condition. Once we have these flats to a mirror like finish, with careful use, they won't need to be touched again as sharpening is done on the end of the scraper.

HOW METAL CUTS

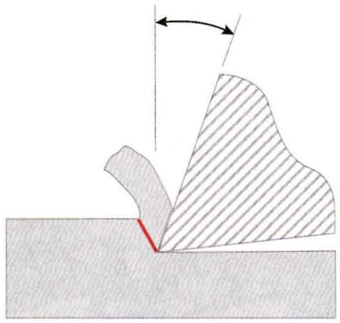
Before we get to the edge, I'm going to treat you to a bit of theory.

Often, the first chapter in a machine shop text has a treatise on how metal is cut. There is usually a well-prepared diagram showing a tool moving through material and an explanation that metal is cut because the pressure

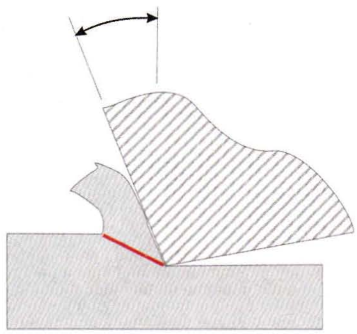
(Continued on page 62)

that the tool imposes creates a shear plane in front of it. I also think that, except for the most stalwart among us, most readers of machine shop texts bypass Chapter 1 in search of more macro chip making content.

This is a shame because this little foundation of knowledge on how metal is cut does play into almost everything we do. So, how many home shop and professionals alike skipped Chapter 1? Before you rush off to your bookshelf to peruse the pristine pages of Chapter 1, I've replicated the essentials here. Don't groan too loudly; it will be brief.



Positive Rake Cutting Tool Action



Negative Rake Cutting Tool Action

Figure 3

Figure 3 shows the basics of how metal is cut. The cutting tool is moving from right to left and because of its depth of cut, it is exerting considerable pressure on an area in front of the cutting edge. The pressure is high enough that a shear plane happens along the red line. The chip literally breaks apart from the parent material, shearing along this line because of this pressure. This is true for a surface grinder, lathe, or hand scraping; metal is cut by a cutting tool edge exerting enough pressure that a shear plane is established ahead of the edge.

In Figure 3, the upper illustration shows a positive rake to the tool in that the angle off of vertical is behind the cut. Negative rake is shown in the lower image, with the top of the tool in front of the cut. Note that the angle of the cutting edge presented to the work affects the location and the length of the shear plane. The longer the shear plane, the more force is required for the metal to shear. This is exactly why some carbide tools can be a challenge to use effectively in light lathes – their more obtuse cutting edge requires more oomph to drive them through the cut.

The best analogy I can come up with is running your fingernail across a bar of soap. Whether you do so with your fingernail and a positive or a negative rake position, the soap builds up in front of your fingernail along a shear plane created by the pressure of your dancing fingernail. Metal, unlike wood, is not split or sliced but is cut by an action similar to the soap shearing off in front of your fingernail.

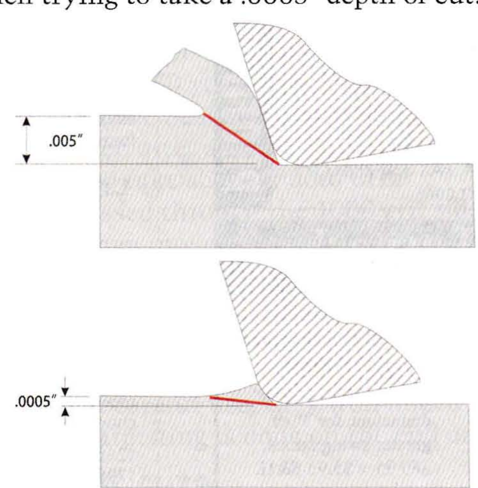
While we are on the subject, let's expand the understanding by one dimension. The cross-section view presents a shear plane as a line, whereas in fact it is a plane. In other words, it has not just a length as shown but also a width, hence an area. If we know the area of a shear plane, and we know what material we are working with, we are dangerously close to an engineer's understanding of what is happening when cutting or machining metal. Each material has a tensile strength expressed in units of force for units of area (such as PSI, pounds per square inch).

Taking this information and knowing our shear plane area, we could calculate the force required to machine the piece. This is important if we are designing machines and want to understand how much force they are subjected to or how much power is required to machine something.

BACK TO SCRAPING

Another aspect of when metal is cut along the shear plane is deformation around the cutting area. This is why we inevitably get burrs when cutting metal. Even when only doing a .0001" deep cut with fine scraping, there can still be burrs along the edge of the cut. Thus the stoned file or stone to remove them.

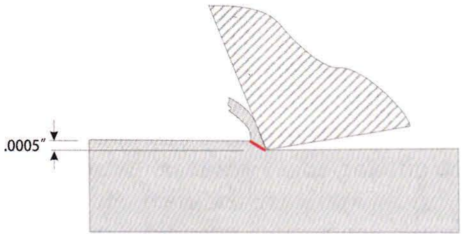
Finally, appreciating what is going on at the edge of the tool will help us understand how fine an edge is required to take the very tiny cuts we do with scraping. Figure 4 shows us the same tool (possibly a negative rake lathe tool, for example) taking off .005", with the edge rounded off by approximately .001". While this might work with a .005" depth of cut, it does not work when trying to take a .0005" depth of cut.



Edge shape relative to depth of cut

Figure 4

In the latter example, the bluntness of the tool is exaggerated against the depth of cut and the tool wants to skip along the surface, as the intended shear plane is approaching parallelism with the work surface. At a certain point, as the shear plane trends toward parallelism with the work surface, the force required to deflect the tool away from the work is less than that of the shear plane and the tool skips over the surface. In the example, we can definitely make the .0005" cut, but we need a refined level of sharpness to remove the rounded corner and create a more vertical (shorter) shear plane.



A sharp tool permits a fine cut

Figure 5

As Figure 5 suggests, to take the very fine cut that scraping does, a very sharp edge is required. This is an important point. Scraping forms a very fine chip and to form a fine chip requires a sharp edge. Some thought has to be given to the cutting edge.

A key component of scraping is being able to readily put this edge on; it's a prerequisite to the tool's effectiveness and redoing the edge is frequently required.

The front of the scraping tool, called the breast, where it meets the broad, flat faces of the scraper's sides forms a cutting edge. Since we have a sense that the rake angle of the tool determines how much force is required to cut, it stands to reason that we would vary depth of cut as we change the angle for a given applied force. And this is in fact the case.

A square faced scraper as shown at the top of Figure 6 is considered to be too aggressive. While it presents some negative rake, it is not enough and this tool will cut too deeply for scraping work.

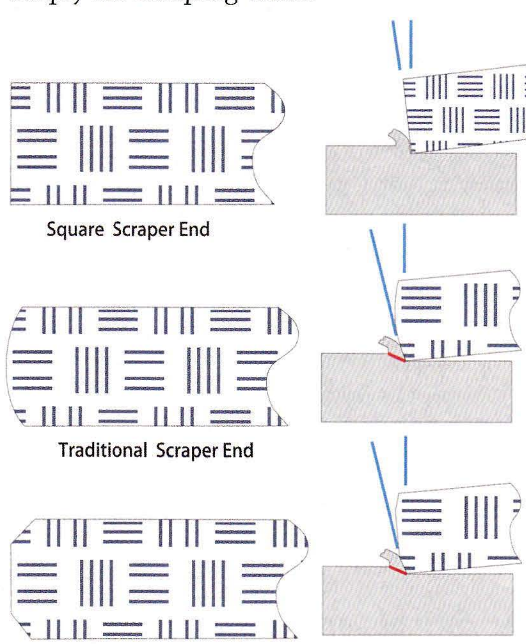
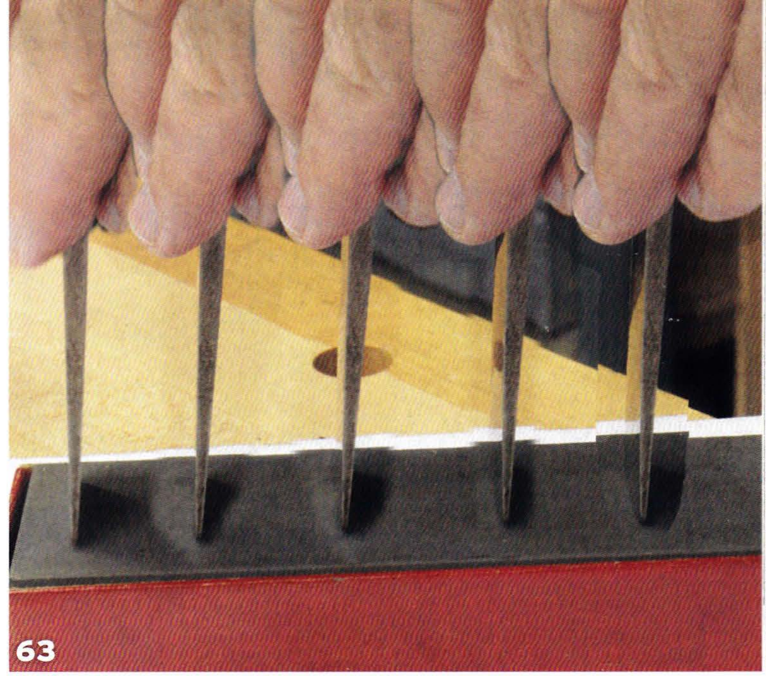


Figure 6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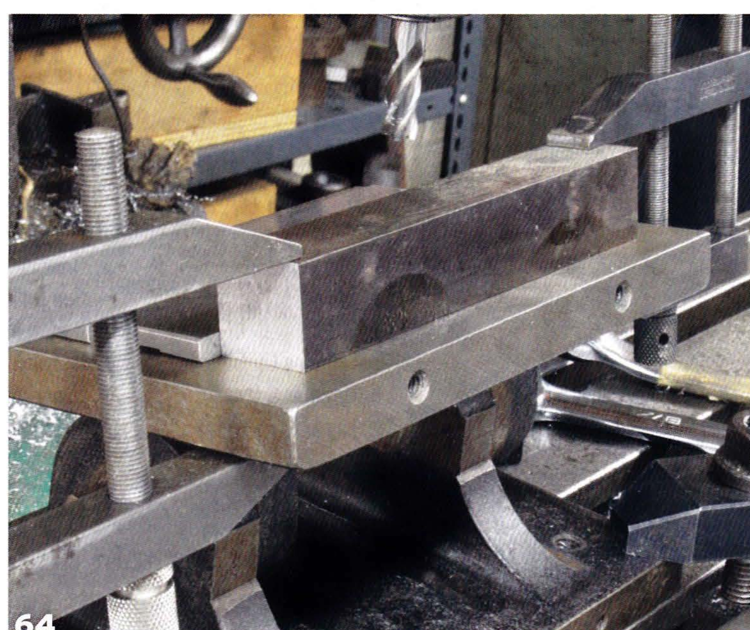
This is overcome in the traditional scraper edge as shown in the middle of Figure 6. A slight crown (I exaggerated it in the diagram) is the natural result of how the scraper is sharpened. The scraper is sharpened as per the multiple exposure (Photo 63). Holding the scraper close to vertical, it is drawn toward you over the stone. The unavoidable fluctuations in the angle both left to right and fore and aft as the scraper is drawn across the stone produce the crown.

That it is a curve does not matter, as only a small section of the curve at the edge of the tool is engaged in the work. As per the bottom image in Figure 6, if we can put a faceted edge on the scraper, it will work just as well as the rounded crown.

In the traditional approach for putting an edge on (Photo 63), I'm using an oil stone of fairly fine grit, I'd guess around 600. One challenge is getting the correct stone; too fine a stone and you're there forever, too coarse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and it creates a poor edge that breaks down quickly.

I experimented with methods for creating a faceted edge as shown at the bottom of Figure 6. One idea was to mill a block with a 5° angle on one side and a second angle of 8° on the other side (Photo 64). The idea was to wrap the block in a piece of paper to protect the mirror finish on the scraper's top and bottom surfaces and use it as a fixture to hold a hard Arkansas stone at the right angle (Photo 65).

The results were so-so. When sharpening a tool, no matter how fine the abrasive, at some level of magnification peaks and valleys reveal themselves. These are, of course, formed by the abrasive and should be perpendicular to the cutting edge, whereas my setup had the microscopic lines parallel to the edge and this caused the edge to break down more quickly. The fineness of the Arkansas stone mitigates this to a certain degree; however, it is not the correct direction to sharpen – the correct direction being perpendicular to the cutting edge. My conclusion was the technique shown in Photo 63 is probably best.

I do have one trick for putting on the ultimate edge but you'll have to wait until after the carbide section when we'll build a rotary lap. The rotary lap will put a faceted edge on your steel or carbide scraper like you have not had before.

Photos and drawings by Author

SCRAPING for the Home Shop

Part Three

BY MICHAEL WARD

66

MAKING A CARBIDE SCRAPER

Now that we have mastered the techniques for making carbon steel scrapers, let's take a look at carbide. There is no doubt that a carbide scraper is a superior scraper; it simply holds its edge much longer and makes scraping items such as hardened beds a reasonable (if not less challenging) proposition. If you have a lot of scraping to do, it's definitely recommended that you make or acquire a carbide scraper. The style I make is simply a length of steel with a file handle on one end and a bit of carbide brazed on the other (Photo 66).

A carbide scraper is something of a good news, bad news scenario. The good news is a carbide scraper is not that difficult to make, or they are commercially available. The bad news is it's going to take some specialty tools to put/keep an edge on your scraper.

Carbide can't be sharpened by the regular aluminum oxide wheel on your grinder. It's too hard. You may know that silicon carbide wheels (the green wheels) will grind carbide but they do a poor job. Especially when we need a very fine edge. The edge formed after grinding with a silicon carbide wheel will likely be chipped and a long way from a usable condition.

To move up to carbide, you've got to move up to diamond sharpening equipment. Ideally, you'll have a diamond grinding wheel to grind the crescent shape on the end and a diamond lap to put on the sharp edge. I say ideally, as you can form the crescent shape with the lap; however, it's a lot of lapping!

I've a lot of scrapers. I tend to make them in batches and have experimented with different lengths and thicknesses of the body, or shaft, of the scrapers. I like to grab a handful at a time when I head to the lap and keep scraping until they're in need of another tune up. I have the traditional, long handled versions that machine tool scrapers would use, as well as short versions that are preferable for smaller bench-work projects.

The batch I photographed for this article are long handled scrapers, two 12" and two 14" long shafts, with one of each being of 1/8" thick steel and one of 3/16" to allow a variety of shapes and sizes and to ensure enough photo ops. I ground some as square end scrapers; handy for getting into the corners that sometimes present themselves. I've also made some shorter handled scrapers that are convenient for finishing and bench-work, some narrower scrapers (not of much value), and some very thin scrapers using 1/16" carbide to allow me to reach into the corners of small dovetails.

Over time, I've developed the opinion that my shorter, 4" or 5" bladed models are more convenient and they see more use. I generally use the power scraper for heavy stuff and the shorter hand scrapers end up much more convenient for finishing and bench-work. As they aren't very much effort to make, you might consider making a variety pack until you find the most comfortable size for you.

Regardless of build or buy, you will need a diamond lapping setup, which we'll cover in a later part. In addition, you will need a diamond grinding wheel to create the initial shape on the carbide. These wheels are expensive, but if you are using carbide in other places in your shop, perhaps it can serve multiple functions.

Theoretically, you could use the hand held diamond "stones" to put the curve on the end of the blade; however, I don't think there is a substitute for the rotary lapping operation we'll cover later.

I started by cutting to length blanks for the body of the scraper, as well as some shorter, thicker pieces that will be used for tangs (Photo 67).

I decided that the easiest method of getting a nice

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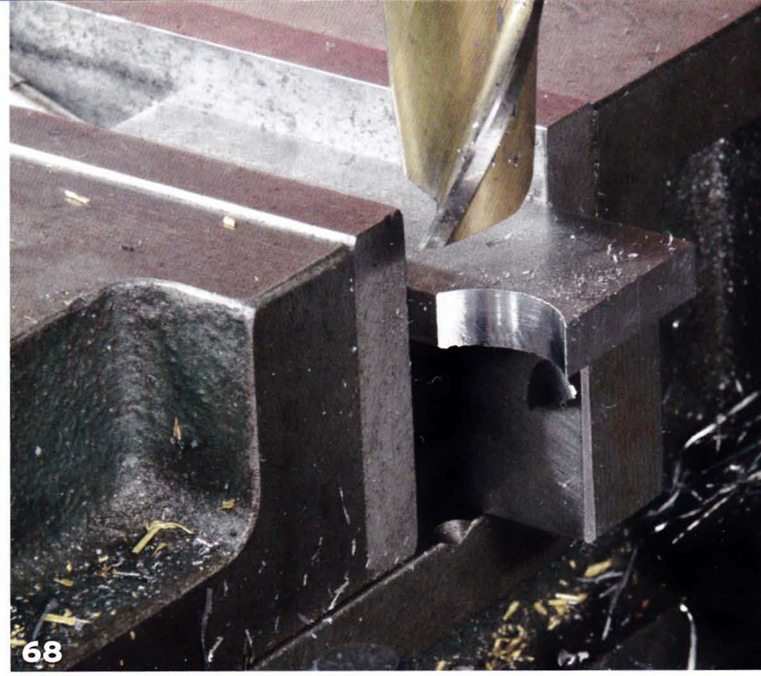

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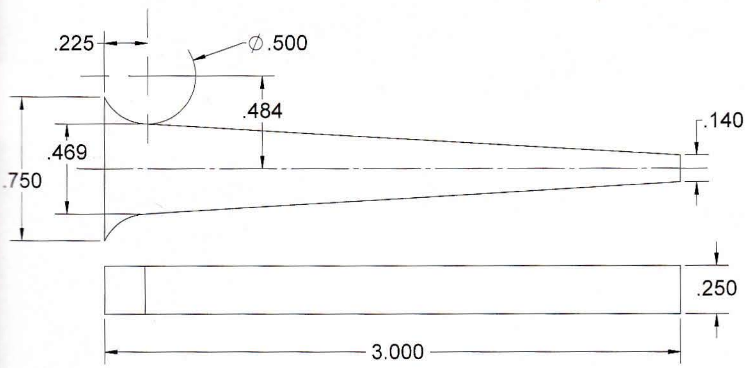
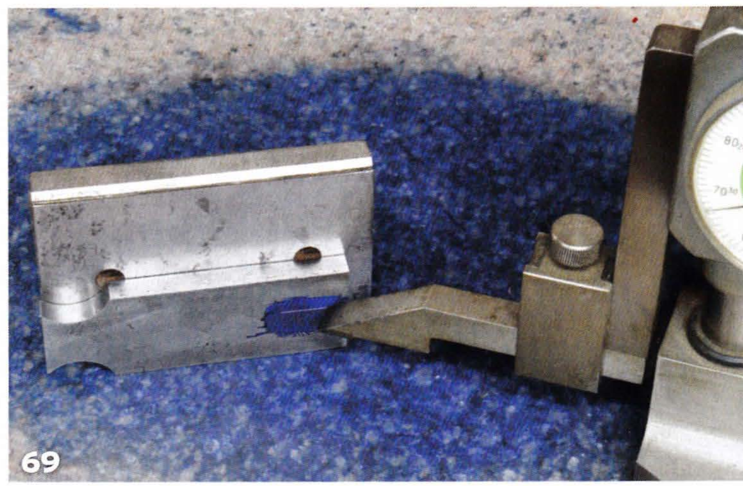


Dimensions to fit Lutz #8 File Handle
Figure 7



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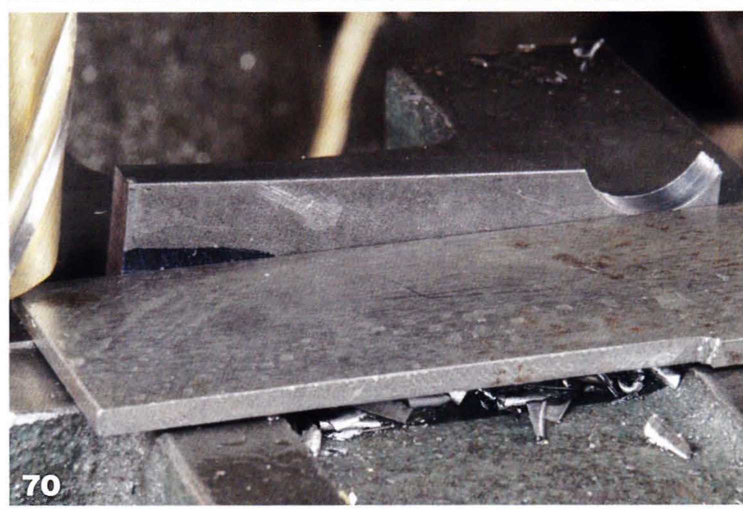

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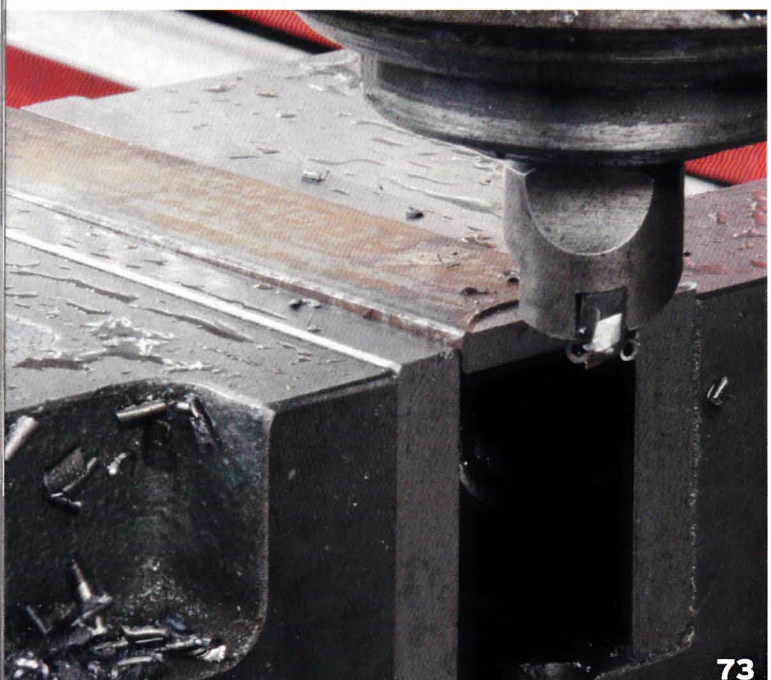
handle on the file was to use Lutz file handles. They are nicely made hardwood handles and are inexpensive. To use them, we need a shape like a file tang on the end of our scraper, so our first task is the unlikely job of making a file tangs! I have to chuckle at myself, and maybe you will to, for making file tangs, but making tangs and using commercial handles seemed the easiest route to get a decent handle on our scrapers. When I've done so it's been in batches, which maybe makes it seem less silly; much less time per piece this way.

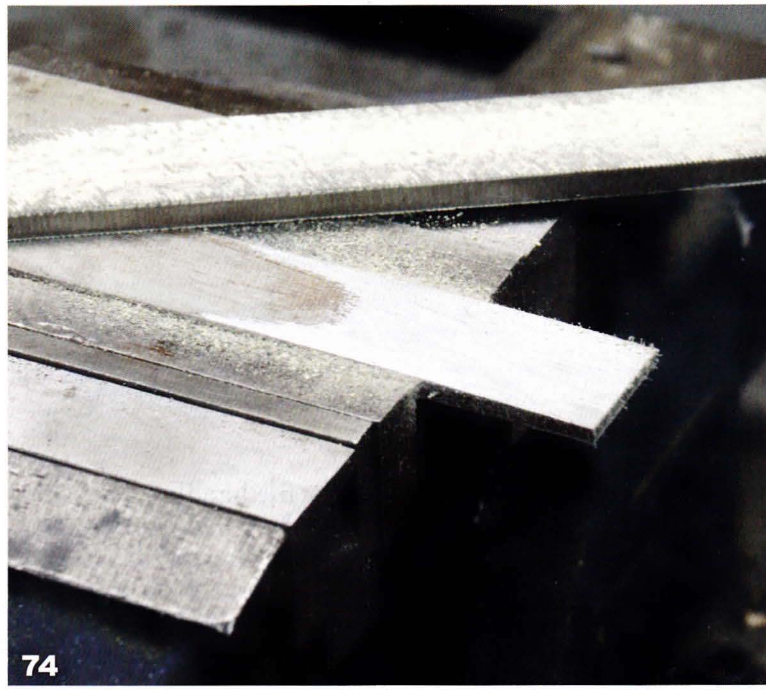
To get a proper bite with the handle, I deemed the shank itself too thin to machine a tang on so I carved out some file tangs from 1/4" stock. Using a Lutz #8 file handle, which I think makes a comfortable scraper handle, I tried various files until I found one whose tang fit the handle nicely. Figure 7 shows these dimensions.

1/4" steel, hot- or cold-rolled, will do nicely for the tang(s). Start by cutting a piece of 3/4" wide material to 3" long and clean up one end in the mill. Having a bunch to do, I set up a 1/2" slot drill (two-fluted end mill) in the mill, offset to the end of the work. A vise stop let me plunge one side, turn the work over and plunge the other (Photo 68).

You could, of course, just cut a tapered piece and braze it on. I chose to replicate the fanned shape of the end of a file, primarily so it would create a larger surface area to silver solder between the tang and the body of the scraper. The narrow end of the tang should measure about .140" wide. With a height gauge set at .570", it was quick work to scribe two lines on the end the proper width (Photo 69).

This is a long way from high precision work and the quickest way to finish the tangs is with some eyeball





alignment. Place a parallel across the top of your vise jaw and align the work in the vise such that the scribed line at the end of the tang and the curved cutout section both touch the top of the parallel (Photo 70). Mill down until this taper section smoothly meets the radius. The thin parallel is just an aid to set the scribed line against and is, of course, removed before milling.

Milling like this, where there is more material protruding from the vise than clamped in the vise and with the work not supported underneath by a parallel, can be tricky. Use a gentle hand feed and orient the cutting forces so they are trying to push the work toward the fixed jaw of the vise. Flip and repeat on the other side.

We are going to silver solder, or silver braze, the finished tangs (Photo 71) onto the end of the body of our scraper. I made the bodies out of 1" wide steel, either 1/8" or 3/16" thick. Some was cold-rolled, some hot-rolled, depending on what I had in stock. I made the bodies 12" and 14" in length.

TAPERING THE BODY

I thought it advantageous to thin out the main part of the scraper where it comes to meet its carbide end. The main reason is that if lapping work is required on the carbide at some point, it would be nice to have it proud of the steel shank.

Photo 72 shows setting up a blank in the mill vise for tapering. This is eyeball engineering; cut to what looks good to you. The steel block across the jaws in the photo is held against the work while the work is being clamped in the vise. It helps to remove any angle in the Y direction as the part is clamped. Keep the work in contact with the steel block as the vise jaws are tightened. Photo 73 shows the slight taper on the end of the shank being milled with a fly cutter.

(Continued on page 50)

In Photo 74, I'm doing some clean up; removing tool marks and fine tuning. Too fussy perhaps, but I'm the one who will have to look at them and I like to make decent looking stuff. The subsequent decision to paint makes removal of tool marks a bit superfluous – the cellulose filling primer fills the tool marks quite easily. Finish as you see fit.

The variance in length and thickness of different bodies allows you to vary how flexible the body is. By all accounts, there is no right answer to the desired flexibility. Among experienced scraper hands it is a matter of personal preference. I'd thought us home shop types unlikely to scrape enough acres to develop strong preferences; however, I find myself grabbing more for the 1/8" thick ones than the 3/16" thick ones. Try a few different thicknesses and see what you prefer.

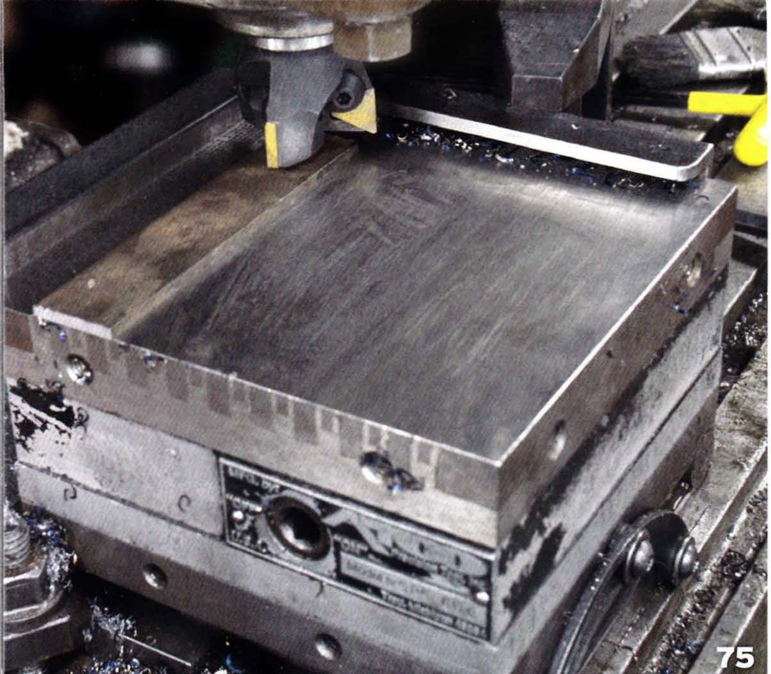
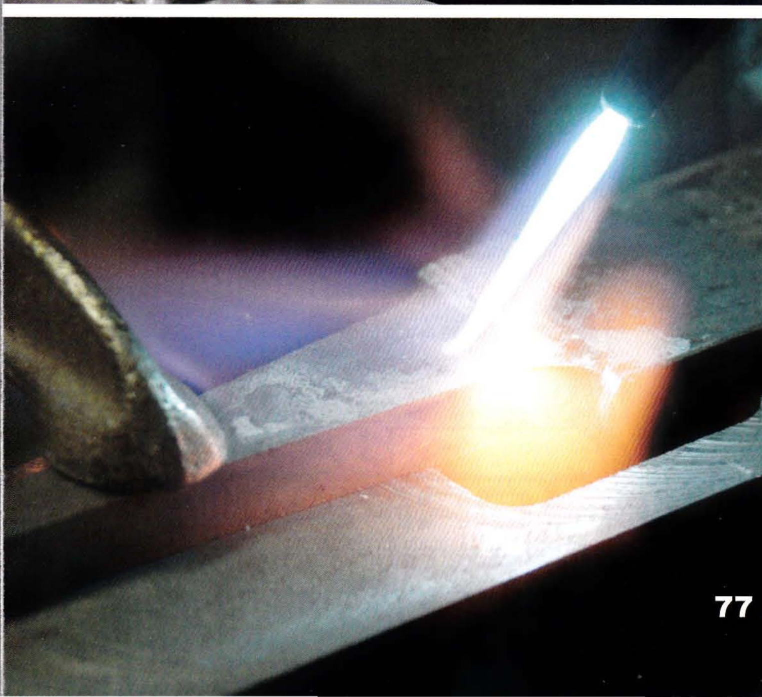

75

Photo 75 shows an alternative approach to tapering the shanks. A recent addition to my tooling shelf is this nice little magnetic sine plate. Normally a grinding accessory, it worked well for this light milling job. You'll note the scale between the fence and work. The magnetic force alone is not strong enough to hold things for milling, so the fence must be used and light cuts taken.


76

Once you have the taper cut, make sure the ends of the body are cleaned up and square in preparation for soldering. I made a simple little fixture to facilitate silver soldering the tang to the body. I took a piece of 2" angle iron, a little less than a foot long, and milled a section out of one side. I then did a skim pass with a fly cutter to make sure the surfaces on both sides of the milled out pocket were on the same plane (Photo 76). The scraper body is clamped to one side of the fixture and the tang to the other as seen in the photo.

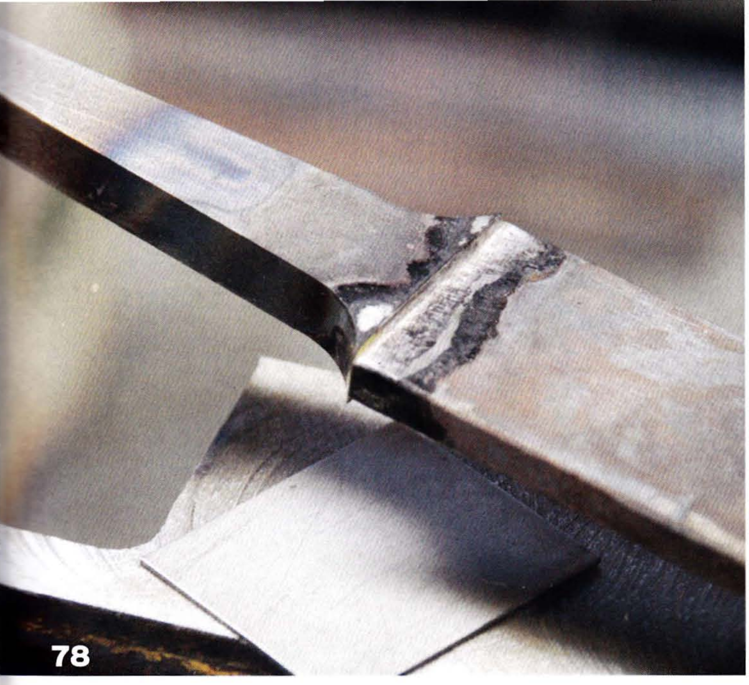
The tang is thicker than the body, so I used some shims underneath the thinner body to ensure it would be centered on the tang. If you are new to silver soldering, the key is to make sure the two ends are clean (not even fingerprint oil) and, as is always the rule with silver soldering, apply copious amounts of flux. I use a flux made specifically for silver solder and would recommend the same.


77

Usually I silver solder by carefully creating an assembly, figuring out some method of holding the parts in alignment, and placing small lengths (1/16" – 1/8") of 1/32" diameter silver along the joints. The parts are often small and are surrounded by air or, if larger, insulated fire brick. Propane/air is the fuel of choice as it doesn't get hot enough to burn the flux or damage the silver solder.

With this job, I departed from my standard methodology and fired up the oxy-acetylene torch. We have a lot more metal here than my typically fidgety little silver solder assemblies and the angle iron will also act as a heat sink. So, we need to apply more heat, more quickly. Photo 77 shows how the oxy-acetylene flame is directed away from the joint and flux, as its temperatures are too high to apply directly to the solder and flux.

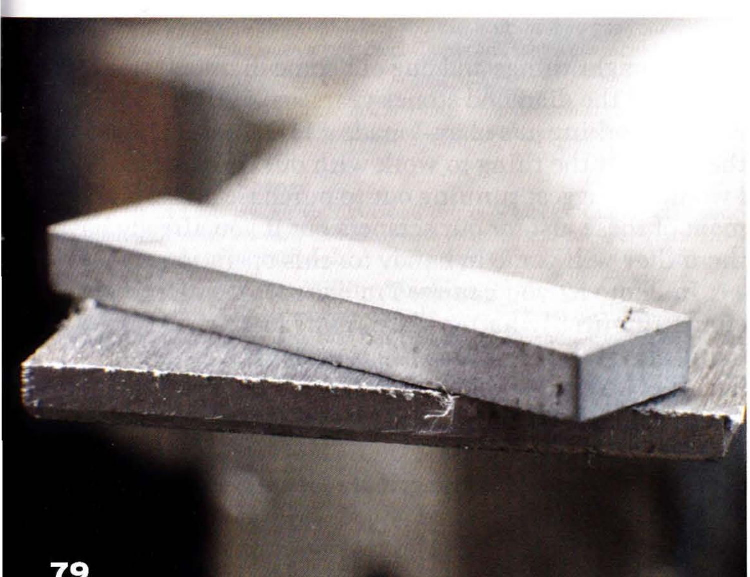
I place a small piece of silver solder along the joint, where it serves as the perfect indicator that everything


78

is at the right temperature. It is very easy with acetylene to go too high in temperature, resulting in a weak and brittle joint. Direct the flame away from the joint, alternating from piece to piece. I keep applying heat until the little lengths of silver solder are wicked in. The solder beautifully and immediately fills the joint and forms a nice fillet.

If you feel there is not enough silver solder, take a length of silver solder whose end was immersed in the flux container and touch it to the joint. However, in my opinion, better work results from placing the right amount of solder (judging the right amount comes with a bit of practice) on the joint prior to heating. The reason being is when the solder is applied to a hot joint it is more difficult to control how much solder is used, often resulting in blobs of excess solder. I judged there was enough solder present on the pieces and called the job done (Photo 78).

The next item of business is to silver solder the carbide end to the body (Photo 79). Note how the body


79

has been thinned such that the carbide end will be thicker than the steel. This is a small, non-essential improvement but it does make it easier to do additional lapping on the top and bottom of the carbide should it be necessary.

WORKING WITH CARBIDE

With either carbide or tool steel, it's important that the flat sides of the scraper that meet the breast forming the cutting edge are very well finished. As noted previously, an edge is the intersection of two surfaces, so if we want the intersection to be good and sharp, each surface must be very well finished. If these surfaces are rough, it will be impossible to get a good edge on the tool. If there are scratches or chips, they will result in ridges on the scraped work.

The primary cutting material for working with carbide is diamond. Photo 80 shows a selection of diamond stones. These diamonds are much less expensive than buying a ring, are useful, and require minimal ongoing maintenance. The most difficult part about working with carbide is overcoming our frugal nature and springing for some diamond stones. Throughout this article you will see diamond stones, diamond lapping compound, and diamond grinding wheels – all of which play a role in creating and maintaining our carbide scraper edge.

80

The carbide blanks I used came from KBC Tools and Machinery. I bought an assortment of sizes, with the most common ones I used being 1" × 1/4" × 1/8". The smallest blanks, used on the little dovetail scrapers, were 1/16" thick.

The first task is to put a very high finish on the two sides that intersect with the end to form the cutting edge. The little pieces of carbide are much easier to work with now, rather than after attachment to the body, so let's start by putting a very fine, lapped finish on them.

I was surprised at how curved the surfaces seemed to be (Photo 81). This photo shows the results of taking the carbide blank directly to a lapping operation. With the carbide this out of shape, lapping would take some time

81

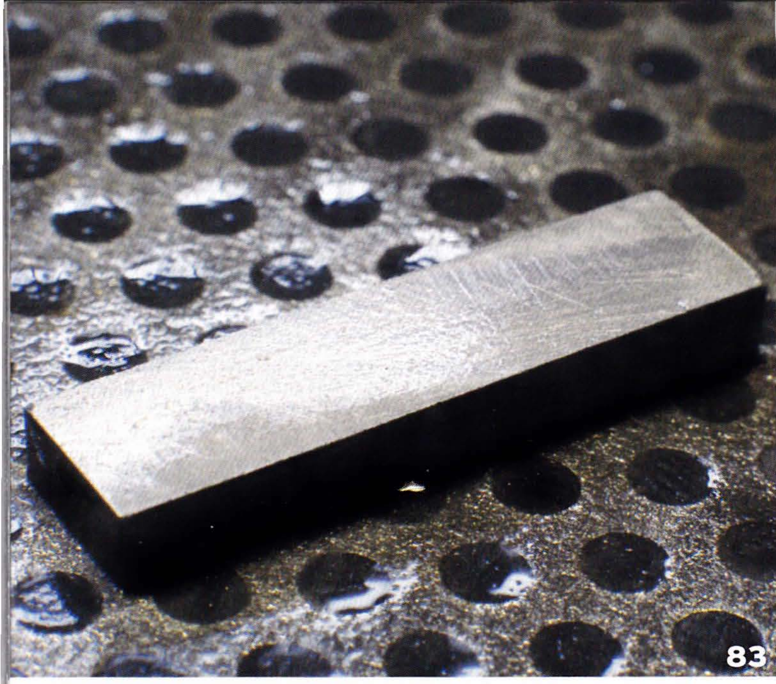
82

so I rethought things and dug out some diamond stones. I acquired the diamond stones years ago during a bout of woodworking (it's okay, I made a full recovery) and they are just the thing to work with our carbide bits. I wouldn't suggest running out to purchase an assortment of these just for our scrapers but if you already have them they will come in handy for this operation.

In Photo 82 you can see I'm using three diamond stones to initially flatten the carbide bits. As with many abrasive operations, life is easier if we start with a coarse stone and sequentially use finer grits.

In this case, I was glad to have the coarse stone. Photo 83 shows the carbide being worked on the coarsest of stones and the grit size is quite visible. Once the curvature was removed, I worked towards the finest stone, removing the previous stone's scratches. Make sure to use water to help carry away chips.

(Continued on page 54)



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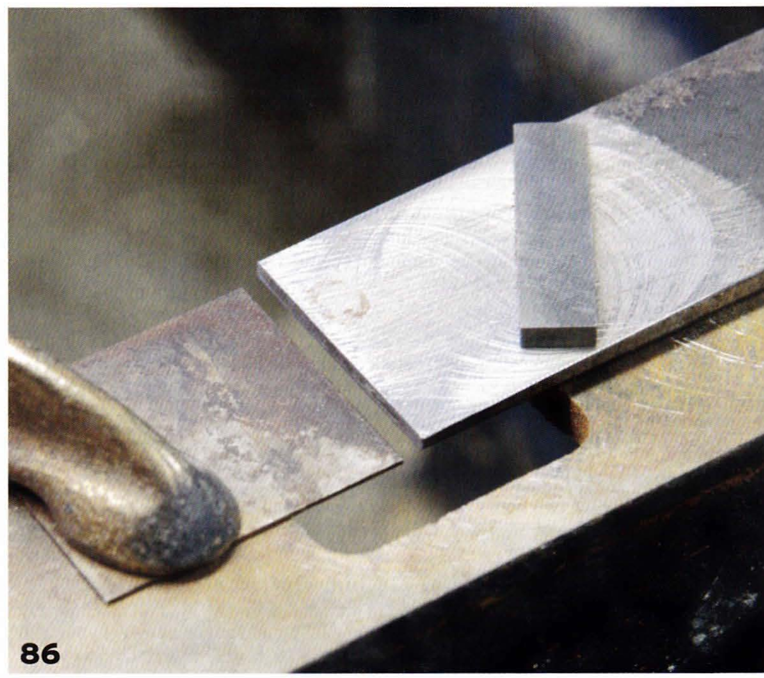

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PUTTING A POLISH ON THE BLANK

After using the finest diamond stone, we'll be using a fine diamond lapping paste (#9) to put a mirror finish on the carbide. Diamond lapping compounds are color-coded, with the green I used being #9, or a 9 micron particle size. This is categorized as "super fine" and the range (at least what's commercially available to me) goes from 90 microns down to 1/4 micron. #9 seems to be commonly recommended and has worked well for me.

While I'm accustomed to thinking cast iron is a better choice than aluminum for a lap, I had a scrap of aluminum cut from a channel that needed to be used and it worked well. I fly cut the aluminum piece and, using an old Torrington bearing on a shaft, pressed the compound into the lap (Photo 84).

This is the general principal of most laps. The lap is "charged" by having the abrasive grits pressed into its surface, which are then used to cut the work. Use maybe a couple of pin heads worth of diamond paste and roll it out with the bearing like grandma on a pie crust. Keep going until the mirror finish shows up across the carbide blank. A little water helps (Photo 85).

SILVER SOLDERING CARBIDE

The carbide blank gets silver soldered to the end of the steel body. The trick in silver soldering carbide is to clean the oxidation layer off first, as any oxidation will prevent a good joint. As we just proved with the diamond abrasives, carbide is a bright, silvery color. However, it oxidizes, giving it the dark grey color we're accustomed to.

While emery won't cut carbide, it will cut the oxidized material on the surface. Rub the edge with some fine emery to prepare for silver solder.

My setup for silver soldering is shown in Photo 86, using the same piece of notched angle I used for silver

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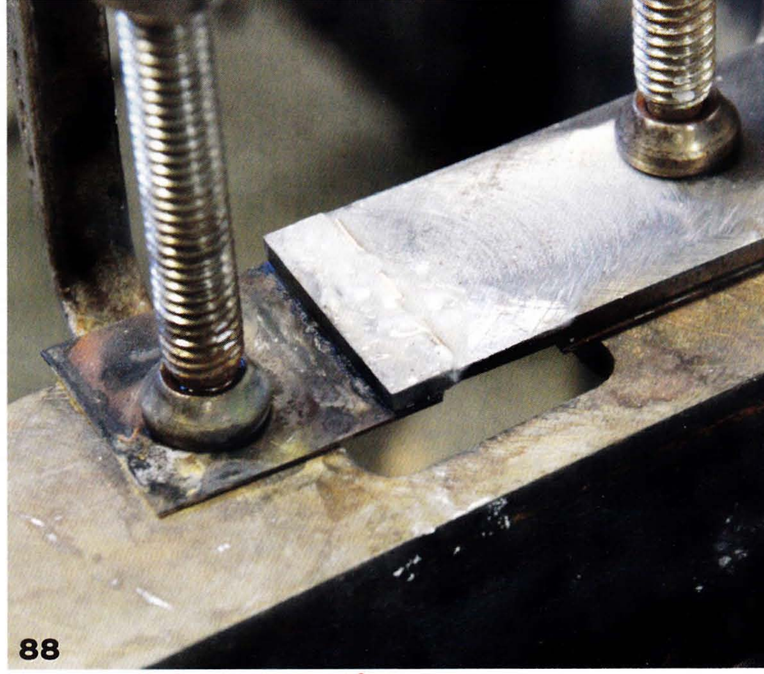


88

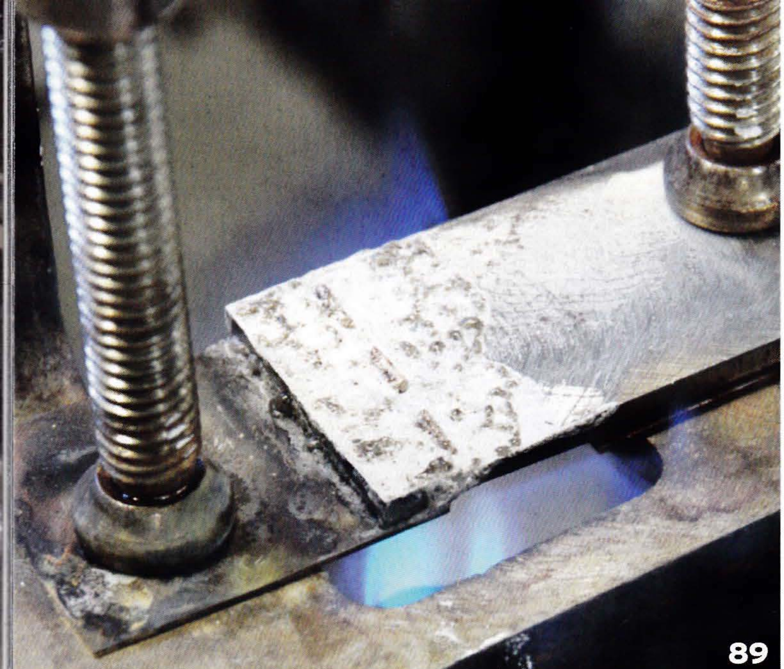
soldering the tangs. The carbide rests on a thin piece of sheet metal while there are other shims under the body, raising it to the right height. The thickness of the packing is such that the end of the blade gets soldered to the middle of the carbide blank.

Make sure to remember the keys to silver soldering. First off, make sure the surfaces are clean. Secondly, use lots of flux. Fix everything in position and place small pieces of silver solder along the joint, just as when soldering the tangs on. I use 1/32" diameter silver solder (Photo 87). Gently warm things evenly between the two pieces and, when ready, the silver solder beautifully wicks in with no extra blobs or globs.

Silver soldering (also correctly called brazing) seems one of the subjects where those new to it are full of questions and perhaps a bit of trepidation. I thought it might take some of the mysteries out of it if the process was presented in pictures.

Photo 88 shows everything ready to go. Both workpieces are clean, fluxed, and clamped to the fixture at the right heights. The job is well fluxed and ready to go. The small pieces of silver solder are visible in the flux along the joint.

This time I used a propane/air torch. Propane burns at a temperature that is more than hot enough for most silver soldering. The time to abandon propane air in favor of higher temperature equipment such as oxy-acetylene is when a workpiece of larger mass requires more heat. Oxy-acetylene, burning at much higher temperatures, can deliver much more energy in a short period of time, letting us get larger assemblies to silver soldering temperature. The advantage of propane is that it burns at a low enough temperature that it can be applied directly to the fluxed joint. Given the small size of the carbide piece, being able to apply the flame directly is a lot easier than the indirect approach required with oxy-acetylene.



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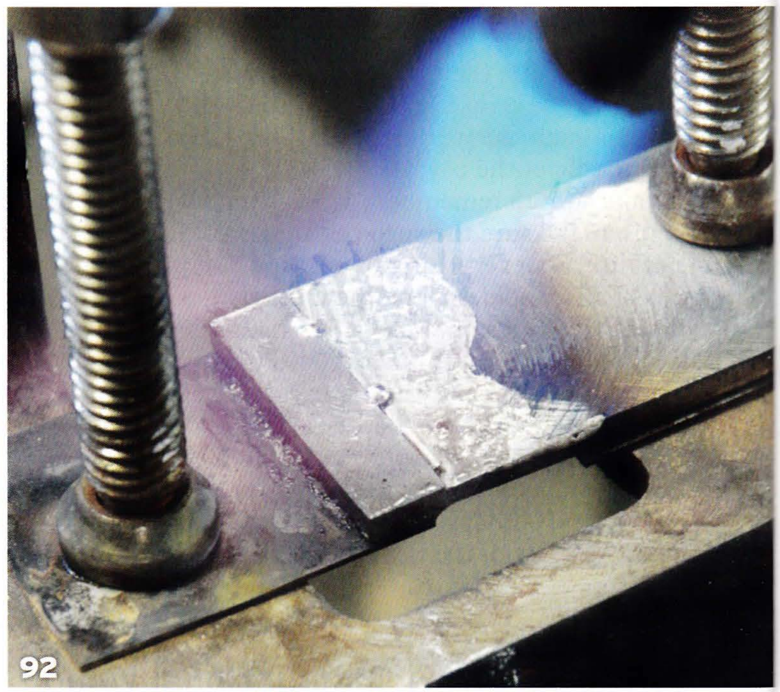


92

At first the flux is quite active, as the water in it boils away (Photo 89), and care is needed to avoid blowing away the bits of silver solder. Occasionally, the boiling will move the solder and it will need to be nudged back into position (I use tweezers for this and for placing the tiny pieces).

In Photo 90 the water is almost all gone and the flux looks sticky, with just a bit of sheen to it.

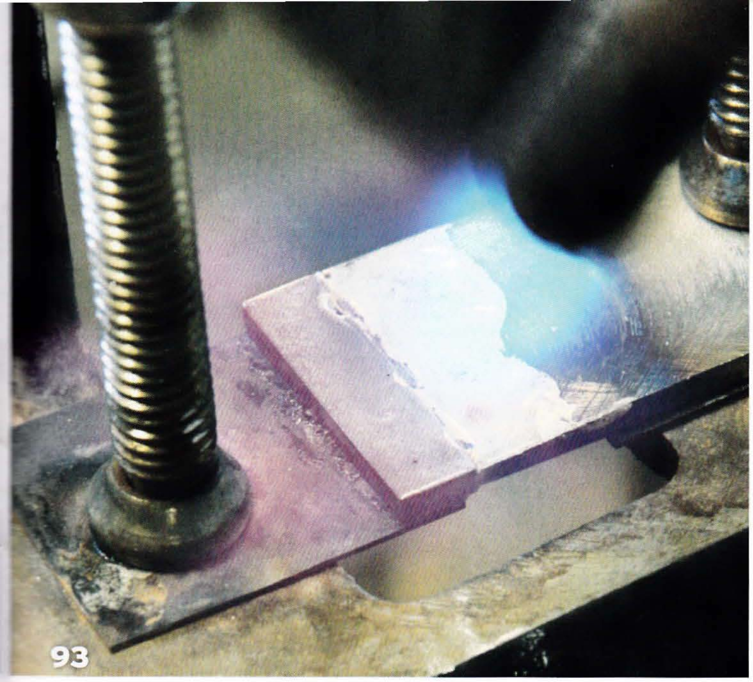
As you get to the point where the silver solder wants to melt, the flux will look like it has mostly disappeared (Photo 91). The flux is still there, it's just that all the water in it has boiled away.

Although you can directly apply the propane torch to the joint, do keep the torch moving. Ideally, both pieces of work will come up to temperature at the same time and the solder will wick in nicely. It's easy to melt the silver solder by concentrating the flame on it but this accomplishes nothing; we need to bring the work and solder up to the right temperature together for a good joint to result.

In Photo 92 the solder on the far side has started to melt, while the closest has not. I'll concentrate heat now toward the near side and to the shank. Again, we're using the flame to warm the entire area, using judgment on which pieces are bigger heat sinks and therefore require more attention from the flame.

At the point of Photo 93, we're essentially done. I will play the flame over the bottom of the assembly just to make sure it is warm enough all over for good flow; however, that is probably braces and a belt. If we've got the joint to temperature by gradually heating the surrounding work material, we can have confidence that the joint will be good throughout.

And we're done! Wash the scrapers in hot water to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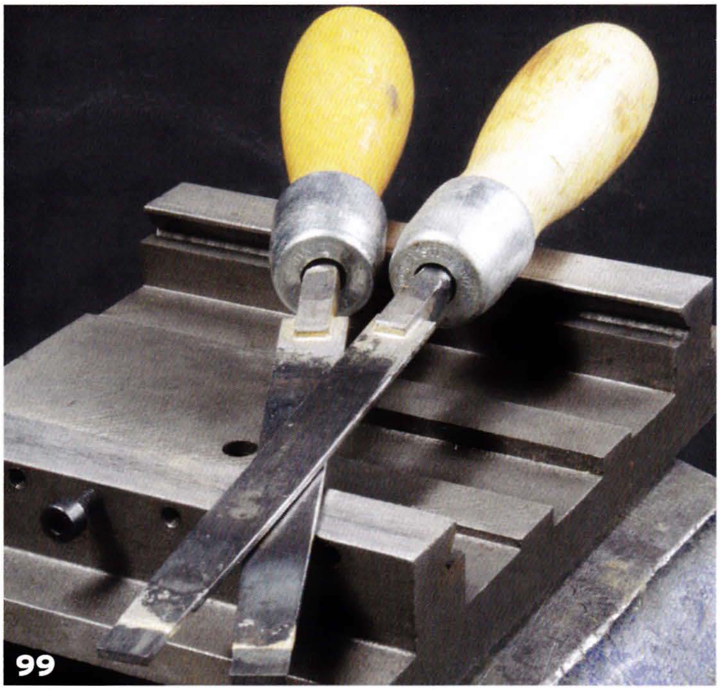


99

remove the flux (I used an acid pickle, but hot water works just as well) and paint if you like.

Our collection of scrapers can be seen out of the pickle in Photo 94 and with handles installed in Photo 95. I ended up painting the bodies to stave of rust.

OTHER FORMATS

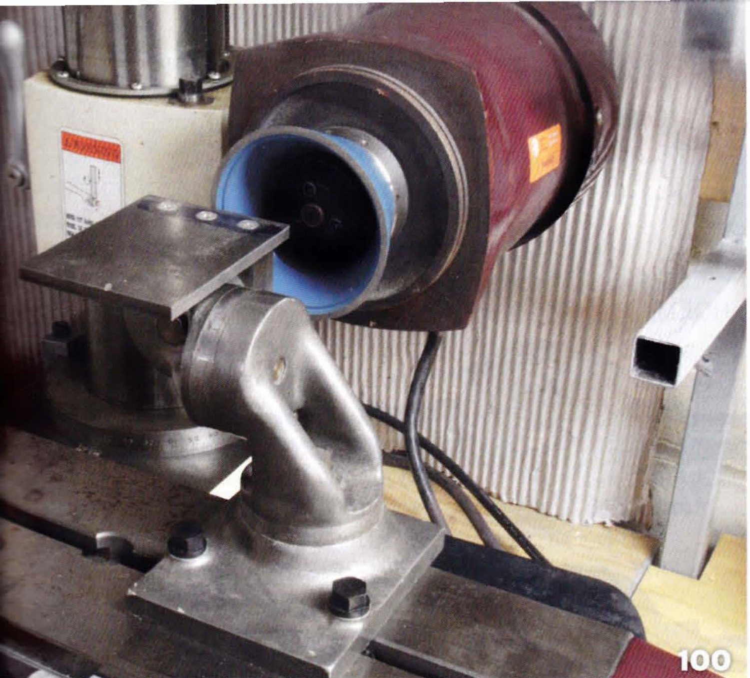
The short blade scrapers on display in Photo 96 are probably my favorites. I've made them with 1/8" thick carbide as well as 1/16", which is just the thing for tight places such as dovetails. As shown in Photo 97, the blades for these were tapered. I'm not sure if it's aesthetics or if it contributes to the blade having the right flex but it seems the right thing to do.

I've made one other style that is quite handy, shown in Photos 98 and 99. These are small and use very thin 16-gauge steel with a 5/16" × 1/4" × 3/32" piece of carbide. You could easily bend the blade in your hand, so they are not a robust tool. However, small dovetails can be very constricted and small scrapers are just what is needed.

RADIUSING THE BREAST

The end, or breast, of the scraper requires that a radius be put on it. There's no magic to this and Connelly suggests it is particular to the individual scraping hand. He suggests a 12"-18" radius, which is consistent with what I've seen on others and what I use myself – although I must confess I have not measured the actual radius.

Constructing the breast is a task that requires a diamond wheel. I use a diamond cup wheel for my bench-top tool and cutter grinder for this operation (Photo 100). It is a frustratingly expensive purchase for something that is only needed for creating the curve on the breast. Perhaps readers could outsource this operation to a friend with a diamond wheel. While it's



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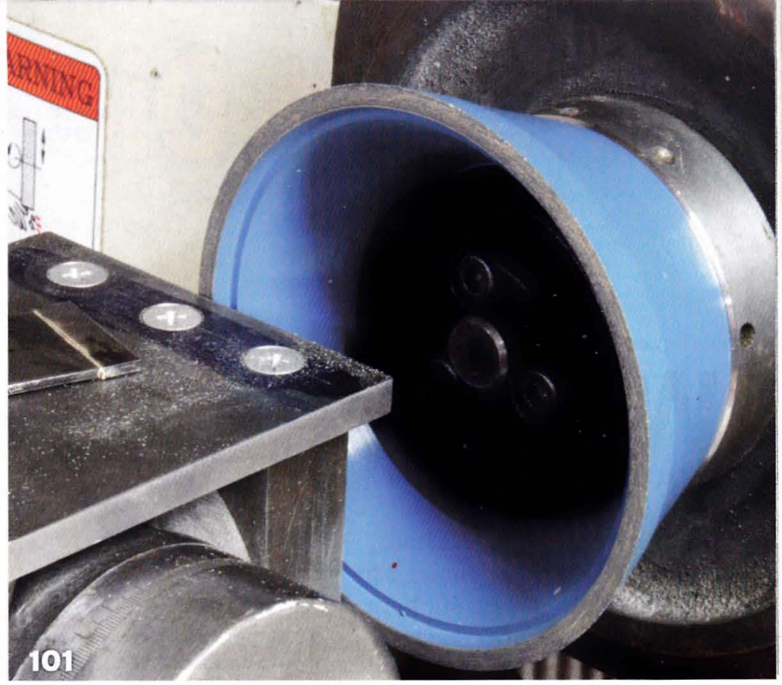


101

quite an extravagance if only for scraping, the wheel will, of course, handle more than just scrapers.

The green silicon carbide wheels are too likely to chip the edge and we need a perfect edge for these tools. An alternative to purchasing a diamond wheel would be to use the coarse diamond stones mentioned earlier. Held against the edge of a bench, or something similar, working the scraper against the stone should put a radius on in a not entirely unreasonable length of time.

The other possibility is to use a rotary lap. While the lap is intended for fine finishing, I suppose it could be used for removing more material to create the radius. It will be slower than a diamond wheel, but will save on purchasing a wheel.

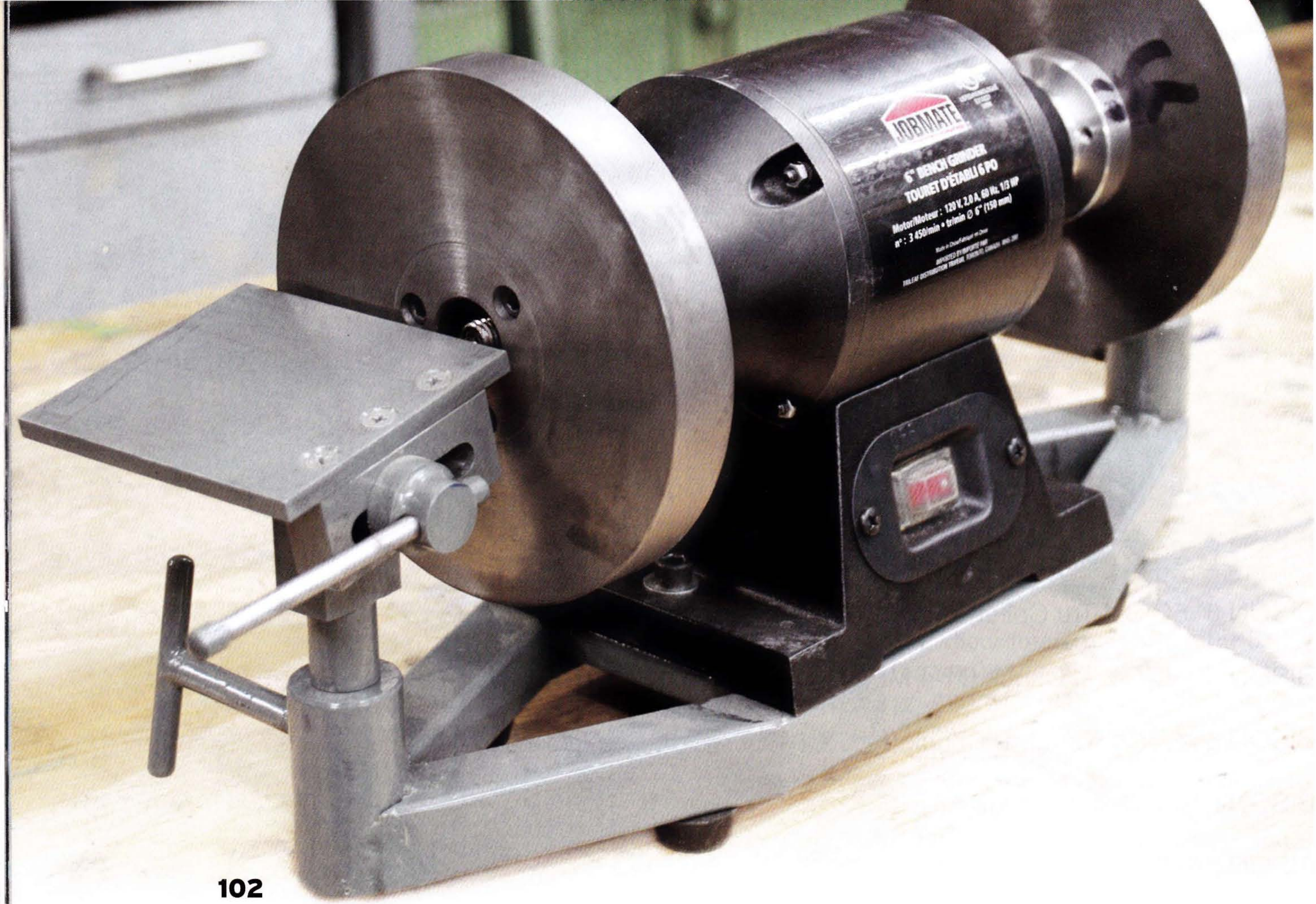
SAFETY ISSUES WHEN GRINDING CARBIDE

Be aware that the dust resulting from grinding carbide is hazardous. Cobalt is used as a binding agent and shouldn't be inhaled. I have no knowledge as to at what quantities it becomes dangerous, but where safety is concerned, erring on the side of caution is a good way to make up for ignorance. Longer term, my plan is to rig up a mist coolant system that should dramatically reduce the amount of airborne particles resulting from grinding.

I made a simple little rest to work with my bench-top tool and cutter grinder's homemade uni-vise (Photo 101). The cutting edge should have an included angle of close to 95°, although personal preference again enters into this, even though I may never scrape enough to develop such a preference!

Remember when I said one of the most difficult parts about scraping is getting an edge on a scraper? Well, we're not done yet. The ground surface is not near fine enough to make an effective scraping edge. In the next part of this series, we will start in on building a rotary lap to give our scraper the edge it needs.

Photos and drawing by Author



102

SCRAPING for the Home Shop

Part Four

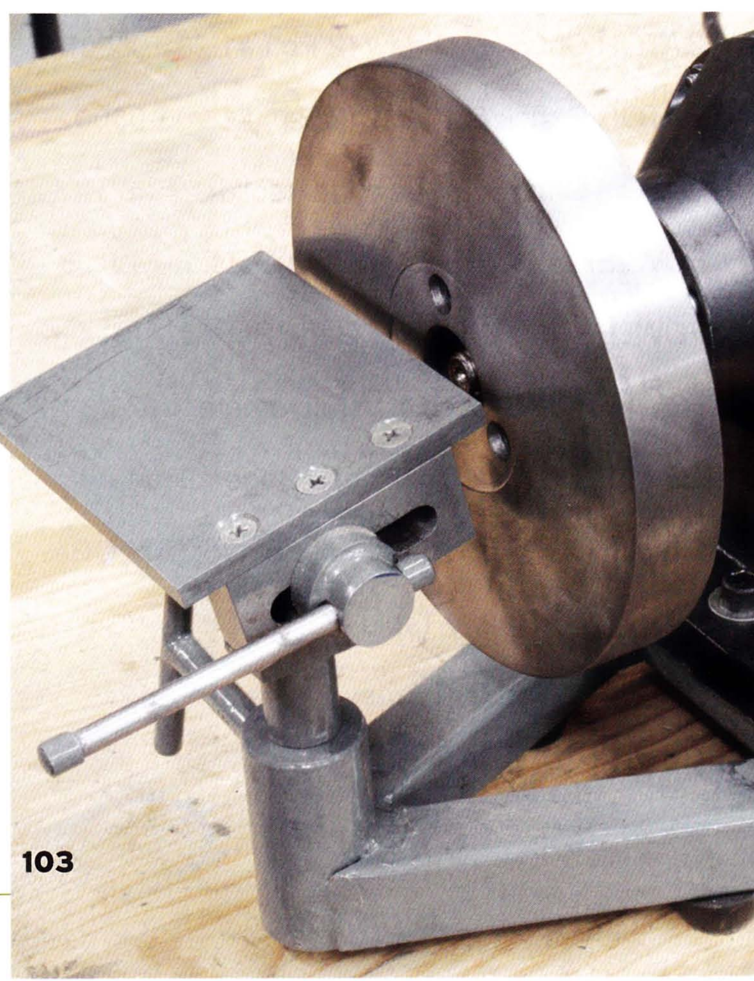
BY MICHAEL WARD

In our last installment, we built our carbide scraper. In this issue, we'll start building a rotary lap for putting a proper edge on it.

IDEAS ON A ROTARY LAP

As has been repeated, it may be that one of the most challenging parts about scraping is putting a great edge on the scraper. In this section, though, we get to develop our secret weapon that will make it a walk in the park; the rotary lap shown in Photo 102.

As shown in Figure 5 (July/August 2011), the very tiny size of the chip formed when scraping necessitates a very sharp edge on the cutting tool. An edge that would be perfectly fine for taking .050" off in the lathe



103

will frustratingly skip over the work if used in scraping. I've tried to look at a few different ways of putting an edge on; however, none come close to what can be done with a rotary lap.

We can, as shown in previous parts of this article, use ever finer stones and abrasives to put a mirror finish on the broad, flat areas of the scraper. The challenge remains, though, of how to treat the end such that we get a terrific finish, resulting in a perfect edge where the two surfaces meet. In addition, we need to be able to create that perfect finish on the end over and over again, as the tool will need frequent sharpening.

The undisputed best way to do so is with a power lap. I made the rotary lap presented here from a low-cost bench grinder and some cast iron disks (Photo 103). You're going to love the finish this puts on. Starting off as something I thought I needed just for carbide lapping, it ended up being a fun project and has far exceeded my expectations – and not just for scrapers but for virtually any cutting tool. You don't have to want to scrape to benefit from this project.

104

I made my lap double-ended; one end for carbide and one for steel. Never before was I able to put an edge on a steel scraper like this rotary lap can. You may recall the discussion about how to put an edge on a steel scraper and how the abrasives should be used perpendicular to the edge rather than parallel to it. This lap will put the perfect angle and mirror finish on your edge, and if you decide to make this you won't spend time stoning scraping tools anymore.

WHAT IS LAPPING?

Lapping is one of the oldest of machining operations, with sketches for rotary laps going back to Leonardo da Vinci's time. It is also one of the finest machining operations, insofar as the finish achieved and the minute amount of material that can be removed. Machining is being defined here as material removed via a cutting tool, which, just like a lathe, is what abrasives are doing (if you could slow it down and zoom in on a particle of abrasive, you'd see it forming a chip in a similar manner to a lathe tool bit or milling cutter). Finer finishes than what can be produced with grinding are easily achieved with a lap.

A lapping operation involves a lap, an abrasive, and a workpiece. Material is removed through either a sliding or rolling action of micro-abrasive particles against the work, or through the cutting of the work by particles embedded in the lap. For instance, with work lapped against a flat lapping plate with loose abrasive, all three actions (rolling, sliding, and cutting) act on the work. With our rotary lap, the action is primarily through cutting by embedded abrasive particles. Indeed, unlike the slow process of hand lapping, our electric powered rotary lap will fling un-embedded lapping compound all over the shop if we're not careful.

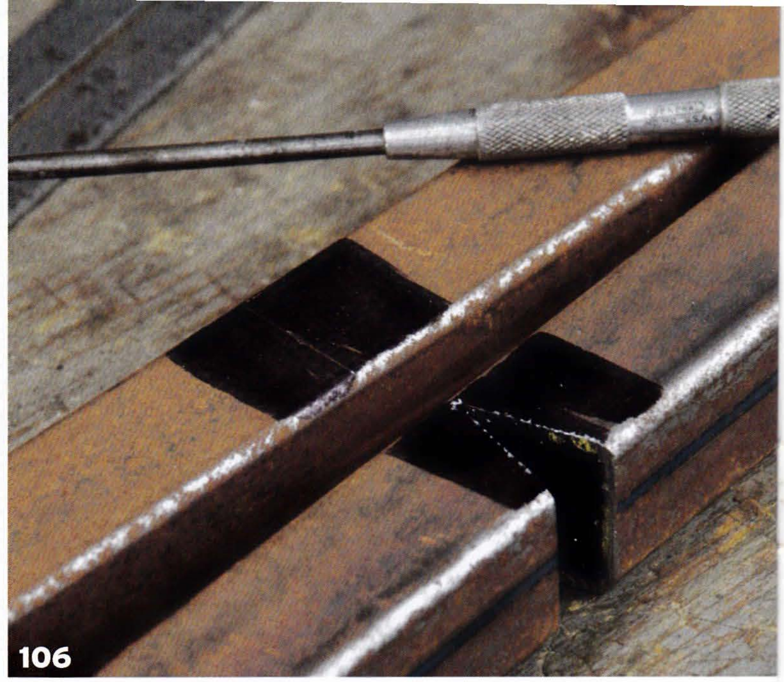
The idea is to take one of the low-cost, imported 6" bench grinders (Photo 104) and convert it to a rotary lap. Some people have created serviceable rotary laps by somehow affixing a plate of metal to any old, fractional horsepower motor. To keep it simple, that is a workable approach. I elected to go a different, slightly more complex route. First off, bolting a plate onto a shaft wouldn't make for much of an article, but more importantly, there is broader functionality to a well-made lap other than just for use on scrapers.

Finally, a disk of spinning cast iron contains a lot of energy. For safety's sake I thought it worth putting some effort into making sure things were concentric to at least have a shot at the machine being somewhat balanced.

There are a number of reasons for going in the direction of having more than just a disk and a motor. It's probably in contradiction to some long standing home shop machinist code of honor but, believe it or not, I didn't have a spare fractional horsepower motor in stock.

Also, I like the idea of a double-ended lap such as this one that can be charged with diamond compound for carbides and other abrasives for steel tools. The bench grinder gave me this format, along with some necessities such as a stand and switch already present. At $50 (that's Canadian dollars) it seemed like a good starting point for the project.

105



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As can be seen in Photo 105, the shafts on this unit are 1/2"Ø or thereabouts. It was a treat to see that new and out-of-the-box it came complete with a complimentary layer of rust! Another advantage of this unit is that it is of entirely bolted together construction, making our hacking quite easy.

Let's start with the frame (Figures 8 and 9), which I made from 1" square × 1/16" wall tubing (Photo 106). I made the frame from two pieces, with two V-notches cut at the bend points to allow the tube to be bent to shape (Figure 10). Lay out as shown and commence with some precision hacksawing (Photo 107).

Obviously there are big tolerances here. Who can hacksaw to exactly 23°? Lay it out as best you can,

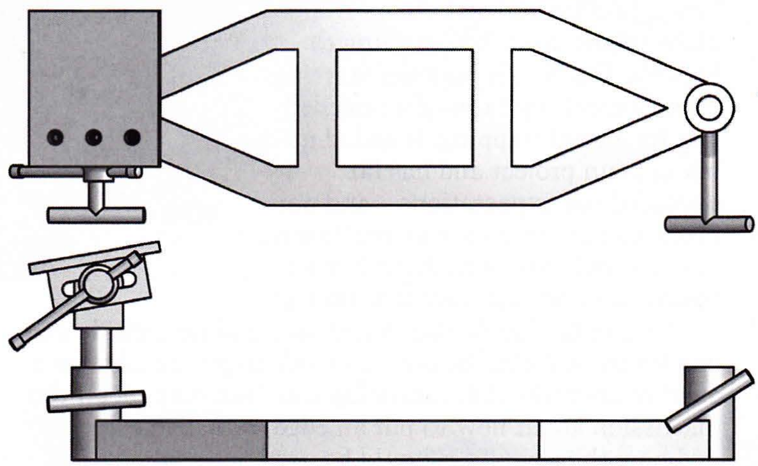
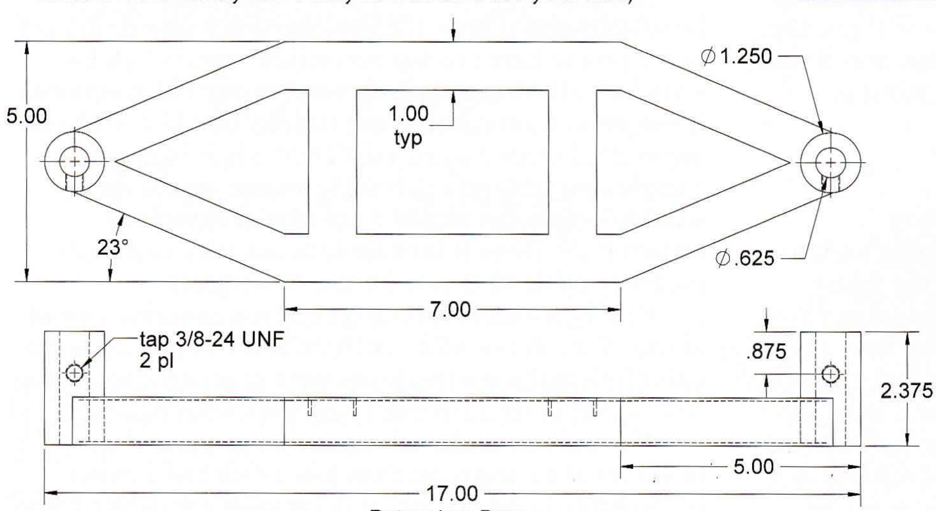
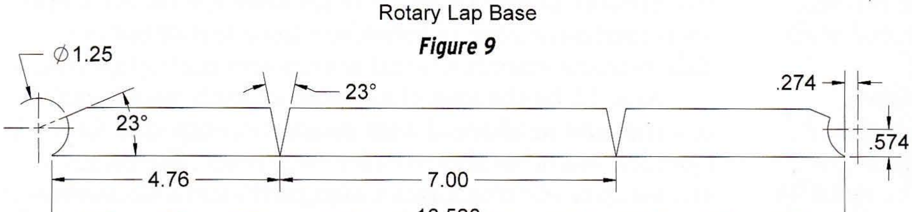


Figure 8



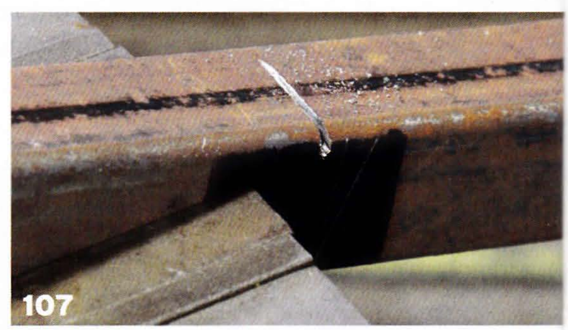
Rotary Lap Base

Figure 9



Base Pattern
1" square steel tube

Figure 10



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try to cut to the lines, and it will work out just fine. Welding beads and brazing rod will make up for less than perfect hacksawing; in fact, it might be easier for you to intentionally cut more than is required and then fill the gap with bead afterward.

File out the Vs to match the scribed lines. A hole saw was used in the mill to profile the ends of the two frame members, as seen in Photo 108. Exercise caution: hole saws are crude and the material is thin. Feed slowly

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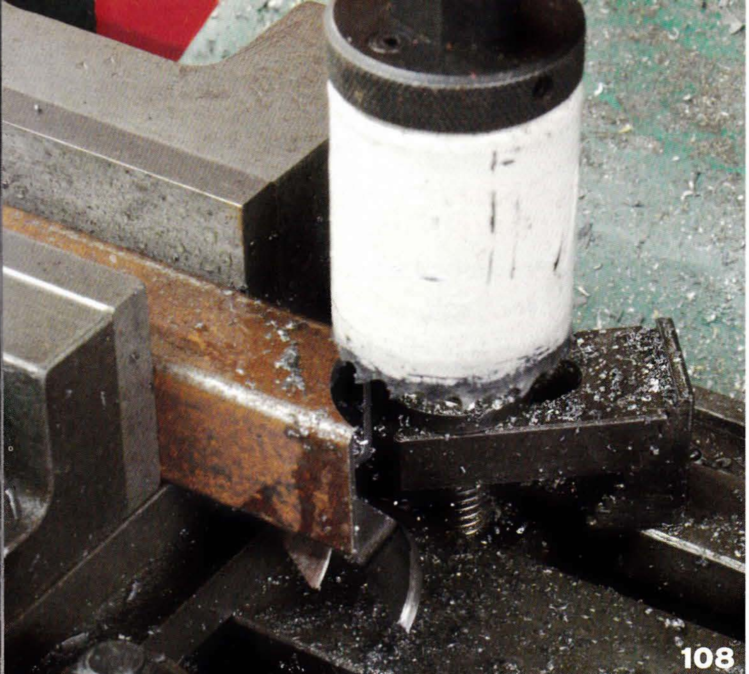

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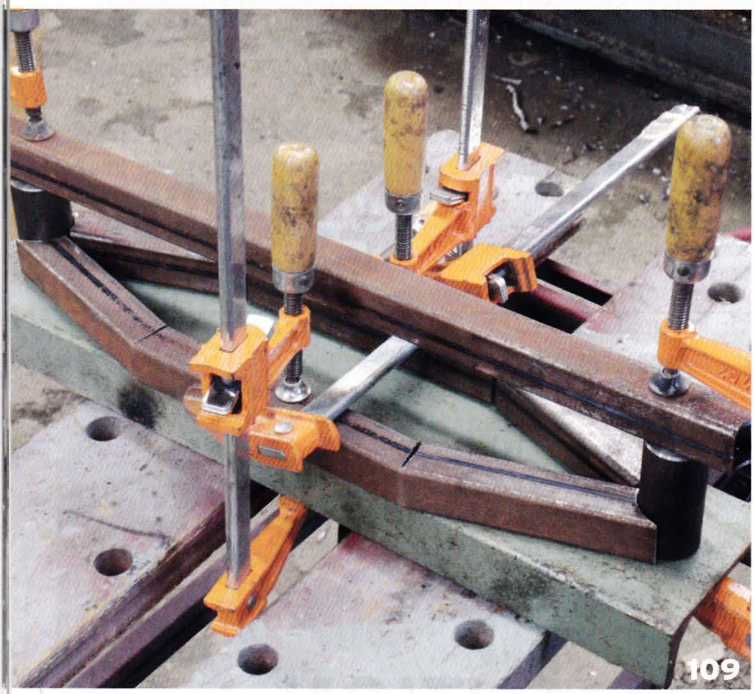

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110

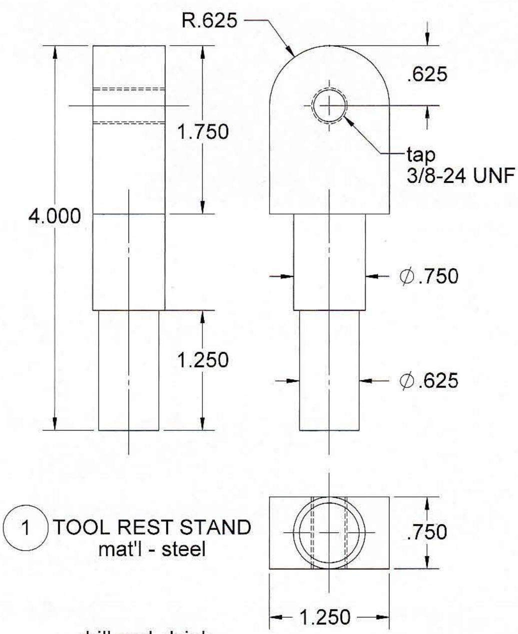
and squirt some coolant on the cut. I recall I did not have the correct sized hole saw but, with a torch and hammer, I was easily able to form the ends to the vertical stands.

I clamped the square tubing and vertical stands together, using a piece of 4" channel as a welding table (Photo 109). I also added cross-pieces, both for strength and to provide something to bolt the grinder to. I used some small, 1" channel because it was available; however, almost any flat stock will do. I've left the location of the cross-braces and the mounting holes off of the drawings, since your grinder may have slightly different dimensions than mine.

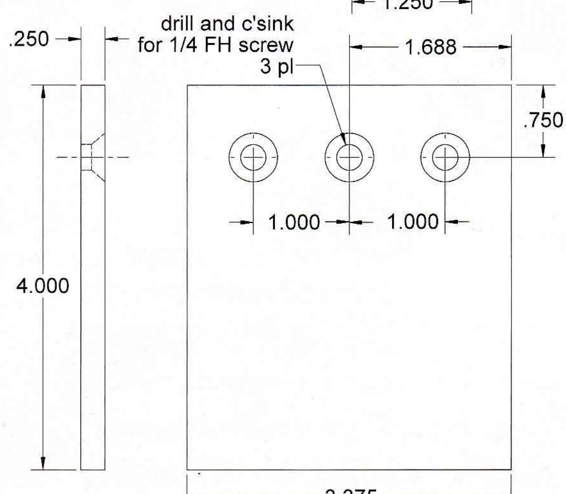
I gas welded everything except the vertical stands, which were brazed. The vertical stand material was free-machining steel, which can be impossible to weld.

TOOL REST

A decent rest is nice, especially for lapping the ends of the scraper blades. I designed it such that the rest can be dropped into the vertical stand and used on either side of the rotary lap. This cut the work in half by not having to make two tool rests.

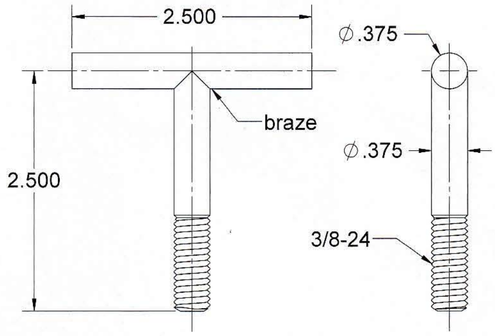


1 TOOL REST STAND
mat'l - steel

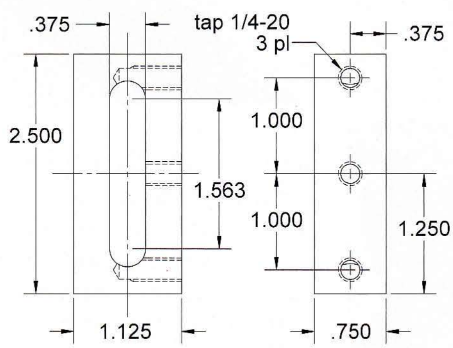


2 TOOL REST TABLE
mat'l - steel

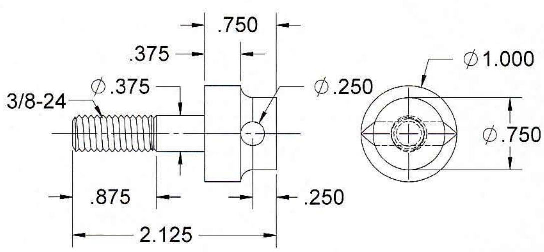
This is straightforward machining work. I have provided some detail drawings (Details 1-6) of the parts, but I did not record their machining.



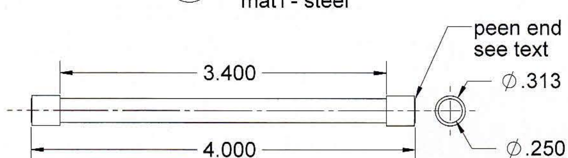
3 LOCKING SCREW
mat'l - steel



4 TOOL REST BRACKET
mat'l - steel



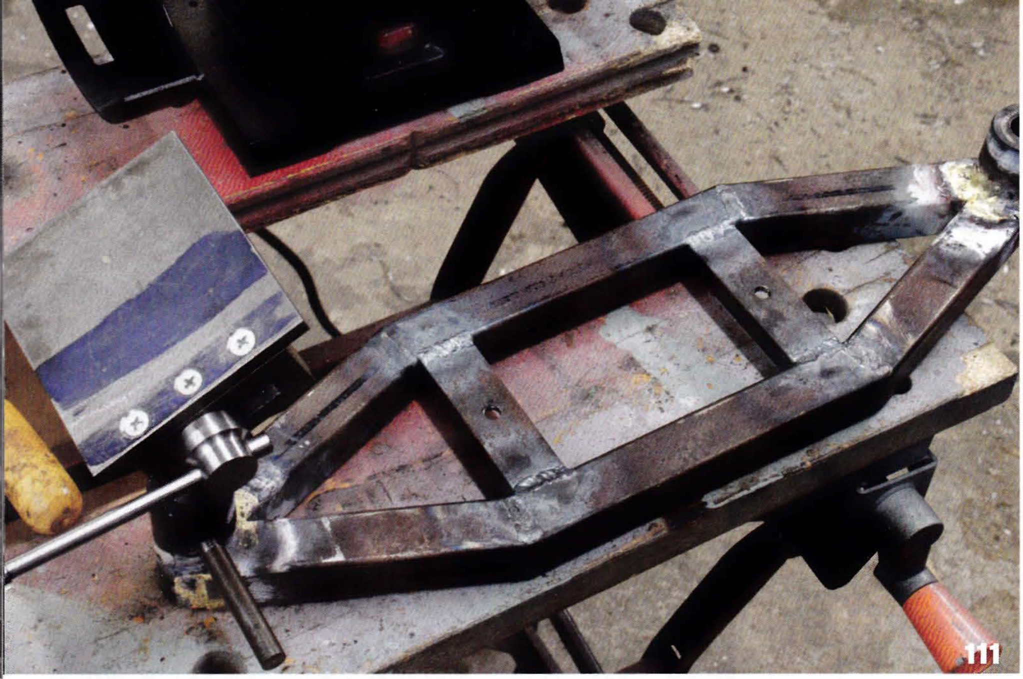
5 TABLE CLAMP
mat'l - steel



6 TOMMY BAR
mat'l - steel

Photo 110 shows the method of holding the locking screws for brazing, using a C-clamp to keep things together. For the vertical stands, two T-handled locking screws are required (Detail 3). I threaded one end then, with a 3/8" end mill, cut the other end such that it mated with the handle of the "T."

Photo 111 shows the completed fabrication with the tool rest in place and Photo 112 shows it with the grinder attached. While detailed machining instructions are unnecessary, I will leave you with this tip. The holes into which the T-handled locking screws go should have a small brass pad dropped in first. This will prevent scoring. On tightening up the



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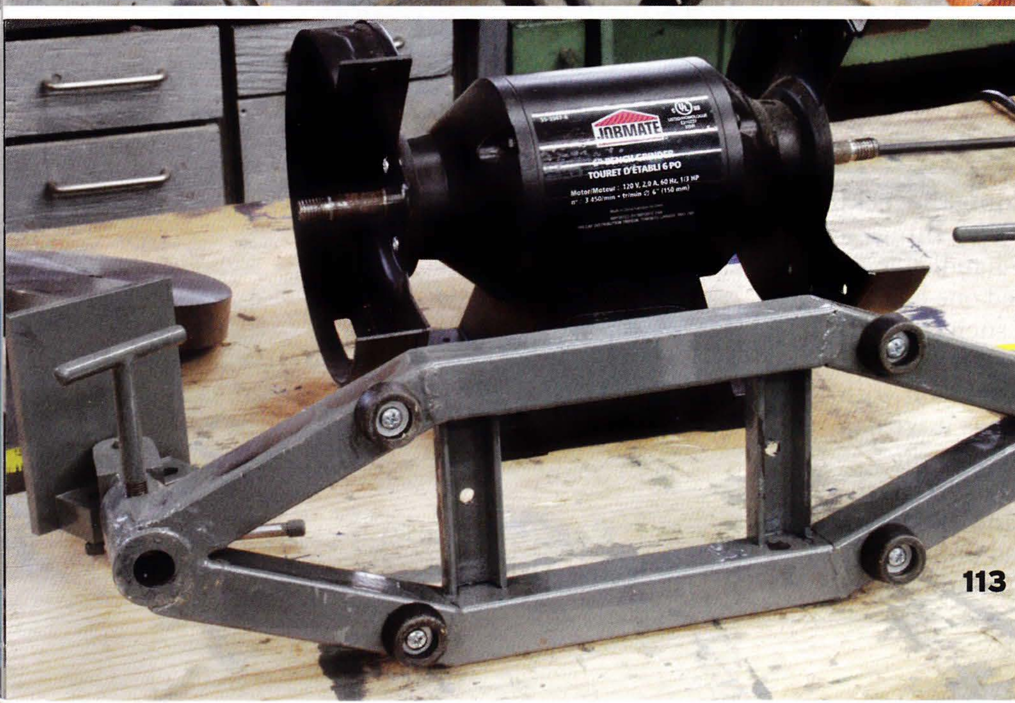

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114

screw for the first time, it should deform the brass pad enough that it gets stuck in position.

The grinder came with four rubber feet that were removed and installed in tapped holes on the underside of the 1" tubing frame (Photo 113). The 1/16" thick tubing was just thick enough to hold a few threads. The grinder is bolted to the cross-braces, which were made from some 1" wide channel that was approximately 1/8" thick. I used this because it was available – most anything, such as a 3/16" or 1/4" thick length of hot-rolled steel, will do.

A neat way to make the tommy bar (Detail 6) is to take a piece of 1/4" diameter cold-rolled steel and turn the ends to 3/16"Ø. Make two end caps 5/16" in diameter with a slight countersink (I used a center drill to create a 60° countersink) that slip over the 3/16" ends, but are not quite as long as the 3/16" section (Photo 114). Carefully peen the protruding tommy bar end into the countersink. Be sure to install the tommy bar before peening on the second end!

Peening continues until the recess is completely filled and the end is nicely domed. Photo 115 shows the work about half-completed. Keep peening until there is no visible line between the bar and end cap. If you accidentally

115

116

glance a blow off the end cap, clean up the cylindrical shape of the end cap with a fine, smooth file after finishing the peening and it will look great (Photo 116).

MAKING THE LAPPING DISKS

This is where the real work on the rotary lap starts. We are going to be spinning about 10 or 12 pounds (each disk will be about 5-6 lbs.) of cast iron at 3450 rpm. Lapping will be easier without things shaking and moving about. However, it's also important from a safety standpoint that this mass, spinning at speed, is calm and stable. There is a lot of stored energy in the spinning lap

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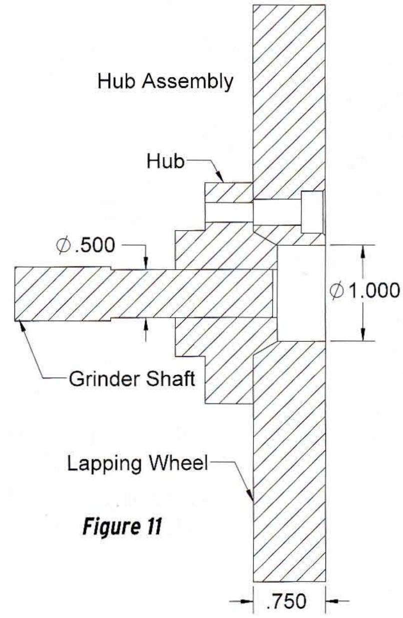


Figure 11

and it could be dangerous if it's not running smoothly. The plan is to carefully construct things so the various rotating parts are concentric.

The other design feature I thought advantageous was to allow the laps themselves to be removed and reinstalled while maintaining concentricity, and hence balance. We may want to resurface the laps in the lathe one day, or it might be easier, in some instances, to charge the lap with it off of the spindle. As a side note, if you do resurface a lap that has been loaded with abrasives, obviously take special care that the lathe is well protected from the abrasive chips you'll make. Paper towels, held down by pot magnets and covering everything, are the safest way to go. Do not use rags; there is a risk they can be grabbed by the work/chuck and entangle you in the process.

Good quality cast iron is uniform and holds the embedded lapping abrasive well. It is the right material for a rotary lap. It works well and is the common lapping material of choice. Other materials can and do work; however, cast iron is ideal. For those interested, the *Handbook of Lapping and Polishing* by Ioan D. Marinescu, et al. details some of the whys.

The challenge is then finding a suitable disk. If you live in the United States, some of the catalog houses sell 6" diameter × 1" thick disks for a reasonable amount of money. Unfortunately, in Canada we do not have the same well developed industrial supply catalog resources. However, Terra Nova Steel and Iron in Mississauga, Ontario has perhaps the best stock of this material in Canada and they will deal with an individual's orders. They are a good bunch to deal with, but call ahead. They cater more to industry and aren't set up for walk-in traffic. I was fortunate to find some cut-offs of the correct size (Photo 117). Elsewhere in the world, I'm afraid I can't help.

Safety Note: When you start spinning large, heavy objects at high speeds, you have to be concerned about safety. Maintaining balance is crucial and will be commented on throughout the build; however, bursting also needs to be considered. At some speed, materials will fly apart as the centrifugal forces overcome their tensile strength. We are fine in this case. *Machinery's Handbook*, using an 18k psi strength for cast iron, suggests we're good to about 15,000 rpm based on the 6" diameter of our material, so this should be safe at our grinder's 3800 rpm.

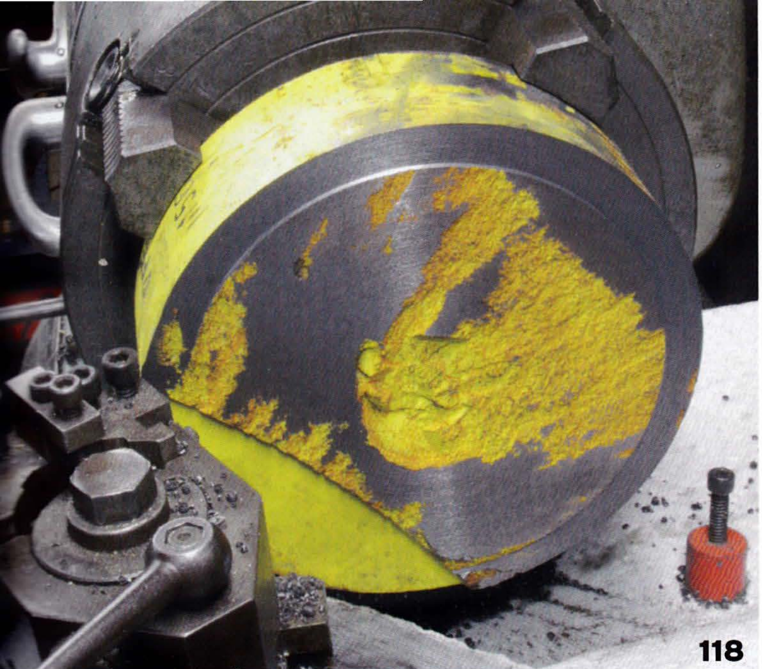
To be confident that the material is safe at this speed, we must have confidence in the material itself. Good-quality, continuous cast iron such as Durabar is fine; barbells, whose engineering requirement is nothing more than being heavy, may not be. It's my view to err on the side of caution where safety is concerned and it's important, both to balance and to safety, that quality, homogenous material is used.

Figure 11 shows a cross-section of the rotary lap mounted on the grinder shaft. The strategy is to affix a hub to the shaft, do the final outside diameter turning in situ, and then mount the laps on the hubs using a tapered register to maintain concentricity.

This is heavy work for our home shop machines and the four-jaw chuck should be used for its added rigidity and holding power. In Photo 118 you can see an interrupted facing cut taking about .050" off. I'm using a high speed steel tool because the interrupted cut necessitates running the lathe at its slowest speed. Make sure you have some other shop projects to do, such as a general cleanup or some milling machine work, as this is a slow, long cut. If you don't have power cross-feed on the lathe, this project might be a good reason to devise one.

As frugality is as important a part of home shop machining as making chips or taking measurements, I was delighted to see that I might in fact get two disks out of one cut-off. The challenge is slicing a 2" long × 6" diameter disk in half. As the solution required some interesting band saw work, I thought it worth sharing.

In the end of the freshly faced disk, I drilled and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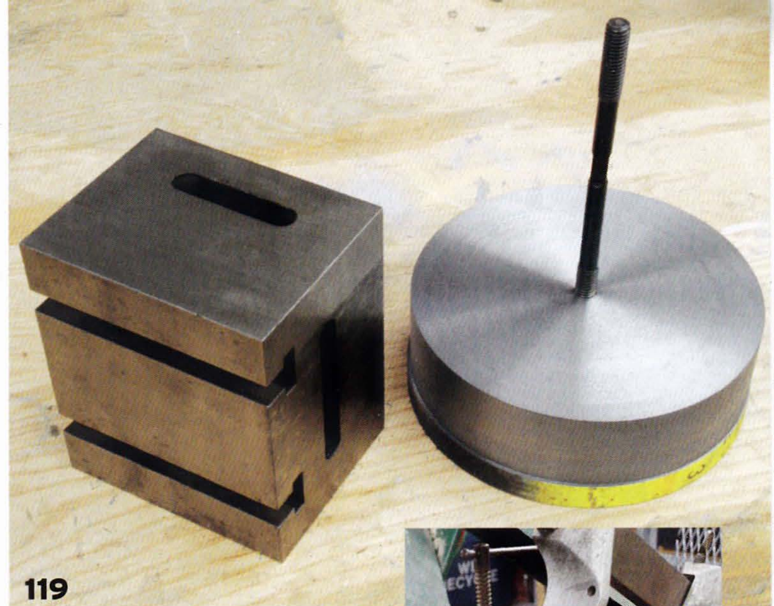
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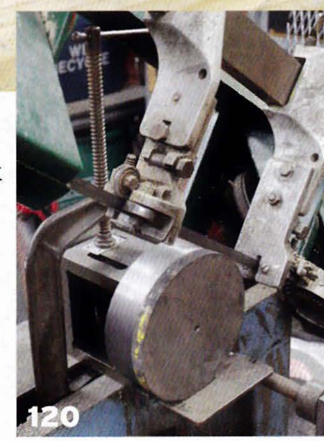
tapped for a small diameter stud (Photo 119). I have an Eclipse toolmaker's cube with a through hole, through which I could pass the stud. Incidentally, a mate to that toolmaker's cube appears later in the article as a scraping exercise where we'll get it near perfectly square and parallel. An angle plate would work equally well as a means of holding the disk.

To fit this concoction in the band saw, the movable jaw was pushed out of the way. With a large C-clamp, the block was then clamped to the bed of the band saw (Photo 120). I used a small piece of angle iron underneath the bed to bridge the slot and oriented the screw of the clamp so its handle would line up to clear the band saw arm.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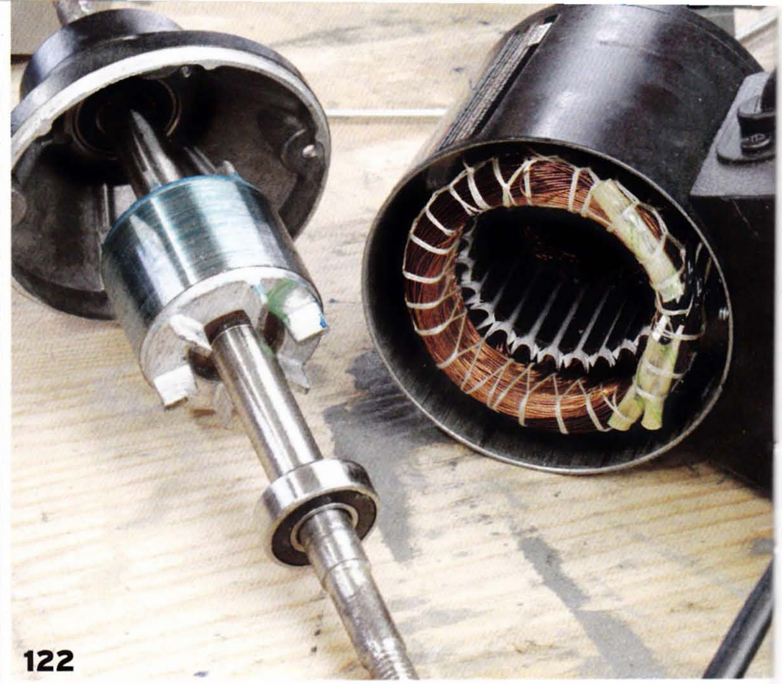

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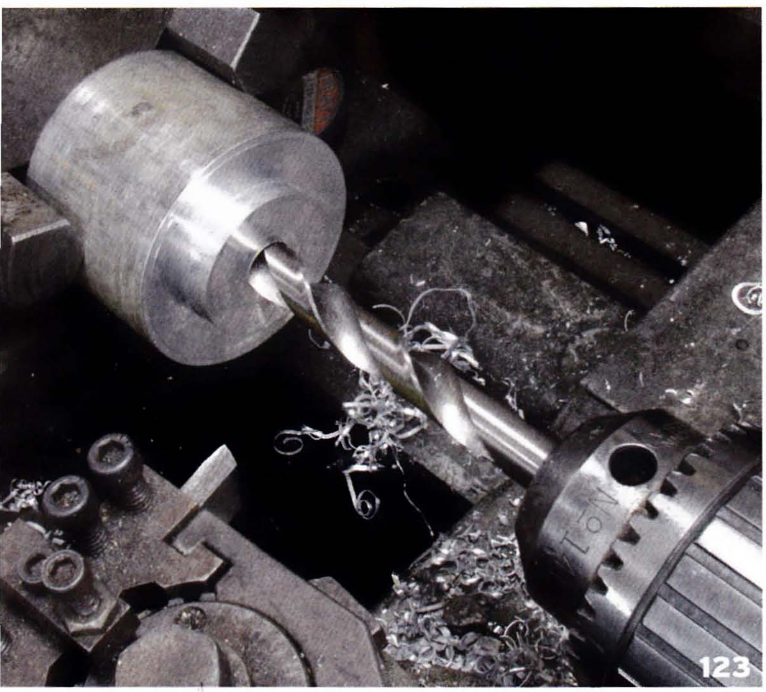

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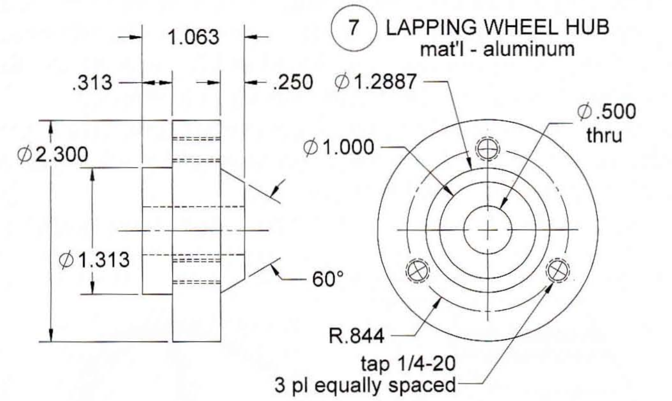


This is a real test of how well-tuned your band saw is. With fingers crossed and breath held, I started the cut and was pleased, upon completion, to measure only .030" of difference from one side of the disks to the other. Whether that was skill or luck, I'll take it.

WHEEL MOUNTING

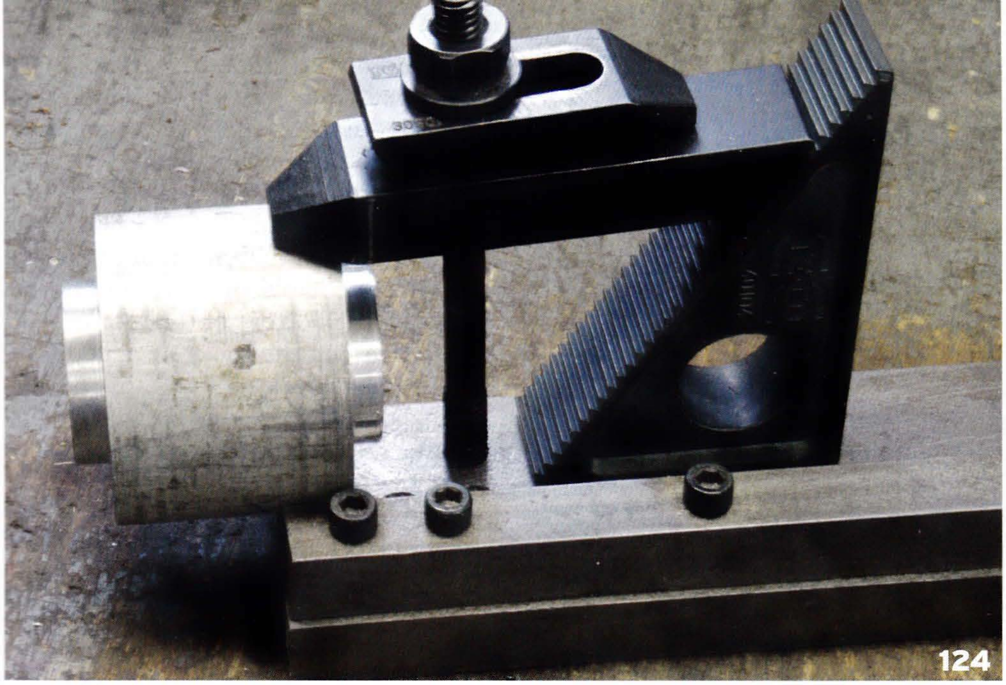
It can be difficult to mount a largish outside diameter object on a smallish shaft. There needs to be some clearance or else the parts won't assemble. However, whatever clearance there is can show up as shimmy on the face of the disk when in operation. The tiniest of errors in the fit to the shaft become exaggerated as you move outward toward the periphery of the lap. This, for example, is why it requires careful workmanship to build flywheels that run straight and true.

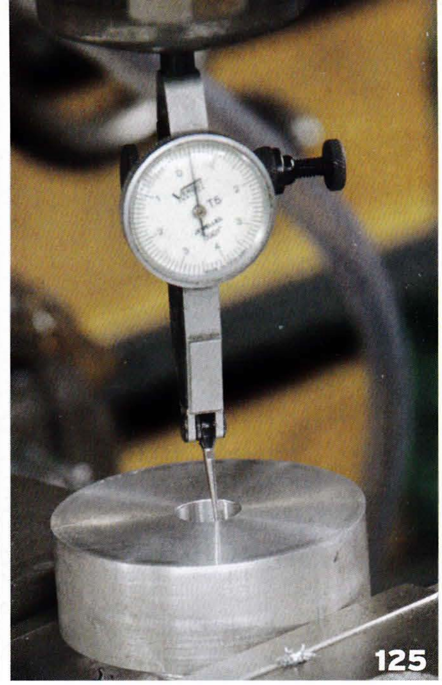
As I wanted the laps to be removable, the challenge is greater than just a superhuman fit between the shaft and lap. The difficulty is exacerbated by the poor finish and questionable accuracy of the grinder's existing shaft OD. The shafts measured around .498" and there was several thousandths of variance in the diameter to go along with the rough finish and rust.

The solution is to use a two-piece assembly; a substantial hub permanently mounted on the shaft, with a taper mount onto which the lap wheels are bolted. The hub material is fixed to the shaft with cylindrical retaining compound and then, using the shaft's center holes, the hubs are finish-turned in situ between centers. This will create surfaces on the hub that, in theory, should be perfectly concentric to the motor shaft/rotor.

As mentioned earlier, a big advantage of this model of grinder is that it is entirely bolt-together construction. Start by disconnecting the wires, which are accessible via the base (Photo 121). Make notes and/or take pictures of where the wires go and then disassemble. The pyramid shaped base bolts to the cylinder shaped motor housing with two large Philips screws.

Photo 122 is just included for interest, to show the innards of an induction motor if you're not familiar with them. The only moving parts are the rotor and shaft, which run on sealed ball bearings. With no brushes or





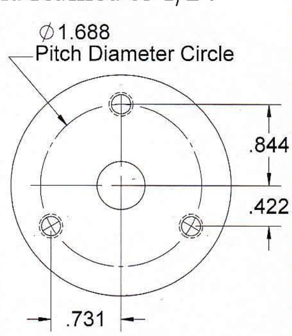
other contact parts, they are long-lasting, low maintenance motors. When taking it apart, I had thought I would be able to afix the hubs to the shaft and machine them with the shaft outside of the motor housing. Like the man who builds a boat in his basement with no way to extricate it, I quickly realized that with the hubs machined in situ on the shaft, there would be no way to get the motor housing back on!

I used aluminum for the hubs because I had a suitable sized piece (Photo 123 and Detail 7). It has a slight advantage over steel in that it reduces the inertia; however, I think steel would be an equally good choice.

Incidentally, the concern over inertia is because our laps are going to be much heavier than the grinding wheels the motor was intended to accelerate. Hence, start-up places a much larger load on the motor than the manufacturer envisioned. In use so far, this has not been an issue. During initial testing the unit was powered up numerous times in succession and no problems were encountered. I do, however, like to manually give the wheels a spin just before power up to give the rotary lap a helping hand.

I set up the work in the lathe and roughed out the shape of the hub (Photo 123). The part was then loaded into my band saw strap clamp fixture and sawn in half (Photo 124). With the part back in the lathe, I faced the freshly sawn surface and drilled and reamed to 1/2".

Next, set the work up in the mill and indicate the spindle true to the 1/2" hole (Photo 125). We are going to use the mill as a jig borer; that is, to locate the three mounting holes via their X and Y coordinates. *Machinery's Handbook* lists tables of XY coordinates for a variety of bolt hole circles. If you are drilling three holes, you simply look it up and the XY coordinates are given for the three holes based on a pitch diameter circle of 1. The values of these coordinates are multiplied by the actual pitch diameter circle being used, but for this project I've done the work for you (Figure 12).



Bolt Hole Coordinates
Figure 12

Make sure whenever you're doing this type of operation that you take care of backlash. That means that whatever location you're approaching, make a rule

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with yourself that you are always rotating the feed screw handwheel in the same direction. My covenant with myself is for clockwise rotation, so I always arrive at a coordinate by moving the wheels clockwise. This means that for half the movements you have to go past the point and come back to it so you're getting there by turning the wheel clockwise. Unless you have an accurate digital readout, this is how to eliminate backlash when determining XY locations.

Drill each of the three holes with a No. 7 drill and tap 1/4-20. In these situations I usually start the tap in the mill, as it's a quick way to get things aligned, but finish on the bench so I don't break any taps.

With the hubs rough machined and jig bored with three drilled and tapped holes, clean the shafts and hubs with acetone and fix them in place with a cylindrical retaining compound (Photo 126). Cylindrical retaining compound (*Loctite* 620, for example) is available from industrial supply places or automotive parts shops.

Photo 127 shows the installed hubs set up in the lathe for finish turning. Duct tape is used to hold the wires out of the way on the bottom of the motor.

Clean up the backside and OD of both hubs. Work will remain concentric, because it is done between centers. Incidentally, you may wonder why the three-jaw chuck is deployed while working between centers in Photo 127. The work *is* being done between centers; before the work is mounted, a small length of steel was gripped in the three-jaw chuck and, with the compound set over at 30°, a 60° point was turned. The part can now be set up on the new center, with the leg of a lathe dog engaging one of the chuck jaws.

This is the quickest and most accurate way to set up a center in the headstock because, with the in situ turning, the center is perfectly aligned to the headstock bearings. Each time you do this setup, re-skim the center for perfect concentricity.

Do this cleaning up before cutting the angles. Once we slew the compound over to cut the taper, we do not want to disturb the carefully set angle for several operations, and the compound would be in the way when turning these sections of the flange.

The angles on the hubs and laps are critical to the success of the rotary lap and take a little effort to get just right. We'll jump into the tricky stuff in the next installment.

Photos and drawings by Author

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SCRAPING for the Home Shop

Part Five

BY MICHAEL WARD

In the last part, we managed to get the two hubs for our rotary lap roughed in on the lathe, with the non-critical diameters finished. Now it's time for the critical part, the taper.

Set the compound over at 30°, oriented as shown in Photo 128. Ignore what's going on in this picture; it's just there to show the proper orientation. This is a bit of an awkward position to have the compound set at, but the more natural position, 180° from this, would not clear the tail stock.

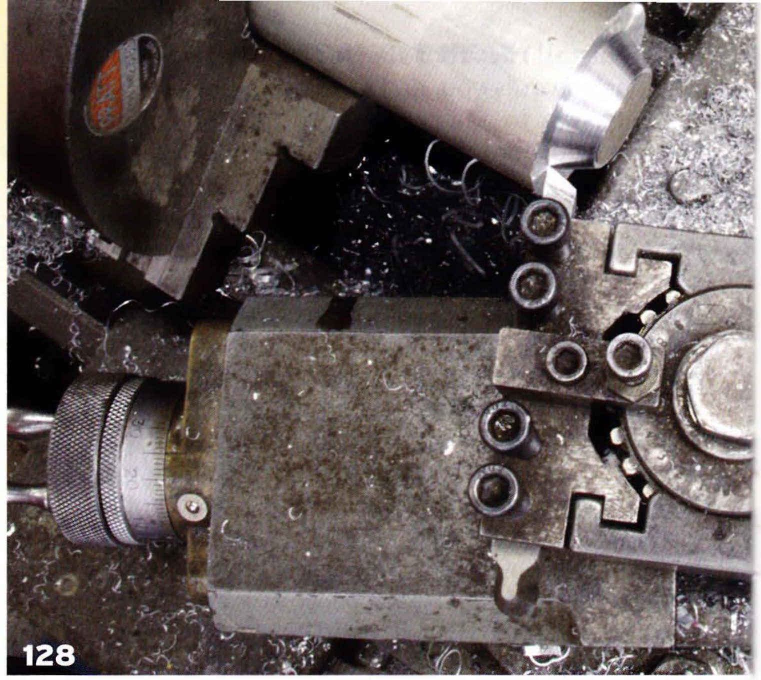
The mount that I've chosen for the laps is a bit tricky. Similar to a D1 spindle, it contains a tapered section running to a shoulder. The complication is that it is difficult to perfectly measure the OD of the taper where it meets the shoulder. We also need to maintain the correct taper angle across several parts and need to keep everything concentric to avoid balance issues. In other words, it takes some effort to get the two parts to mate with both the taper and shoulder in perfect contact.

Incidentally, on balance, there is little opportunity to achieve balance other than by careful workmanship. The bearings themselves have enough drag that using the shaft mounted in the housing is not a very sensitive approach to static balancing. Concocting a more sensitive knife edge balance will not work, as once the flanges are in place, it's impossible to separate the unbalanced housing from the rotating parts requiring balancing.

Furthermore, you could have a configuration like this balanced perfectly in a static setup, only to have it walk across the bench because it is not dynamically balanced. Static balancing means the device's center of gravity is along the shaft's axis while at rest. Dynamic balancing, on the other hand, addresses whether or not things are balanced and vibration free while rotating.

Why would the two be different? Let's say that our two wheels are each 1/4 pound heavier on one side, but are mounted on the shaft such that the heavy sides are exactly 180° apart. While each end would be seriously out of balance, careful static balancing would show things in perfect balance. However, in operation the machine would be hard to keep on the bench! Having the two ends being so far out of balance would show dramatically at speed (dynamic balancing) but not be noticeable with a static test.

As static balancing via knife edges isn't possible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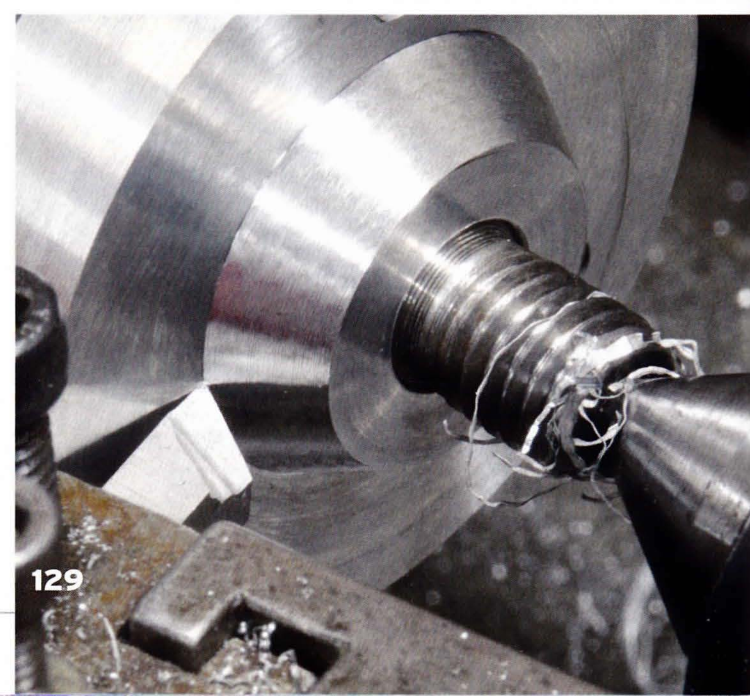
because of the motor housing, and dynamic balancing equipment is not usually found in the home shop, our strategy for achieving reasonably good balance is simply to maintain concentricity of all parts and to do careful work with homogeneous materials. We could, I suppose, construct an arbor for the individual laps and balance each piece on a static knife edge setup; however, on trial runs I found this was not necessary. If you are getting excessive vibration this might be an option, or you could check the rotor itself for balance.

With the compound set over at 30°, rough out the shoulder face as shown in Photo 129. The 1/2" thickness of the flange really doesn't matter much (see Detail 7, Part Four). What matters is that we consistently get the same large OD on the taper where it meets the shoulder. As when doing any taper work, make sure the tool is exactly at center height.

My method for turning this was to lock the carriage in place and work with the compound and cross-feed. Note in Photo 129 how the tool bit it is oriented so it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can machine both the taper and the face of the shoulder. Cut the taper with the compound until the bit starts to cut into the shoulder and remember the number on the compound dial.

Reverse feed the cross-feed, so the tool is coming toward you, to take a facing cut off the shoulder. With a good quality dial caliper (a vernier or digital will also work), place the fixed leg against one point of intersection between the taper and shoulder and bring the movable leg into contact on the other side. Now, unwind the compound to the small end of the taper and advance the cross-feed in by how much you want to reduce the diameter by (of where the taper meets the face). Advance the compound feed to cut to the previously remembered reading and this new cut should be to the place established by the facing cut.

If you've accidentally reduced the diameter too much, fear not. Simply add another .005" or so to the number on the compound dial that you have been stopping at, retract the compound while facing the shoulder, and try again.

Now, we all know that calipers are not a super accurate way to measure. However, we aren't really using them to make an absolute measurement in this instance; they are being used here as a comparative device. In other words, it doesn't matter that much that the large OD of the taper is 1.288" or 1.286", what matters is that all of the male tapers we'll turn have as close to the same large OD as possible. In this sense, with a good caliper in good condition and a careful touch, you should be able to, with a bit of practice, get consistent readings; i.e., each of the tapers we turn end up with the same OD where they meet the shoulder.

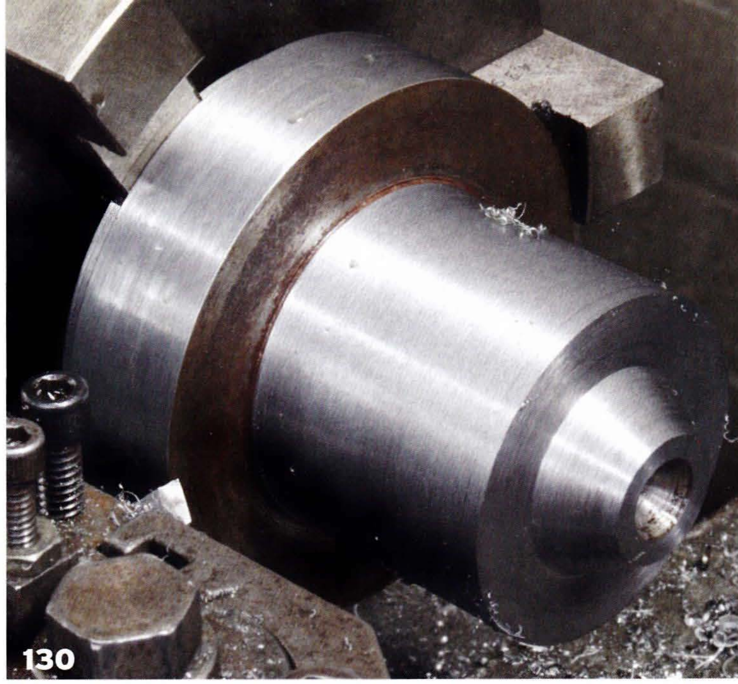
Turn both tapers and shoulders in this manner by flipping the work around in the lathe without disturbing the center in the three-jaw or the compound position.

Next up, we need a heavy mandrel on which to mount the laps for finish turning. Without disturbing the compound, turn a male taper and shoulder identical to the hubs on the mandrel, as shown in Photo 130. The odd shape of this piece is only because that's what came out of the scrap box. However, with the compound slewed over in this awkward position (30° facing the headstock) the work does need to protrude some distance from the chuck or else the chuck will foul the compound. Do be careful to keep your knuckles out of the chuck jaws!

Be sure to turn the taper, face, and OD at the same setting. The wider, larger OD section mounted in the chuck (there because the piece came from the scrap bin) was simply band sawn away after turning.

Set the mandrel up in the mill and locate the mill's spindle axis to the mandrel's axis using an indicator, Photo 131. Using the same jig borer technique described in Part Four, and the locations from Figure 12, drill and start the tapping for the three mounting holes.

Not wanting to break a tap in the blind holes, I finished the job at the bench using a combination of taper and bottoming taps (Photo 132). Especially in smaller sizes, I find alternating between a taper and a bottoming tap lets you remove the metal you need with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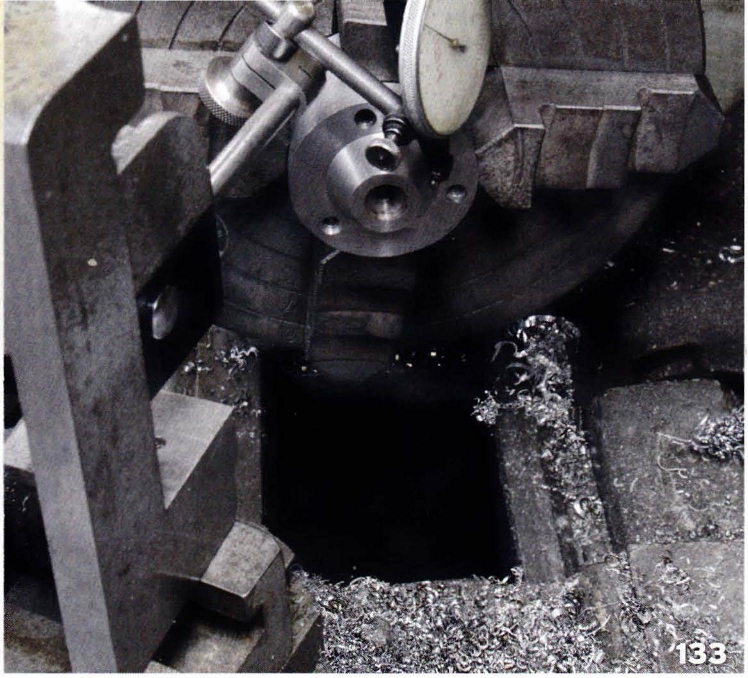

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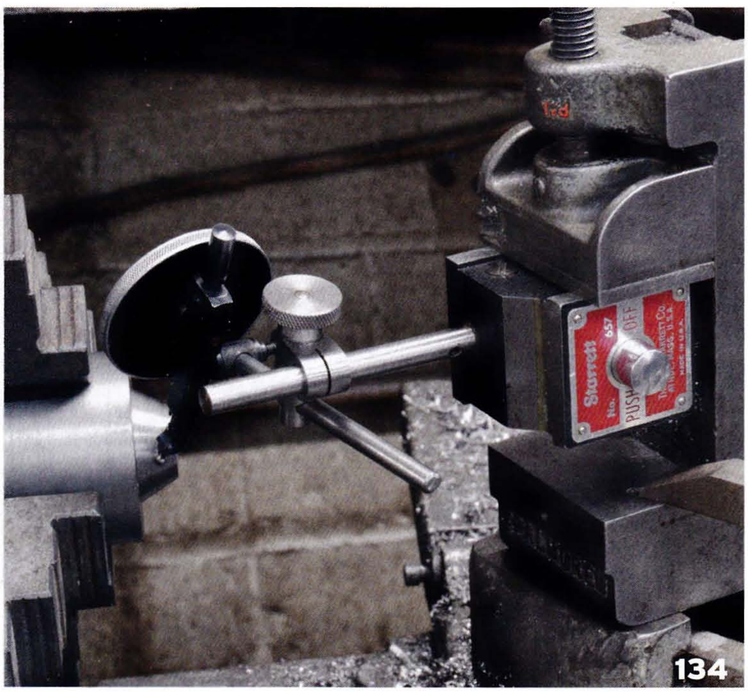

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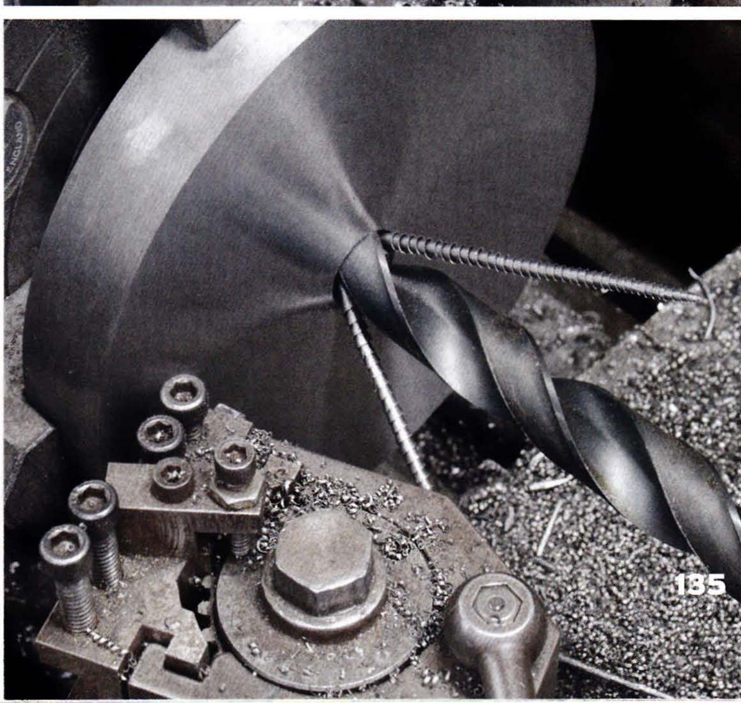

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less strain on the taps. It takes a few extra steps but with less strain on the taps, breakage almost never occurs (there, now that I've said it, I'll break one for sure).

I have not bothered with striving for super accuracy of the tapers, and so long as they are around 30°, all is well. Rather than worry about sine bars and the nominal value of the taper, we simply set the compound, cut the taper, and will now make sure that subsequent tapers match it. In fact, for mating tapers you will get a perfect fit if you do not disturb the compound at all and mount the tool bit upside down to cut its mate. That is, cut the male taper with the tool in its usual position, then cut the female by turning the boring bar upside down and cutting on the backside.

I could not take advantage of this little trick, as I had to orient the compound to clear the tailstock. Now that we've come to boring the female taper in the laps, having the compound in that position would foul the chuck. So, I had to move the compound over to 30° facing the tailstock as shown in Photo 133.

While we don't care to any high degree of precision what the angle of the tapers are, we do need them to be the same. We can precisely re-set the compound to the exact angle by indicating the existing taper.

First, set up the arbor in the four-jaw chuck and indicate it as true as you can get it. I like using a large-dial tenths indicator for this. (That's a tenth of one thousandth, or .0001".) Not to delude oneself that we are always working to a tenth, but I would like to be better than .001" and the resolution a tenths indicator gives is helpful in this regard.

With the OD of the arbor accurately positioned in the four-jaw chuck, we now want to use an indicator to set the compound at an angle matching the arbor's taper. The only tricky part about this is that the indicator will follow a different path (and give different readings) than the actual taper unless the indicator contacts the work exactly at its center height.

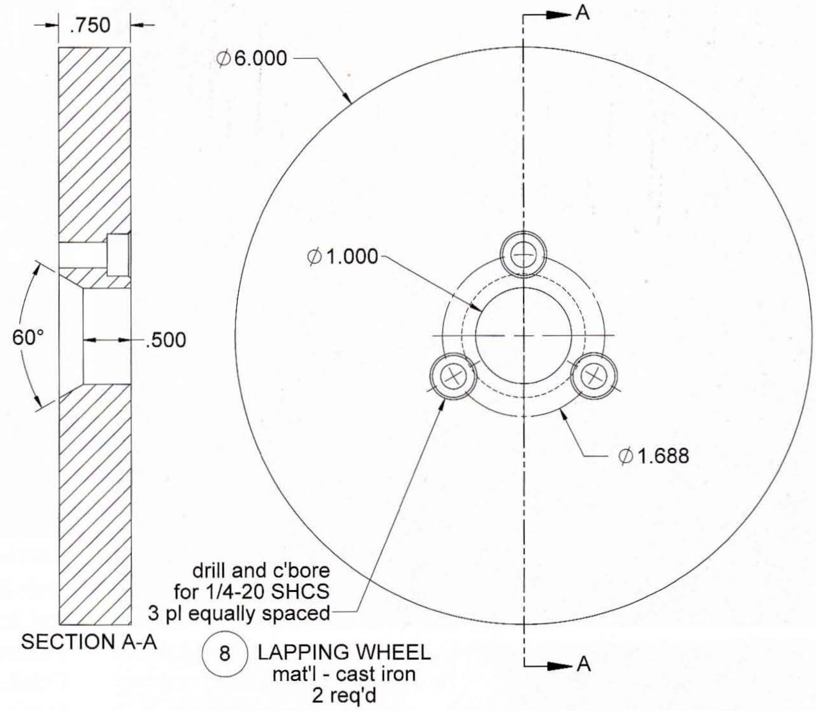
One day perhaps I will get around to making a nifty dovetail slide to raise and lower the indicator, ensuring that it's at center height. Today though, wanting to get on with the job, I pressed my drill vise into service. Mounted on its end with a magnetic base on the movable jaw, this provided a mechanism by which to adjust the indicator up and down so that it was on center. With the needle in contact, simply move the indicator up and down until you get the highest reading. The indicator needle is then at center height to the work and the angle of the compound can be adjusted such that there is no movement of the needle as the compound is moved over the length of the taper. The kind word for this setup would be precarious, and a snicker or two might not be out of place; however, it did work and that is what matters.

Note that Photo 134 is intended to show the setup to adjust the indicator height, but the orientation of the compound is incorrect for boring the female tapers – it was slewed around so the setup was visible. The compound should be oriented as shown in Photo 133 for this operation.

Remove the arbor for now. We only mounted it to get the compound accurately set to its taper. Drill the center of the lapping plates to 1" and run a boring bar through to ensure the center hole is concentric with the female taper we are going to turn, Photo 135 and Detail 8.

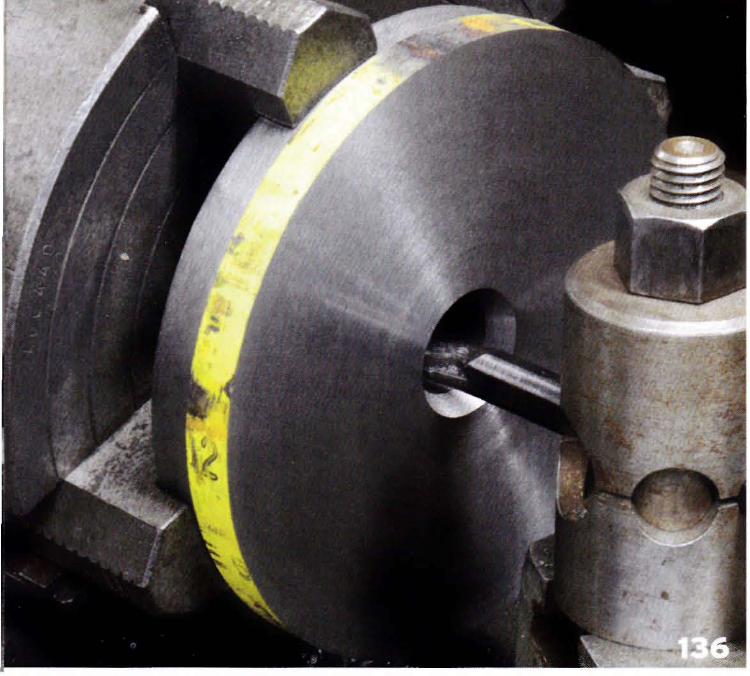
Before we get to machining the taper, make a face cut and skim the OD of the wheel so these surfaces will be axially concentric to the taper. For a variety of practical reasons, most of the time high-speed steel tooling is the best choice with our lighter, slower home shop equipment. However, taking .010" off an easy machining 6" diameter piece of Durbar at 540 rpm is carbide bliss.

We, of course, want to have the large end of the female taper exactly equal to the largest outside diameter of male taper. If we can achieve this, the face of the shoulder will be in perfect contact, as will the tapers. This will let us bolt the laps to the hubs with the faces of the laps perpendicular to the motor's axis, while ensuring they are concentric to the hubs. Let's look at how to do this.



The diameter of the large end of the internal taper is almost impossible to measure, as it exists only in two dimensions; i.e., it is the diameter of the taper at the plane of the face. After some head scratching, I came up with an indirect approach that seems to get fairly accurate results.

To use this method, you will need a micrometer carriage stop or a graduated dial on your lead screw. Rough the taper to the approximate size and then set the cross-feed at some number, any number, and don't touch it again. Bring the micrometer carriage stop into contact with the carriage.



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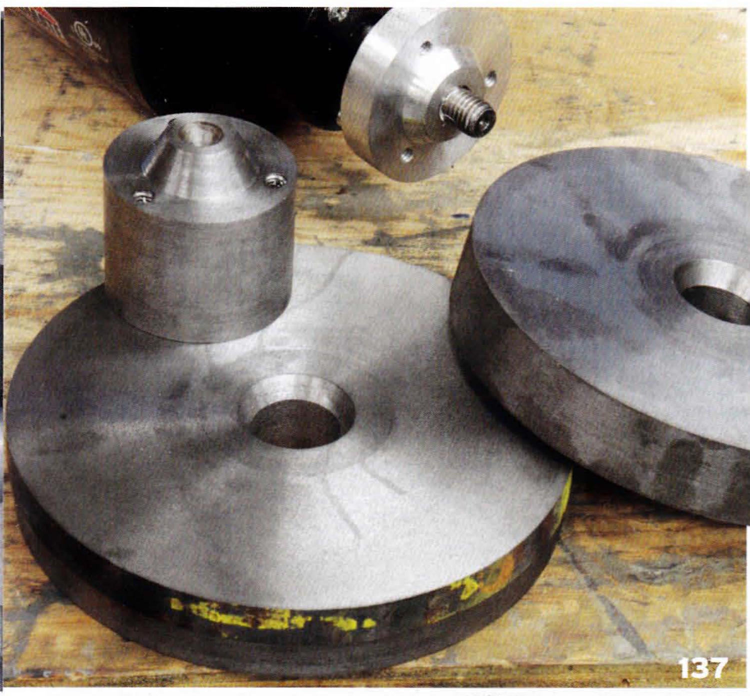

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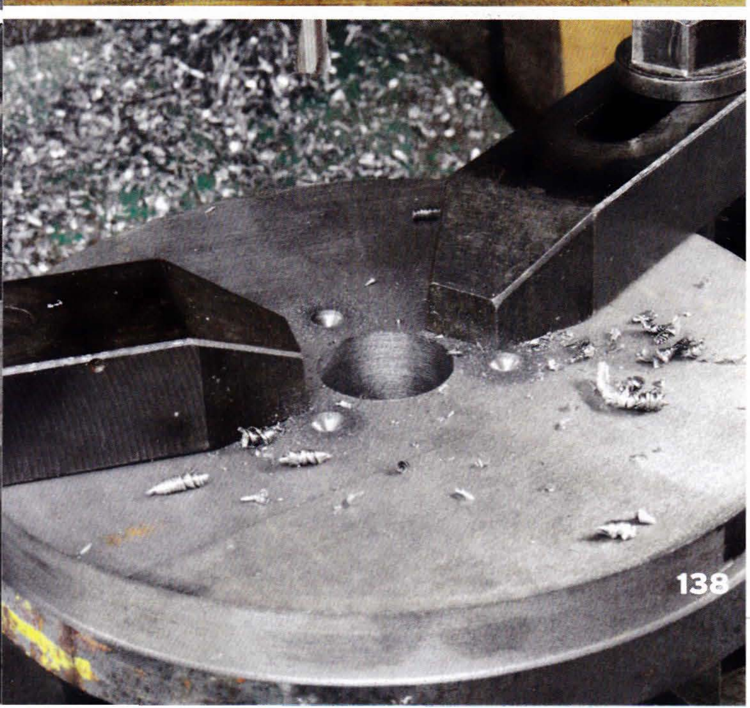

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The idea is that moving the carriage micrometer stop becomes our depth of cut control. The cross-slide is not touched at all and the compound is used to feed the boring bar cutter along the taper's bore (Photo 136).

Snug the carriage up against the micrometer stop and take a light cut by advancing the compound. Place the mandrel into the just turned taper; there will be a gap between the face of the lap and the shoulder of the mandrel. Using feeler gauges, measure the gap carefully. Measure two opposing sides to make sure you're holding the mandrel square to the lap. If there is a gap and you can easily fit a .030" feeler gauge all the way around, we can, with confidence, move the carriage stop .030" and the parts should be a perfect mate.

Keep in mind that we are still using a boring bar, which is less rigid than OD tools and more susceptible to flexing. In the previous example, if I had moved the carriage micrometer stop .030", I would remove the material in a couple of cuts, the last being a very light cut to work out any spring in the bar. Work closer and closer towards a zero gap; don't try to do it all at once. I did mine incrementally and by the time the .0015" leaf would just fit, I had developed confidence in this approach. I moved the micrometer stop .0015", took the final cut, and ended up with a solid mating between the flat sections, with the tapered sections preventing any axial movement.

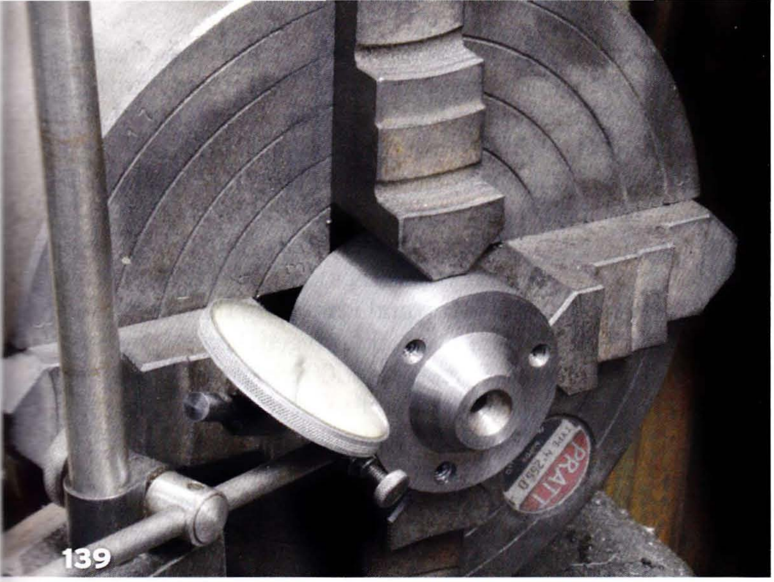
To double check, spread a very thin layer of blue on the shoulder and taper of the mandrel and place in the lap. If all is well, we should get good coverage of blue on both surfaces of the lap disk.

Repeat for both disks, and you'll end up with pieces as shown in Photo 137.

To put the bolt holes in the laps, we'll use the mandrel as a fixture. Mount the mandrel back in the mill vise and indicate the spindle to its center. We could have bolted the lap to the table and indicated it, but I thought it easier to indicate the large, unencumbered OD of the mandrel, plus we can use the same setup for both disks – it becomes a fixture to hold each disk for the drilling.

As shown in Photo 138, clamp the lap on top of the mandrel. Make sure the clamping force is on a section of the lap that is directly supported by the mandrel. Using the XY coordinates we worked out before, spot drill the three bolt holes. Don't drill through, as we don't want to damage the mandrel. Move to the drill press to drill clearance holes and counterbore for the 1/4" socket head cap screws. Use a depth stop; we want to remove the same amount of material from each counterbore to maintain balance.

My view of the drill press is that it is one of the most dangerous machines in the shop. Small work is held in the drill press vise and other work, either because it's a thin section or the holes to be drilled are large, is clamped directly to the table. I also have a large chunk of angle iron, maybe 4" × 4" and about 4" long, firmly clamped to the table to act as a stop in



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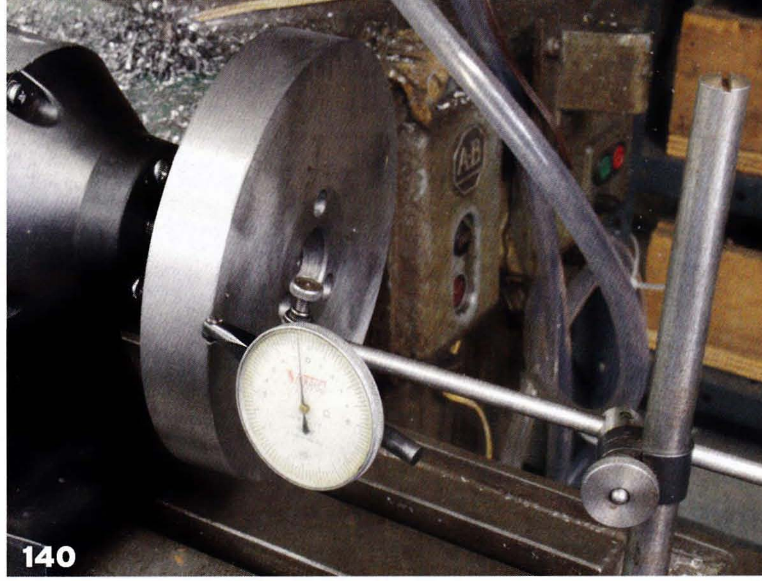

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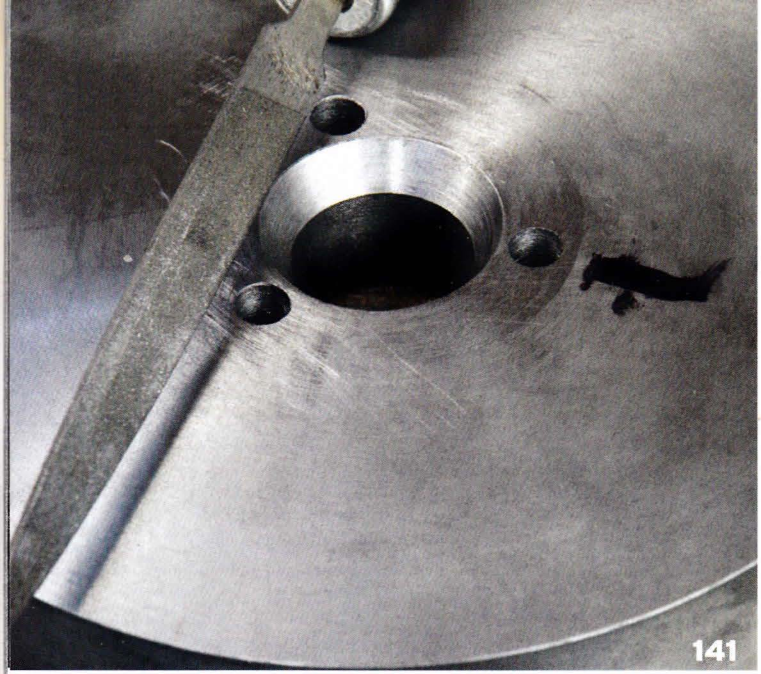
case something grabs and wants to spin. However, it remains common practice for larger items requiring smaller holes to be held by hand for drilling. This is a problem with these disks as the surfaces, freshly laden with slippery graphite from machining, have a very low coefficient of friction against the cast iron drill press table. A piece of plywood between the disk and table would be a good idea – and do be careful!

With the lap disks drilled and counterbored, we head back once more to the lathe with our trusty indicator in hand. Mount the mandrel and indicate it as true as you can (Photo 139). Now, bolt a lap to the mandrel and face and cut the OD. Do each lap and have a fun time doing some fast and easy carbide machining while facing the lap. I used a high-speed steel tool to cut the inner area of the lap where the counterbores for the socket head screws are, as carbide is less forgiving with intermittent cuts. If all has gone according to plan, we should have two disks whose center of gravity lies perfectly along the taper's axis.

Bolt the wheels onto the arbors to make sure everything fits. Do not turn the machine on at this



point; we want to check things out first with an indicator (Photo 140). Check both the periphery and face to make sure the disk is running true.

After this final machining of the laps, I mounted them on the spindle and was disappointed to find the face had about .005" of variance. Hardly the result I wanted after such care to make accurate, concentric parts!

It's times like this we should to remind ourselves that the engineer's approach of cold, hard analysis is far more productive than four letter words.

I started by indicating the face on the flange and was pleased to see that the needle only moved .0001". Figuring that this was about the limit of accuracy and that even a few tenth's difference could just be variations in surface finish, I looked elsewhere for the problem.

It turns out the issue was rather pedestrian. In drilling the laps, the drill had created a very small burr on the exit. Unlike in steel, where the burr is large and noticeable, I had missed these tiny cast iron burrs. Using a 4" smooth file (which has very fine teeth) I ever so lightly addressed the affected area to remove the burrs (Photo 141).

Being in diagnostic mode, I also checked out the mandrel mounted in the four-jaw, which I had not yet disturbed. While I had carefully indicated the OD when setting it up in the four-jaw, when indicating the face there was about .001" of variance. I think this can be explained by inaccuracies in the jaws, causing the mandrel to not be held in an axis parallel to the lathe's axis. Work holding in the four-jaw is often presented as the most accurate way to hold things; and it often is. However, despite being able to indicate something concentric to a tenth, if the chuck is less than perfect, it is possible for the work's axis to be at a slight angle to the lathe's. A close to zero indicator reading is possible where these two axes intersect, but if you move the indicator along some (indicate the part 2" away from the first indicated circumference) the error will reveal itself. Something to be aware of when setting work up and looking for sources of error.

Getting the face perfect is important in this instance, so I took a hunk of copper and tapped the mandrel into better alignment. In other words, after indicating the mandrel perfectly on the OD, I indicated the face and used a piece of soft material to gently tap the face into a plane perfectly perpendicular to the lathe's axis. Back on went the laps for another skim cut.

Between the re-cutting and removing the burrs on the backside of the lap, I was able to get the periphery of the face of the lap to less than .0005" of variance. As errors at the point of contact with the flange are exaggerated with its distance from the axis, I don't think we could expect better than this.

Now, reassemble the machine and make sure the wiring connections are as per your notes prior to disassembly.

STARTUP SAFETY

With indicator checks, make sure there is no obvious eccentricity of the wheels. By installing one wheel at a time, see if there is a heavy side. This is a crude test, as the drag of the bearing will mask all but gross imbalances, but we take what we can get.

Check that the lapping wheels are secured. There is a lot of energy in 6 or 8 pounds of iron spinning at 3450 rpm, but we should be fine so long as it is stable. Stability comes from balance – if you've followed along with the construction procedures, things should be fairly balanced. However, that is not a guarantee. You are responsible for the safety decisions on whether to run the machine or not, and each grinder will have its unique traits from the manufacturer. The slight differences in the parts you've made will create a balance scenario unique to your machine.

My point is not to scare, well, maybe it is if that makes us more safety conscious, but rather to make sure each builder realizes that however carefully they followed the plans, don't just tighten the last bolt and throw the switch.

What I did was a series of incremental starts. Since the cast iron is so much heavier than a grinding wheel, the machine will build speed slowly. We want to experiment by turning the machine on, letting it start to build speed, and then cutting the power. Each time it gets to a speed and is vibration-less and stable, try again for a slightly higher speed.

If at any point in these trials an imbalance or vibration gives you the sense that things are not stable – STOP. That imbalance has to be found and corrected before the unit can be safely used.

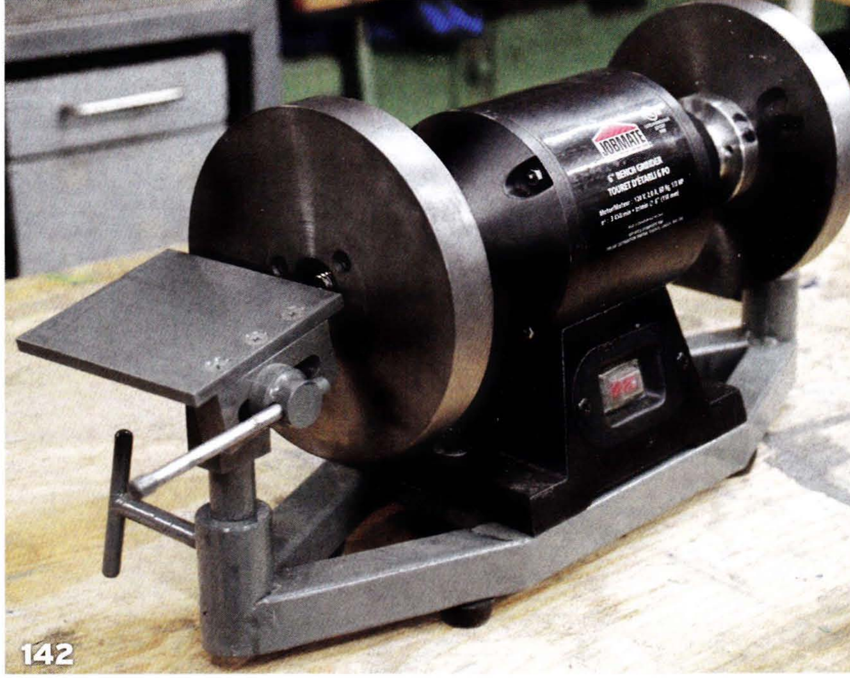
On another note, you will see that the grinding wheel guards are removed on my machine. This is a construction necessity. While I do not advocate removal of machine guards, this is no longer a grinding machine. We no longer have to worry about bursting wheels, containing sparks and metal shavings, or losing a finger through the rapid cutting action of a grinding wheel. Nevertheless, we want to exercise general machine safety procedures; wear safety glass, be aware the wheels can throw debris, keep hair and loose clothing away, etc. Because it requires a certain mechanical aptitude to construct, I am sure builders will deploy equal cerebral efforts toward using the item safely (Photo 142).

USING THE ROTARY LAP

Once charged with abrasive, amazingly, we can press a steel or carbide item into the lap and the lap is virtually untouched, while the cutting tool receives a mirror like finish. The embedded abrasive cuts the work, leaving the lap intact.

How do we get the abrasive there? We charge the lap. Fine abrasive particles are literally pressed into the surface of the lap. We need something harder than the lap to do this and an old ball bearing is perfect for the task

Dab some abrasive (I'm using 1000-grit *Clover* compound) on the stationary wheel. Create a bunch of spots, more or less evenly spaced, around the flat face of the lap. This is a less-is-more type situation. If you've applied too little, it will become apparent and you simply stop and apply more. If you've applied too much, you may end up with a mess. It could be a monumental mess if you've applied far too much. Excess abrasive compound will be flung all over the shop as the wheel comes up to speed. Be careful and start with a small amount of abrasive compound.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Grab the bearing with *Vise Grips* as shown in Photo 143. The grips are clamped on the inner race, permitting the outer to rotate.

Aside from economics, using an old bearing holds the advantage that it's a little looser. Applying a new bearing to the full speed wheel won't work as well, as the drag of the bearing will cause a lot slipping against


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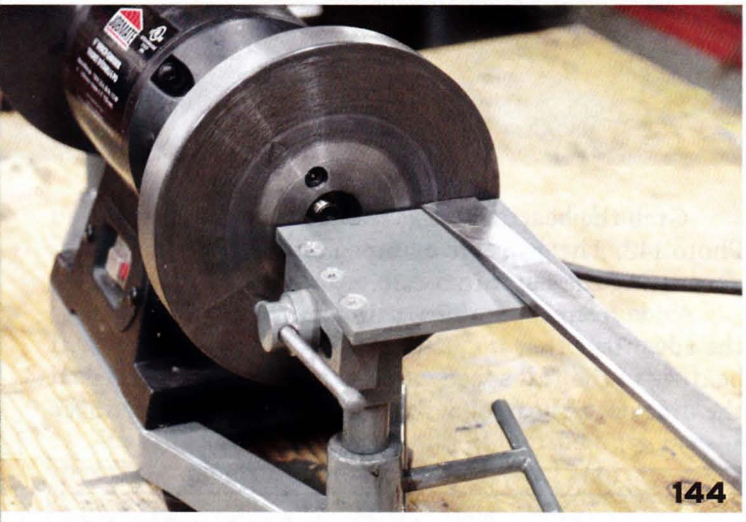
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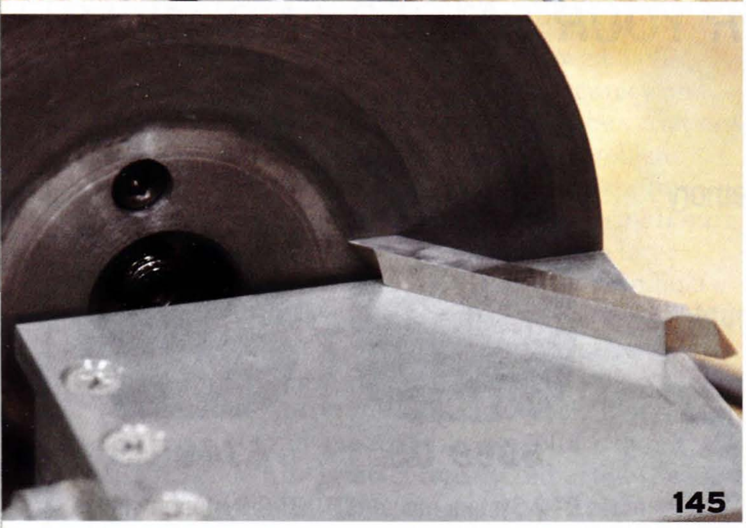
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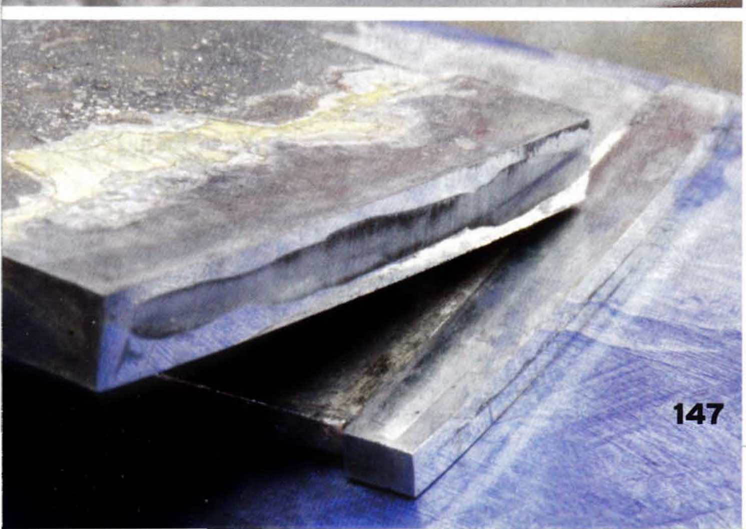
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the wheel. In the photograph, I've shown a sealed ball bearing; a shielded one would probably be a better choice with its reduced drag. This only matters when charging the lap under power; part of me likes charging the lap by hand on the bench because it's easier to press much more firmly into the wheel.

I went with the two lap idea so I could have one charged for ferrous tools and a diamond charged lap for carbide tools. It's considered bad practice to use a high speed diamond lap, or any diamond cutting tool with steel, as at the point of contact temperatures may become high enough that the diamond (carbon) is absorbed into the steel.

Remember, the temperature at the point of where the material is being cut is mostly a function of the surface speeds; that's true for turning steel in your lathe or lapping with a diamond. This is why it's fine to use a diamond hand lap on steel (slow and low temps) but diamond grinding wheels can have their lives shortened due to the temperatures generated by their high speeds. Whether the life shortening is large or small, or even noticeable, I cannot say; diamond tools are expensive enough that I've always just followed the theory.

If you didn't care about having different types of lapping compound, you could do both sides in diamond. One with a coarse grit for faster cutting, for example.

Photo 144 shows the lapping of the end of a steel scraper. I have never been able to get a scraper this sharp before! This rotary lap is quite a fun project to complete as it has exceeded all expectations. We'll need it for our carbide scrapers, but having exceptionally sharp steel cutting tools is a great fringe benefit.

It wasn't too long before a lathe tool bit was tried (Photo 145). Incredible results: a mirror finish and

(Continued on page 60)


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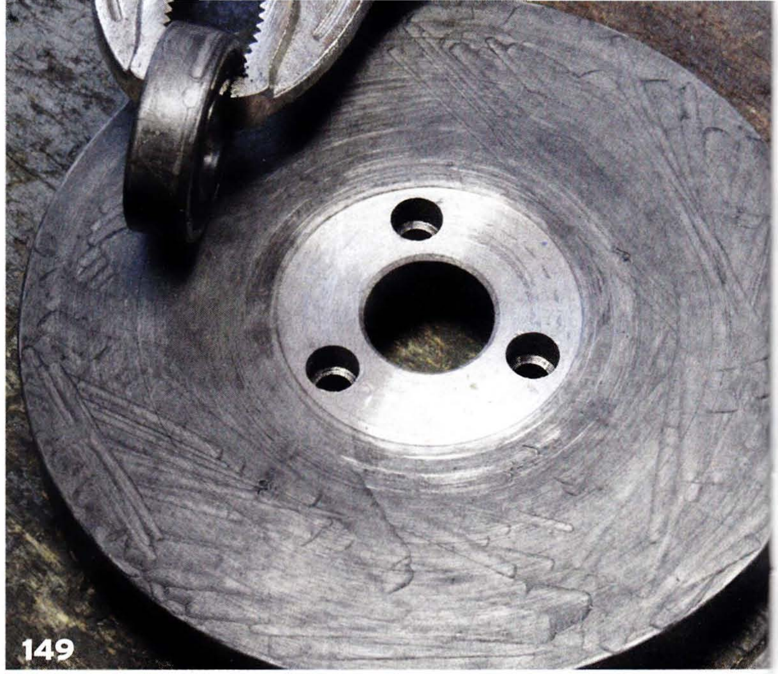

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an edge that feels like a razor – experimentation on what this means to cutting gnarly old 1018, or taking extremely small passes will be interesting.

Photo 146 shows a collection of carbide scrapers finished and ready for action and Photo 147 shows two freshly lapped and highly reflective scraper ends. With the broader top and bottom lapped prior to silver brazing, and the ends lapped to a mirror finish with each sharpening, a very fine cutting edge is put on the tool.

One of the design advantages of this rotary lap is that laps are easily removed and can be reinstalled without materially affecting balance. I've not made my mind up yet on whether it's better to charge the lap on or off the machine. With the lap off it is easier to apply greater pressure, but with the lap rotating at speed it's easier to cover a lot of ground.

Whichever your preference, eventually you will appreciate that the laps can be removed to facilitate resurfacing. Photo 148 shows a lap after some use and you can see that the surface has become scored. These marks aren't very deep but to the extent that the surface is now peaks and valleys, charging will be less effective. Of course, scoring can be largely avoided by keeping the lap well charged. It's often hard to tell that lap needs recharging until it's too late though.

In this case, I felt it was time for a light facing cut. Mount the wheel on the hub it was originally finished-turned on and indicate things true. Very carefully cover the lathe with paper towels held down by pot magnets – the swarf that comes off this facing cut will be loaded with diamond abrasive compound and you don't want that on your ways.

Another thought I had was that lathe work inevitably leaves peaks and valleys in the surface as the lathe tools form a helix, or in the case of facing, a spiral pattern. Perhaps surface grinding the lap prior to charging, or even lapping it, might create a smoother finish that would better take the lapping compound.

Photo 149 shows the freshly faced lap being reloaded with diamond lapping compound and ready to reinstall.

PRACTICAL HOME SHOP APPLICATIONS

My view is that scraping is a basic shop skill with a wide variety of applications. From basic part making, to gauge and tool making, to bringing machine tools into their highest state of accuracy, it's a technique with countless applications. To underscore this point, I've collected a number of examples that illustrate the usefulness of this skill.

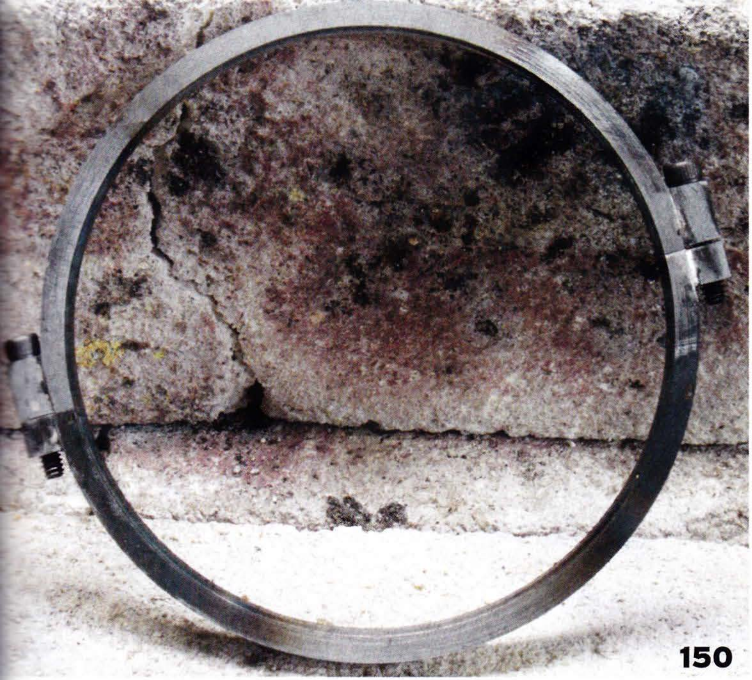
Hopefully the examples will spark ideas and develop an understanding of using scraping not just to achieve flatness, as was the case with the surface gauge discussed in Part One, but also to create highly accurate relationships between surfaces, such as squareness and parallelism, etc. These projects were chosen to both suggest non-obvious applications and also to learn, through a progression of increasing complexity, the relationships between surfaces as we scrape for parallelism, squareness, or a specific angle.

CREATING A DATUM SURFACE ON A FORGING

To get you thinking outside of gauge making and machine tool reconditioning as applications for scraping, I'd like to show you a few jobs where scraping played an invaluable role. Photo 150 shows a two-part ring I made. It's part of a dust collector for a grinder.

For some jobs, you can even leave the scraper in a drawer but borrow from scraping methodology. In this first example, the technique of spotting to a reference surface was used to get a rough forged surface reasonably flat. Sometimes it's advantageous to use a hybrid of the two; roughing something in with files and finishing with a scraper. For expediency, I used files here instead of scraping, but used the scraper's technique of spotting to a surface plate.

For roughing work, it is interesting how localized you can get the cutting action when using a file. Hand pressure on the file over top of the blue area will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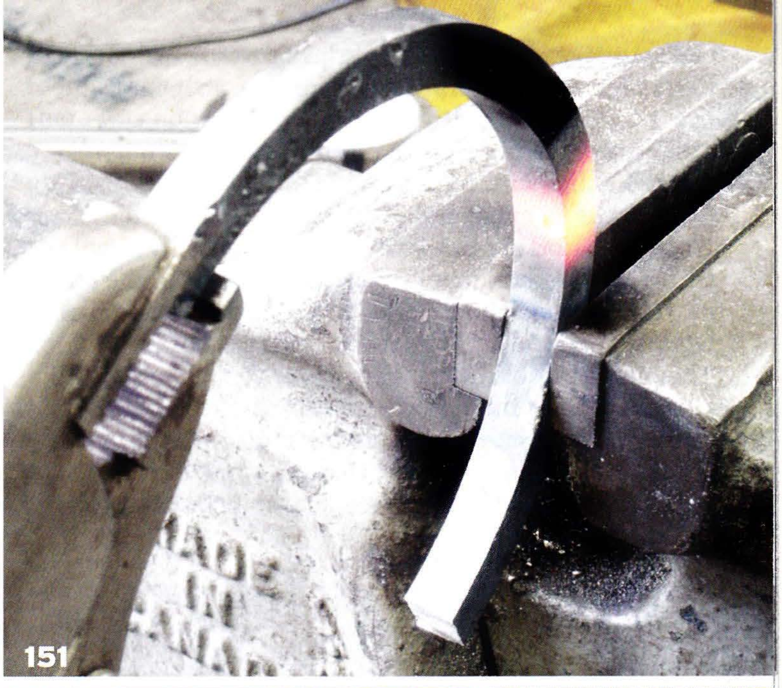

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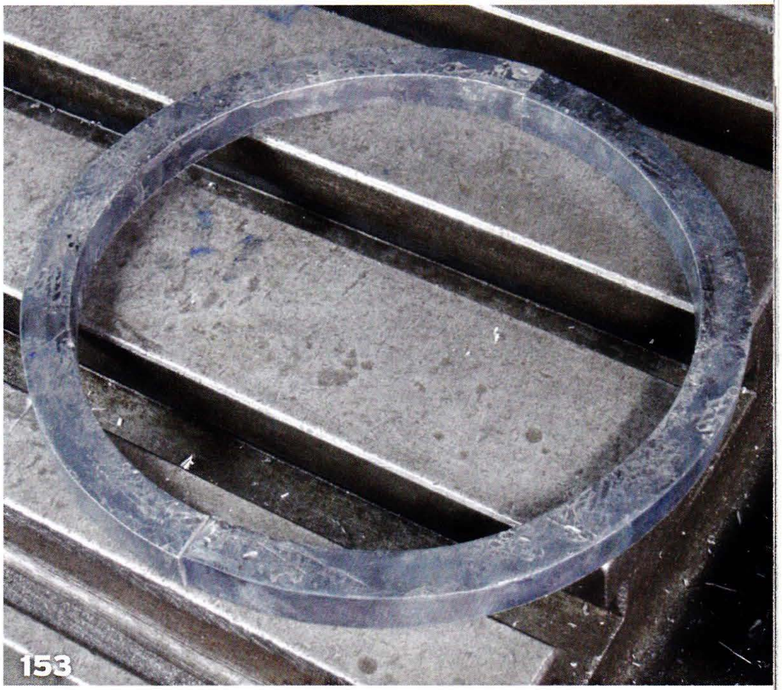
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concentrate material removal there. Keep in mind though that this is for expedient roughing and should be followed up with scraping if you are striving for flatness over the entirety of a surface.

Photo 151 shows its manufacture. This ring, made in two halves, became the attachment point of a tool and cutter grinder's dust collection shroud. I did not have a piece of mechanical tubing near the finished diameter and it would have been a waste to machine this from plate. The idea struck me to take some 1/2" square bar and, using *Vise Grips* and a torch, carefully bend it into a ring shape. In the photo you can see the ring has been split in half and I am doing some fine tuning to the arc shape.

The problem is how to create a datum surface to machine from and clamp to. You can't just clamp something until you have a flat surface, as once the


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clamping pressure is released the part will spring back to its previous irregular and inaccurate shape, taking the freshly machined surface along with it.

Not surprisingly given our subject, scraping, or at least spotting with blue, provided the solution. It's the perfect way to create a flat surface on an irregular shape without distorting the work. Working quickly with a surface plate, thick blue, and some files, I had the two halves flat in no time (Photo 152). A little bit of touchup work with a scraper and I had my datum surface. The pieces sit solidly without any rocking on the mill table, as shown in Photo 153. I was then able to clamp them to a faceplate to complete the machining.

Actually, I soft soldered them to some bars that were then clamped to the faceplate so I could turn OD, ID, and face in one setup.

THE PERFECT WOOD PLANE SOLE

Photo 154 shows another application you might not have thought of – scraping the sole of a wood plane. Woodworkers like to have the soles of their planes flat and scraping is an easy way to achieve this.

Plane manufacturers will tell you that a base that is .005" or more out of flat does not matter. This is a self-serving position of the plane manufacturers, as getting things flat to a small tolerance is both difficult and expensive and I'm not so sure their claim is true.

I tend to side with the woodworkers who think it's important to have the plane sole very flat. Planning something flat and square is an acquired skill based on some pretty amazing human qualities of sensitivity and perception. For example, a good percentage of people, if given two gauge blocks that are only .001" different in thickness can identify the thinner and thicker from feel alone. My belief is that these incredible abilities are accentuated and refined as a craftsman learns to plane square and true – no small feat!

What disadvantage does this place the craftsman at, or worse still, an aspiring craftsman trying to develop the skill, when the plane sole which is both control and feedback is out of flat by .005"? I think that the warped plane sole impedes development of good planning techniques as our perception and sensitivity in working with hand tools might just be finer than we often assume. In other words, it's tough enough to develop hand woodworking skills without the plane sole lying to you, and if you doubt we can sense .005" or .010", do the gauge block experiment. If you've ever tried to square and dimension hardwood to any accurate degree with hand planes, you will likely agree that we want as much in our favor as possible!

Scraping also holds an additional advantage for wood planes in reduced friction. You will note some wood planes, especially the longer fore and jointer planes, sometimes appear with grooved bases. Essentially, long grooves have been cut into the base of the plane to reduce the surface area contact between the plane and the work, thus reducing friction.

Finally, I've heard of people having a planes surface ground to achieve this flatness with disastrous results.


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Apparently, the localized high temperatures generated in grinding can warp the large, thin plane castings.

The finer points of wood plane design are outside of my purview, but I like my scraped plane; perhaps you will experiment and find out for yourself if it's an advantage. If nothing else, it's a large surface of quality cast iron to get you started with something to scrape.

WORKING WITH CASTINGS

Another perfect application for scraping techniques is in the initial preparation of a casting. Castings are the epitome of an irregular shape and require careful thought for both layout and when holding them for machining operations.

Unlike a part made of bar stock, where you usually just grip it in chuck or vise and machine to size, machining castings is a little more difficult. They must be laid out, a datum surface chosen, and all subsequent operations done in relationship to that datum surface. For example, you want a cylinder bore to leave roughly the same amount of material on each side of the block. By examining the rough casting dimensions, finished dimensions, and calculating roughly how much has come off where, you are working towards the establishment of a datum or reference surface. This means picking a surface and getting it flat so you can measure and machine to it, as well as clamp to it.

Sometimes it's possible to estimate where you want the datum surface to be and to machine it in place. However, often the challenge is that there just isn't a flat surface to start with. How do you machine something if there isn't a flat surface to go against a table, vise jaw, faceplate, etc.?

Big, solid pieces can be held sometimes by the use of some cardboard or wood to ensure a decent grip on the irregular surface. In some cases though, the casting is spindly enough that gripping it before there is a reliable, flat surface will distort it. Of course, once the clamping pressure is removed, the part springs back to its original shape and the flat surface you just machined now has more twists and turns than the road in a sports car commercial.

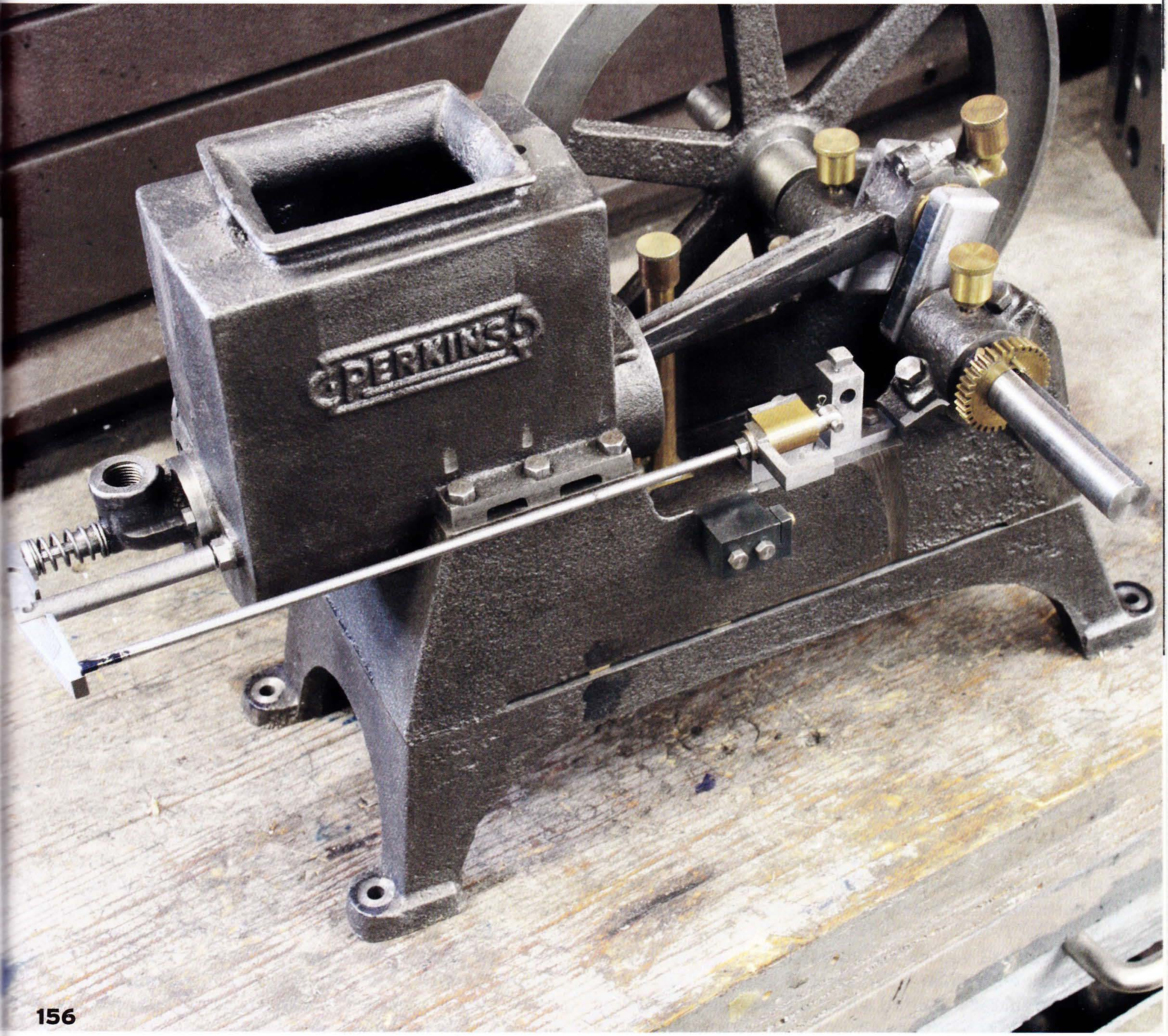
This is where scraping can make your day. Using only hand tools and not having to clamp the part, we can develop a perfectly reliable flat plane that we can both reference other dimensions to and clamp to.

Photo 155 shows the base for a hit and miss engine. I thought it a particularly good example, since it is one of the more spindly shaped castings I've encountered. It would have been very frustrating to get this part flat-footed enough so it doesn't rock without scraping and there was no good way to hold it without distorting it.

As it was, the bottom of the four feet were quickly and easily scraped into the same plane. An old file was used to remove the outer scale and then the bottoms of the feet were scraped, using blue and the surface plate. It was then a simple matter to clamp this to the mill table and machine the top, resulting in a wobble free engine (Photo 156).

Advancing to the next level means learning how to scrape more than one surface while maintaining a precise relationship between the surfaces. Parallel surfaces, square surfaces, and those at a specific angle are examples. Next up – scraping surfaces into relative positions.

Photos and drawing by Author



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SCRAPING for the Home Shop

Part Six

BY MICHAEL WARD

Up to this point, we have done a few basic scraping projects, but we will eventually want to do more than just make flat surfaces. This is where the scraping can become more complex because we must maintain very accurate relationships between surfaces. It also opens up considerable new avenues and opportunities for home shop accuracy and the development of excellent bearing surfaces, such as ones found on machine tools, as well as precision gauges and tooling.

Imagine, for example, scraping in a large horizontal mill. Each surface comprising the tops and sides of the table – the dovetails in three axes, the spindle position, the RAM dovetails, arbor supports, etc. – all have to be parallel, perpendicular, coplanar, or at precise angles to many other surfaces. Puzzling through the sequence of steps and how to maintain these relationships to a high degree of accuracy is where scraping can become a very complicated subject. Getting each one flat is simple; getting them in perfect relationship to all the other surfaces is complex. Incidentally, the Connelly book addresses this complexity in great detail through most machine tool categories.

A WELL FIT SHAPER BLOCK

I recently restored a nice old Atlas 7" shaper. One of the missing parts was the block (Photo 157), a piece that sits inside of the shaper and is sort of the pivotal bit in converting rotary motion to reciprocal.

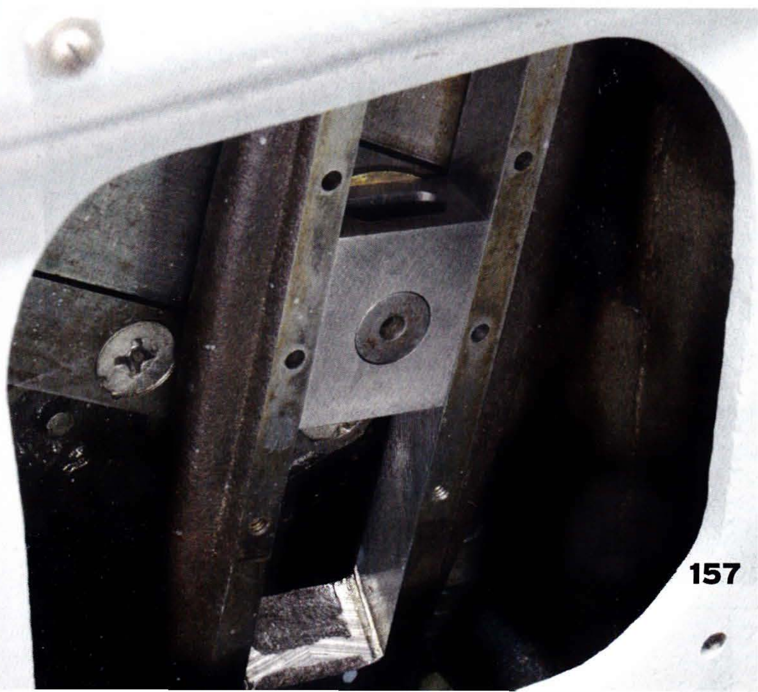
The piece shown in Photo 158 represents two new challenges; we must scrape two surfaces flat and parallel to each other and to a specific dimension. For you shaper owners, this is my take at an improved design – well, actually my take at a design. I've never actually seen an original factory model so can't say whether it's improved or not.

The approach is to machine it to approximate size, leaving it a few thousandths oversized. Scrape one side flat and with a sufficient density of bearing spots to make it past the quality assurance inspector. From here, getting the second surface parallel and the right distance apart is iterative; we measure, we scrape a little, and we measure again.

To start, carefully measure with a micrometer to get a sense of the magnitude of material that needs to be removed from the second side, then place the item on the surface plate, scraped side down. With an indicator in a holder (I like to use a 10ths indicator – we are scraping after all) have a look at how far out of parallel the second surface is. Set up the indicator on a height gauge as shown in Photo 1 at the beginning of the series (*The Home Shop Machinist*, May/June 2011).

We're going to scrape (or if there's a lot of material to remove, rough out by filing) material off the second surface until it becomes parallel and a set distance from the first. As the block sits on the surface plate, the top surface will be carefully lowered to bring this about. Where you remove material and how much to remove is a judgment call based on where the indicator says we are high and how close dimensionally we are.

I started by quickly bringing the second surface to a flat state. Once it is flat, the indicator will reveal which quadrant is still too high, and that is where I concentrate the scraping. The iterative part comes in that we want to get it flat and not scrape a curve into the surface. As you concentrate on scraping in one quadrant or another, don't completely ignore the rest of the surface; keep checking for flatness as well.



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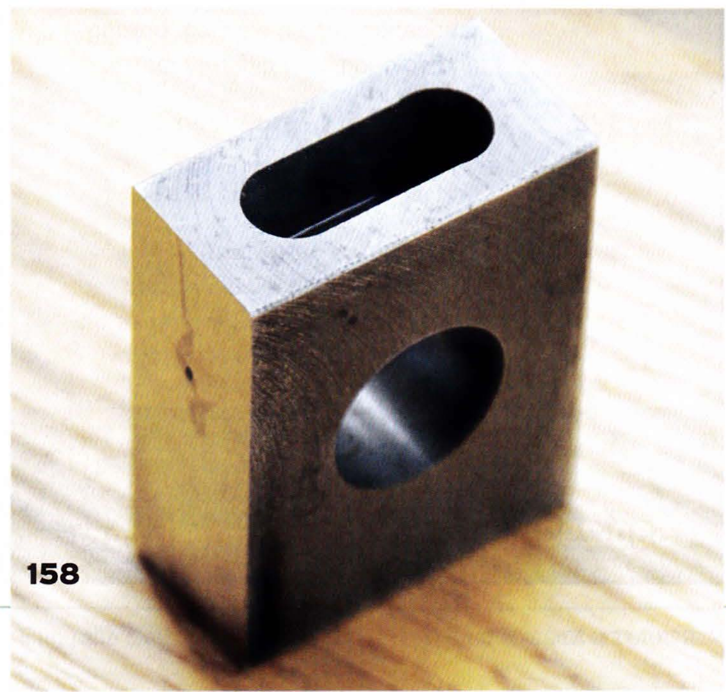

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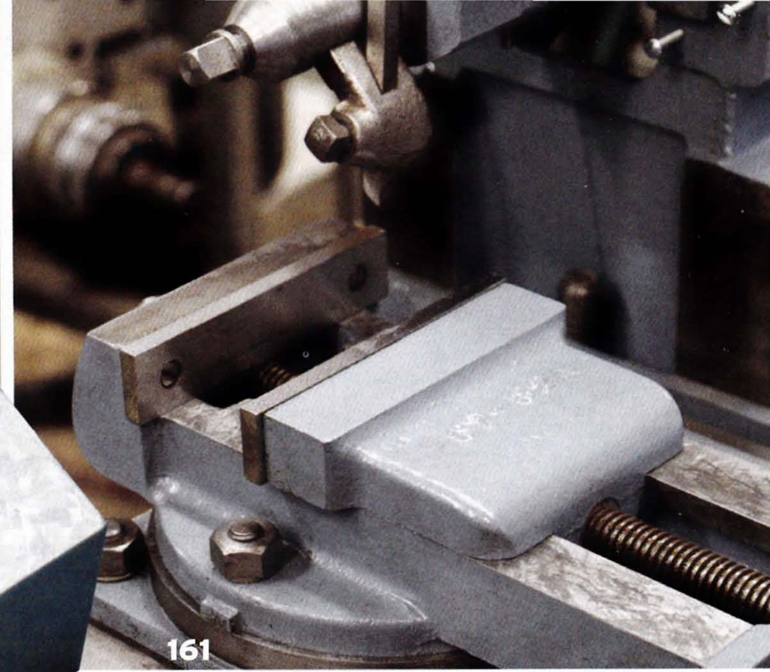
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As things got really close, I began bluing the work, using a reference surface to rub the blue off the high spots. Thus, the high spots are now a negative – they're the shiny spots, and the low areas are blue.

The final fitting, as shown in Photo 159, uses the mating part itself to spot the work. The fit was so close I could press it in by hand, yet it was too tight for a running fit. A bit of blue on the part and the insertion into the mate quickly showed (by where the blue was removed) where the high spots were. Photo 160 shows the complete scraped surface of the block. This picture managed to catch the light in such a way that the bearing surfaces are clearly visible.

Incidentally, if you are making a shaper block, I milled a pocket in the top of the block with small diameter holes to each bearing surface and the bore (Photo 158). The idea is that with the ram correctly positioned, this oil reservoir pocket can be filled by rotating the drive until the block is at TDC (Top Dead Center) and then squirting oil though the hole on the cover plate. A shaper likes lots of oil, and this addresses one of the highest wearing areas.

TUNING UP A MACHINE VISE

Back to the Atlas shaper again; its vise needed a tune-up (Photo 161). It's a good project to expand our scraping abilities as, along with parallel scraping, it also introduces scraping mating parts and scraping for squareness. It's also a relatively straightforward project of manageable size.

When you go to machine something, you have a plan in your mind for the sequence of operations. The objective is to work in an efficient manner, being able to properly hold the work and make sure that all machined surfaces are accurate and in proper position to one another.


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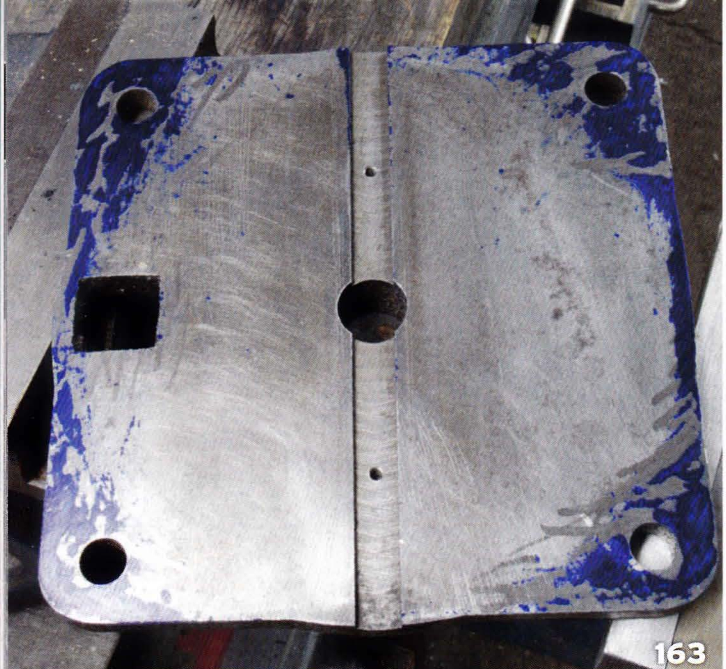
Scraping works the same way. In the same way that you would study a blueprint to work out how to make a part, you need to study what it is you're going to scrape to work out the best plan of attack. For example, I started with the swivel base of the vise as shown in Photo 162. This requires that the two surfaces, the bottom of the plate and the round exposed top, are both flat and parallel to one another. The defining characteristics are that the entirety of the bottom must be scraped flat, whereas there are only two fairly narrow rings on the top.

To get two surfaces parallel, scrape one surface and then, constantly checking parallelism with an indicator, scrape the second surface. Therefore, to minimize the potential scraping involved, it makes sense to start with the bottom of the vise. Get that surface flat first and then bring the top parallel to it. The reason being is that if the two surfaces are far from parallel, it will be much less scraping to bring the top into relation to the bottom, as opposed to doing it the other way around. Photo 163 shows this little vise is far from flat.

We want the base of the vise to be flat and bearing all over. Assuming the table it's bolted to is also flat (as it should be), this forms a stable and solid foundation. If it's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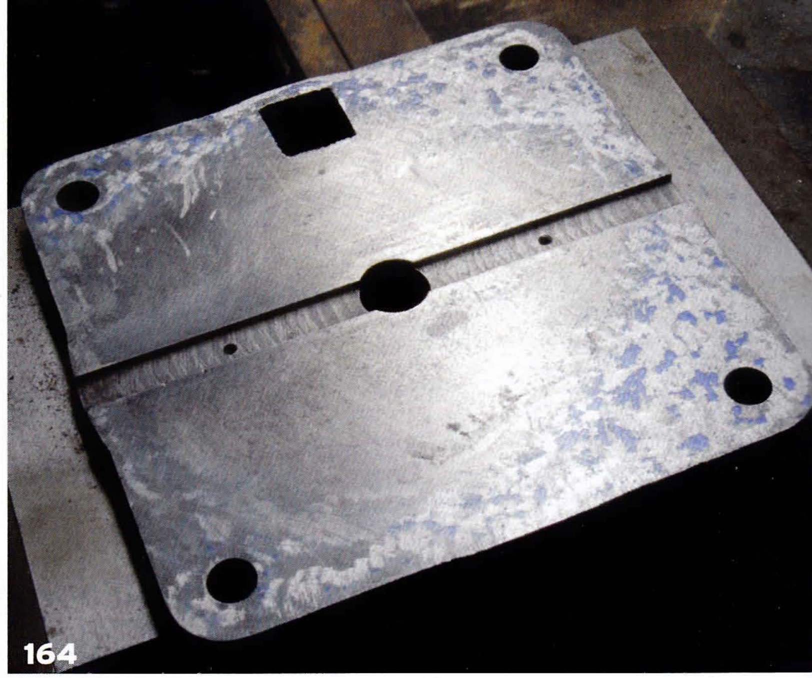
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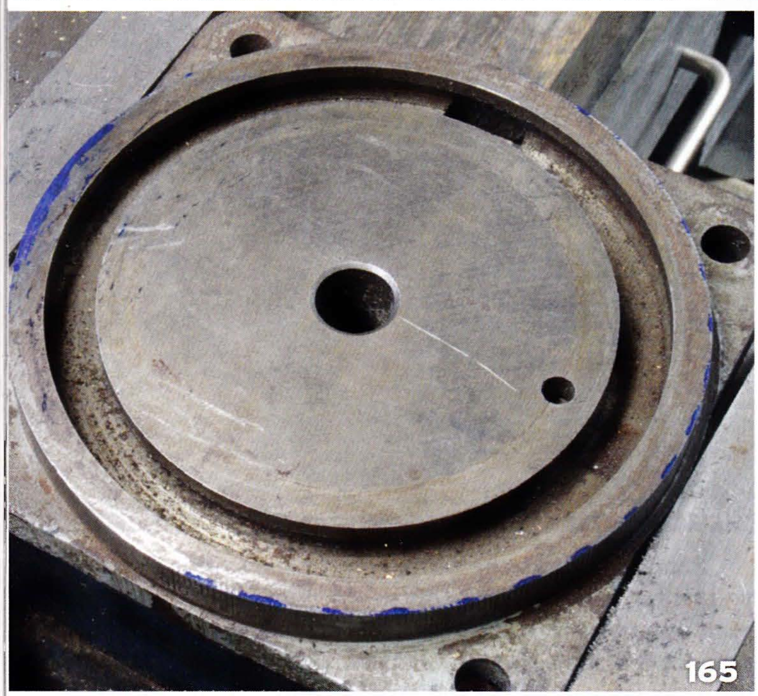
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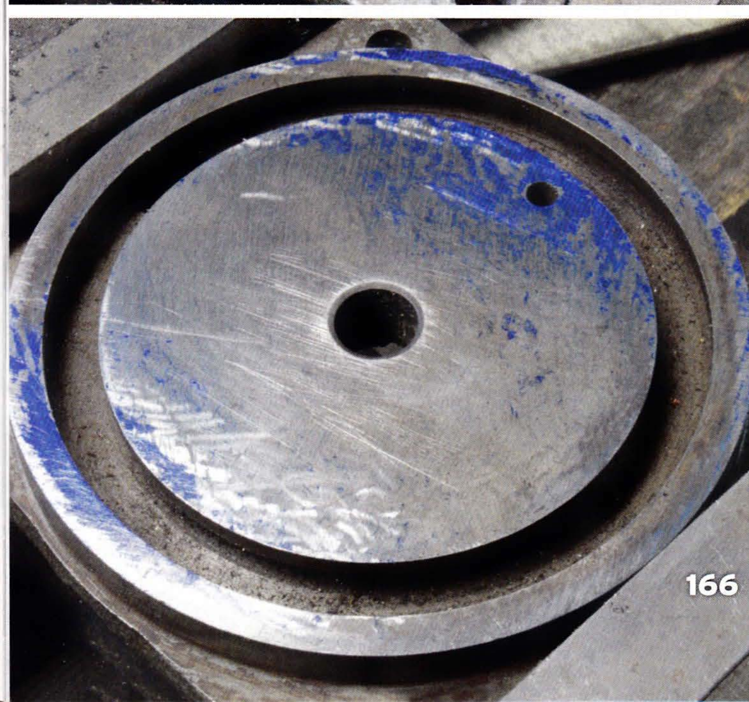
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not flat, merely bolting it down will distort it, potentially affecting accuracy and, as the vise is subjected to cutting forces, areas not in contact can deflect, creating a less rigid machining setup.

Work starts on the bottom. I'm using a fairly thick layer of blue on the surface plate, as this stage involves the wholesale removal of material. I found the pattern of contact interesting. I did not have the chance to run this shaper prior to working on the vise and I wonder whether the now flat face creates any discernible increase in rigidity.

Work continues in Photo 164. Keep scraping the base until you achieve the level of bearing you want. I would suggest that as a stationary object, a lower number of bearing points per square inch would be quite sufficient.

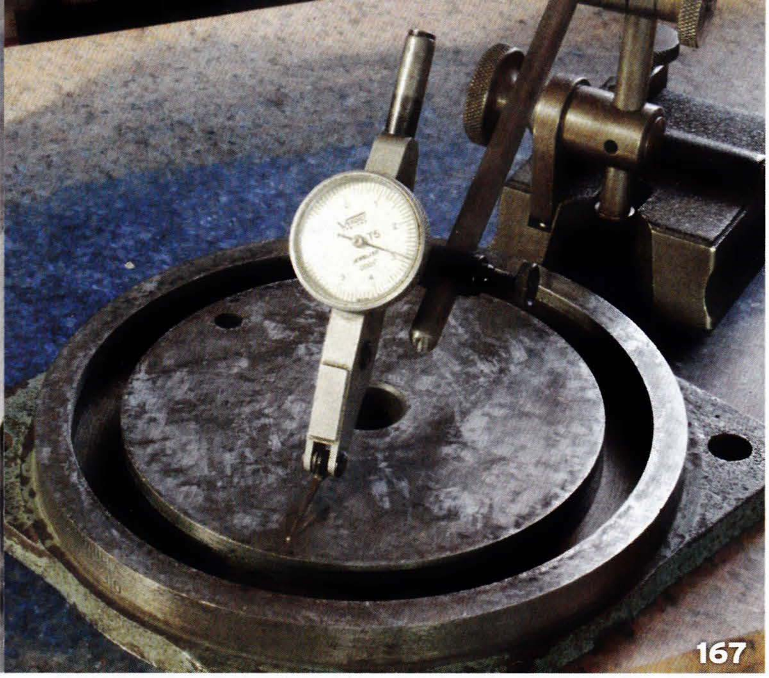
With the bottom scraped in, let's have a look at the top of the base (Photo 165). After being spotted to the surface plate, it's clear that the top of the base is also far from flat. Start scraping until you begin to approach a uniform bearing surface. Particular care is needed along the edges. As they are at the extremities, these regions are important in load carrying. This is tricky because of the amount of edge on this piece. Scraping tends to eat away at the edges if you are not careful. When encountering a job like this, be careful and try to have the scraper approach the edge on a diagonal.

There's still a lot of work to do here before it's flat (Photo 166). Keep scraping until you get it such that spots all over the bearing areas are starting to come in.

The scraped surfaces should be fairly close to being in the same plane to start with. I like to use a sensitive indicator and a surface plate to monitor whether the second surface is parallel to the bottom (Photo 167). A few spot checks with a micrometer will also do, but I like the visibility that moving an indicator across the surface provides.

If they're not parallel, and they are unlikely to be perfect, we need to focus our scraping to bring the high side down. This is an iterative process: scrape, deburr,

(Continued on page 52)



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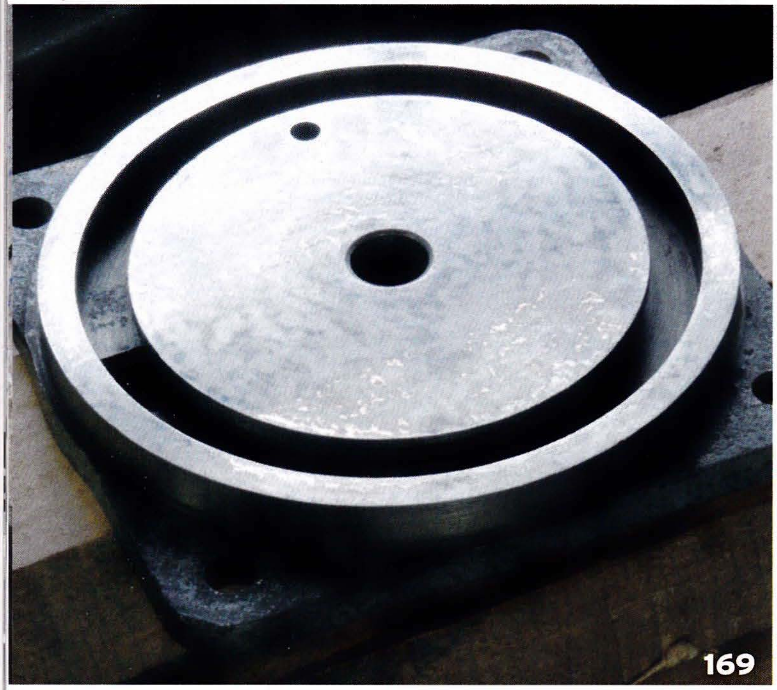

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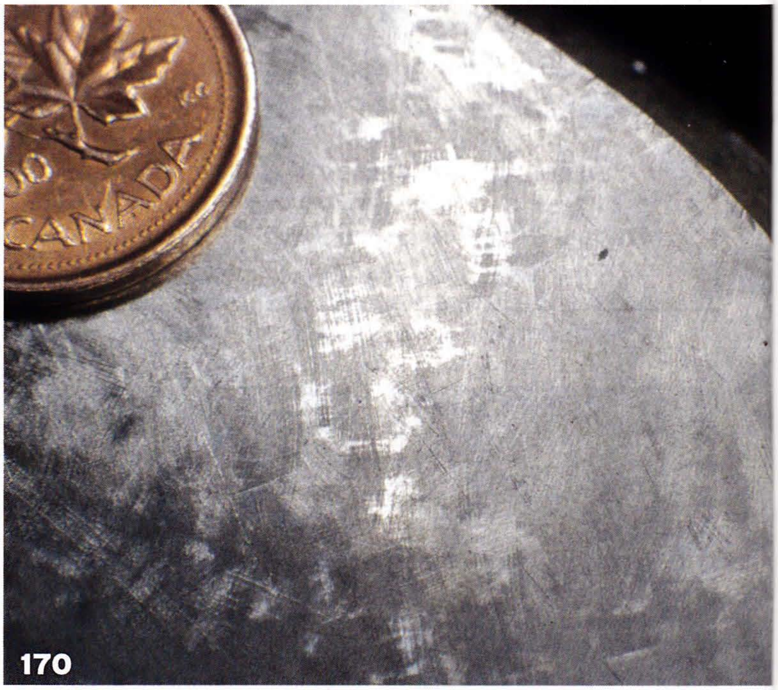

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check for parallelism, and repeat. Keep in mind that both surfaces will end up flat as they're scraped to the surface plate and they will be parallel if each is flat and if each is equidistance when checked along two axes.

Photo 168 shows things almost done. With care, you will be able to bring the second surface very flat and parallel to the first.

In some of these photos, I am altering positions trying to get different lighting on the surface. In Photo 169 you can see some of the shiny spots where the light is hitting the work at a certain angle. These spots are the high spots that have been slightly polished through deburring with the Arkansas stone. A well scraped surface seems to sparkle as movement makes different points reflect, an effect that is lost in a still photo.

Photo 170 is a close up shot, with the light showing a band of bearing surfaces. This is, in my opinion, more


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than adequate bearing as the work is neither an instrument or moving. However, if one was pursuing a high caliber of work, the bearing points would be smaller and more numerous.

Next, we scrape the top half of the vise that mates with the base. This piece has a pin in the middle, making using a surface plate as a reference impossible; it didn't look easily removable. Faced with this situation, we can use the already scraped mating part as the reference and scrape one to the other (Photo 171).

This piece also has surfaces that must be kept parallel – the bottom and the two vise ways. As the vise ways are the larger surface, I chose them as my starting point and planned to scrape the bottom in parallel to them.

The two vise ways were already quite flat and seemed to be induction hardened. Minimal scraping, really just a cleanup, was required. Thank goodness, as scraping hardened cast iron is possible, but much more difficult.

Given how warped the vise base was, I anticipated more woes with the top of the vise and smeared a thick coat of blue onto the bottom of the vise (Photo 171). Apparently, the top wasn't in as poor of condition as I thought, proven by the fact that my thick coat of blue completely spotted the mating part, revealing no useful information. After removing the blue and starting with a thinner coat, the round bottom of the vise was quickly scraped to a good bearing contact with the vise base.

As we are again creating parallel surfaces on this part, keep checking that the vise bottom is parallel to the vise ways by indicating as shown in Photo 172. With the bottom of the vise spotted in to the base, and the ways parallel to the bottom, the last job is to scrape the fixed jaw square to the ways. First, I did a quick double check that the ways were parallel (Photo 173).

The next step is to check for squareness. This is done exactly like we check for flatness, but a square reference is used instead of the surface plate. Photo 174 shows the results of the first check for squareness. I used a hardened toolmaker's cube I'd ground to a very

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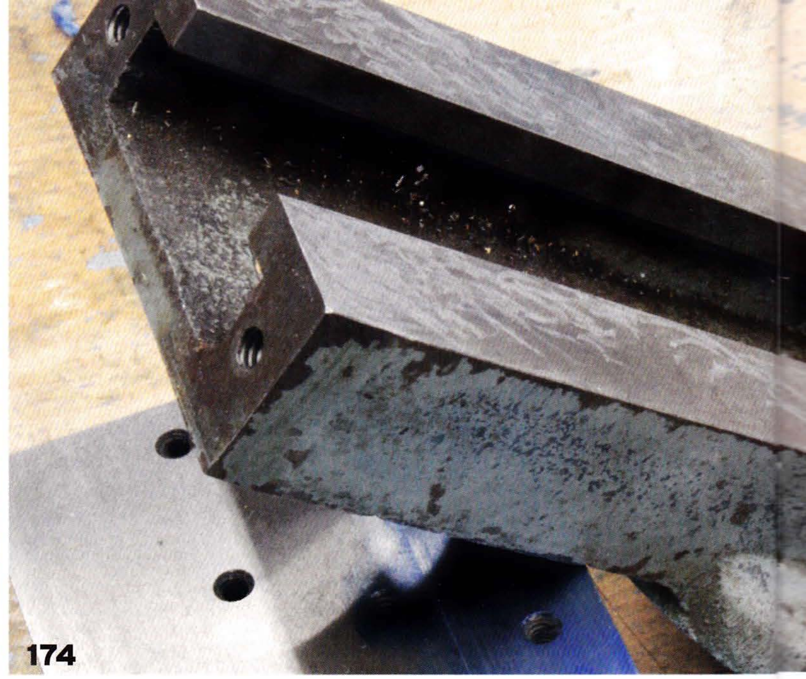

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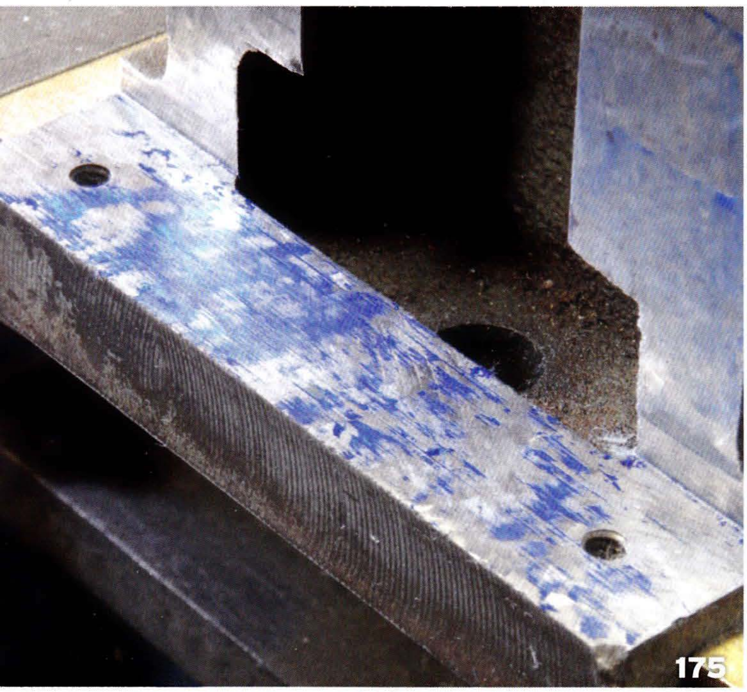

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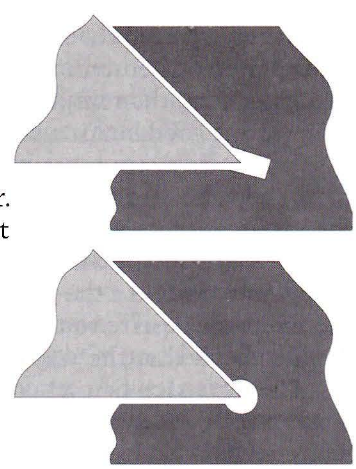
high degree of accuracy, to a tenth of a thousandth over 6", or at least that's what I can measure with my certified bevel edge square and best tenths indicator. It's a very accurate reference, but not the best choice, as a ground surface doesn't hold the blue very well. In any event, it worked well enough. Essentially, one face of the cube is blued. An adjacent side is held against the ways while the blued face contacts the fixed jaw. The photo shows the fixed jaw is out a little bit.

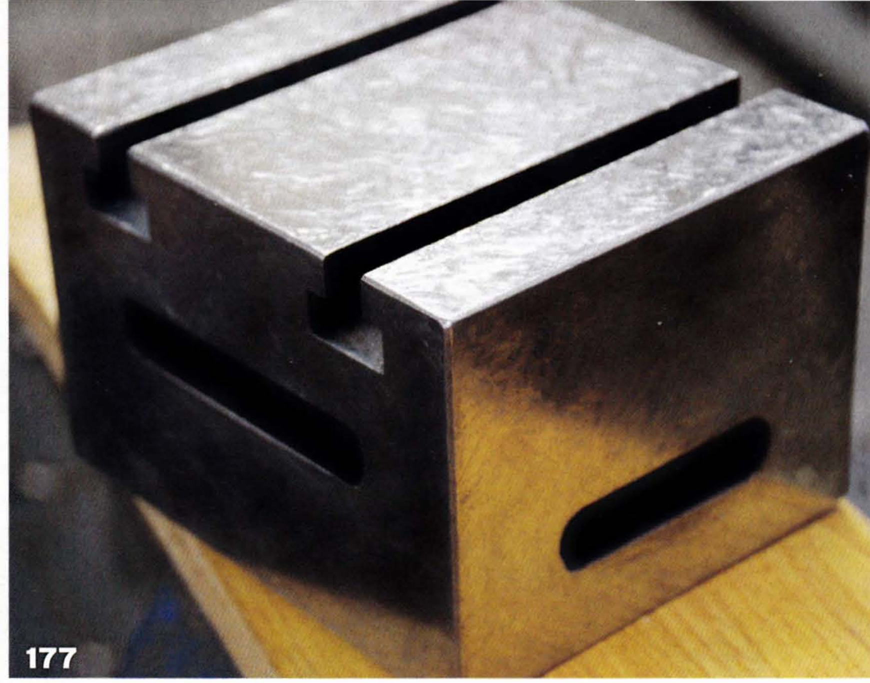
If your tool kit lacks the super square reference cube I used, don't dismay. An upcoming project will take care of that where we'll learn how to square two surfaces to each other to a very high level of accuracy. Photo 175 shows the scraping progressing while the vise is held in the bench vise. A carbide scraper with a straight end (no curve) is particularly handy at getting into the corner.

Corners are tricky to scrape to. Fortunately, we don't often have to because sharp interior corners are a poor design feature and ideally shouldn't be used, especially where parts are subjected to some stress. In an earlier article, we looked at how interior corners are stress risers (*The Home Shop Machinist*, July/August, 2011) and the same principle applies here. A better design would have been a 45° chamfer on the hardened bolt-on jaw and a less sharp, or rounded corner. I momentarily thought about running a ball end mill down the sharp corner to create a round relief grove (Figure 9) but concluded I was tilting at windmills. I've not heard of one breaking before, so I left it as originally designed.



Relief Grooves
Figure 9

In this instance, the



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ground jaw that bolts in place has a slight chamfer which will clear any irregularities deep into the corner. Were this not the case and the two surfaces had to provide support for a sharp cornered mating piece, the corner must be relieved. A small groove should be cut into the corner, very similar to how a V-block has a groove at its bottom, such that the two perpendicular faces don't actually meet. If you are faced with this challenge, the groove can be created by using a short length of hack saw blade at about a 45° angle to one of the faces...and lots of patience.

Photo 176 shows the completed, and perfectly square, vise jaw. With some freshly ground and hardened jaws, this little vise will be better than when it came out of the factory.

TOOL MAKING: A PRECISION TOOLMAKER'S CUBE

So far, we've tuned up some tools, used scraping to create datum surfaces on some irregular parts, and done some good work rebuilding a nice old shaper swivel vise. Let's move into the next area where scraping can bring incredible capacities to the home shop: precision tool making.

I say "incredible capacities" because with this very simple and basic hand tool technique, we can create flatness, squareness, and parallelism in the home shop to levels of accuracy that would rival, or even surpass, that turned out by surface grinding equipment. This opens up new possibilities in the realm of home shop precision tool making – a task that requires high degrees of flatness, squareness, and parallelism.

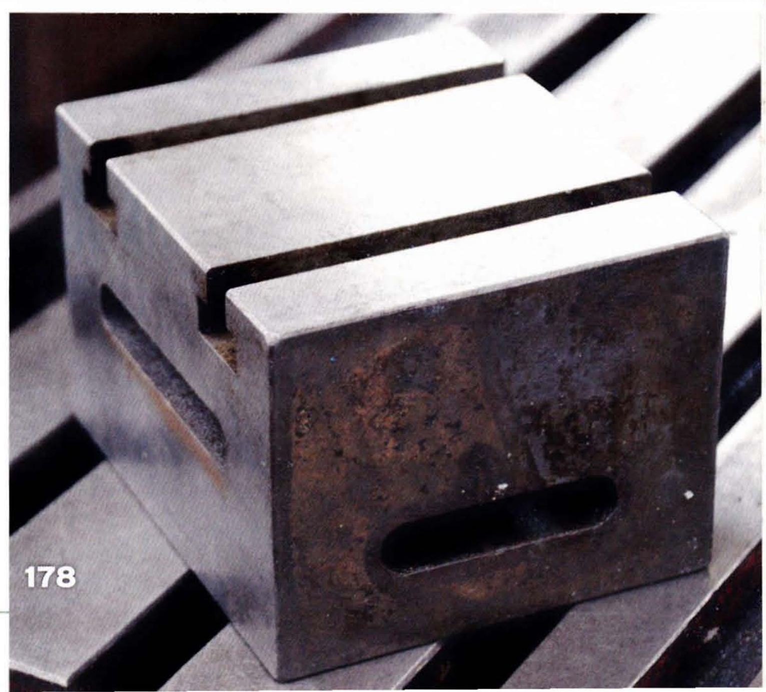
For several hundred dollars, you can purchase a ground toolmaker's cube that won't be as accurate as what you can scrape. You can spend another hundred and something for a precision square from one of the big brands, but it won't be squarer than what you can scrape. Empowering isn't it – that such simple techniques permit such high-end work to be done?

To anchor these braggart claims, let's work through making a master toolmaker's cube. Photo 177 shows an Eclipse cube I obtained and scraped to a tenth of a thousandth of an inch, square and parallel all over. Having that accuracy is valuable as it becomes a very accurate inspection device or spotting tool, or a reliable grinding fixture.

You already know how to get something flat and parallel; with this project we're going to add getting things square without the use of a reference square.

Eclipse is a quality English maker of tools, and while I can't guess at the age of these cubes, my suspicion is that they are well seasoned. For a project like this, we ideally want a stable cast iron cube. Several catalog houses sell machined versions (versus ground versions) that would make a good starting point for a scraping project.

Mine arrived as shown in Photo 178. It had a bit of rust and was rough around the edges, but overall, it was fairly accurate. It came out of a jig boring shop. If you know jig boring, you know it's where very high caliber work is done. They would have reground something



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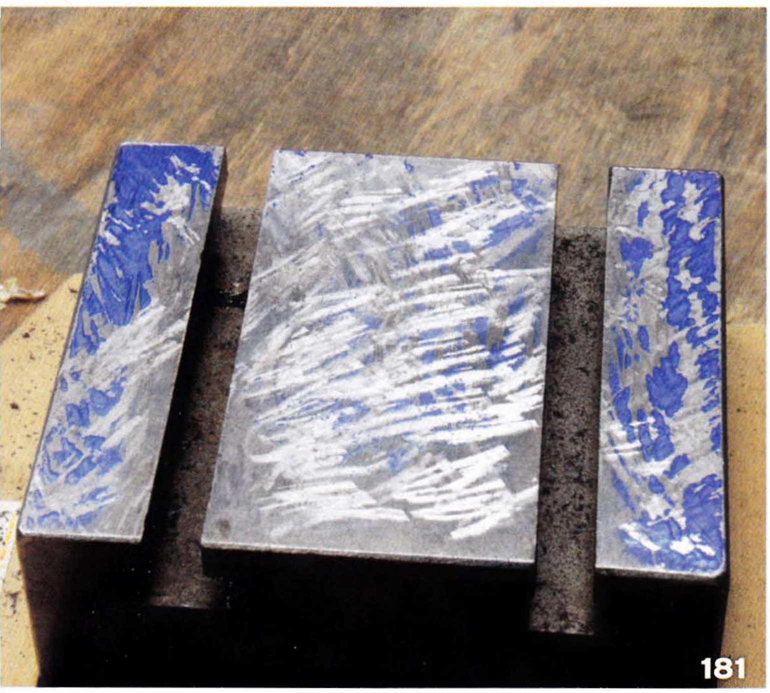

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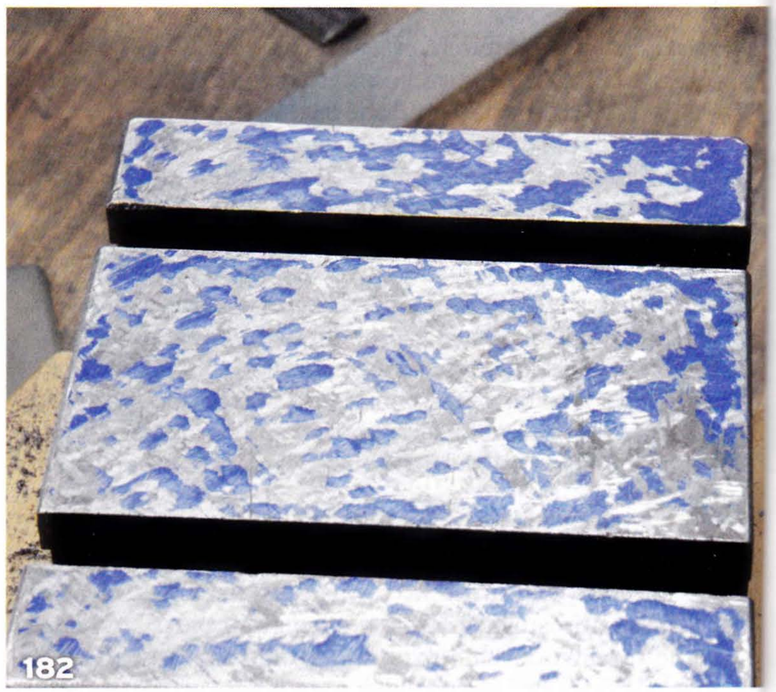

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like this cube from time to time to keep it near perfect. Still, we'll improve upon it.

Photo 179 shows the first spotting. We've got some work to do. Let's call this surface side "A." Start roughing side A, as per Photos 180 and 181. Looking back on these photos, I could be critical in that the spotting pattern present in Photo 179 suggests roughing, using overlapping diagonal passes done in zones, might be a better approach. It might well be.

Two thoughts on that; first, you end up in the same place. The zone roughing approach can be more efficient, but it doesn't make things more flat. Secondly, this block came out of a jig boring shop where it would have regularly touched up on a grinder so I was expecting it to be quite close and not really require much roughing. As you'll see, our scraping efforts will improve upon the last grind done on it. However, material removal was minimal enough that my scrape the blue approach versus


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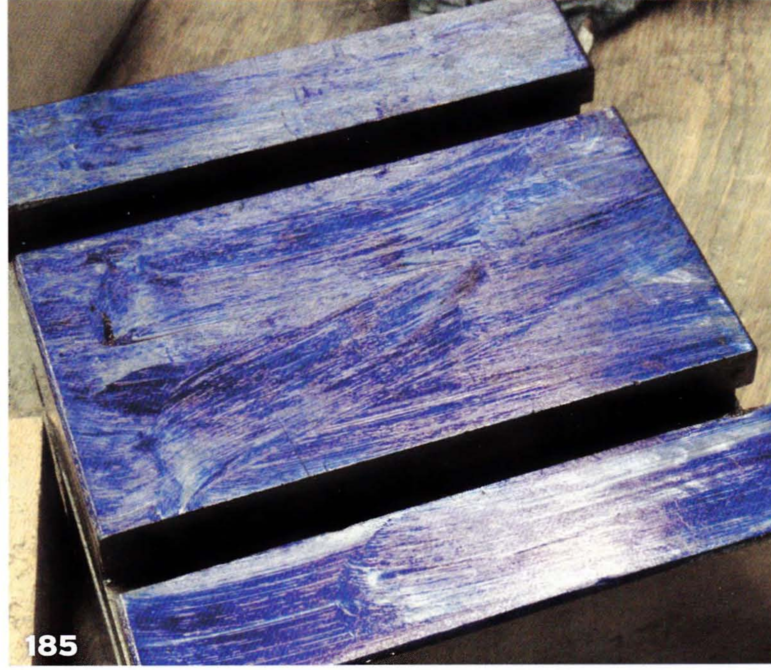
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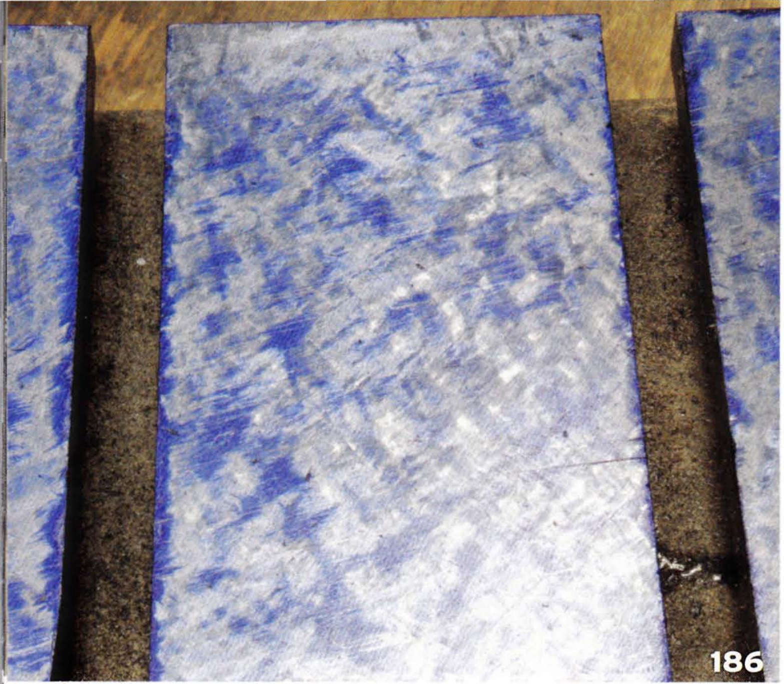
cross-hatch rough was okay in this project.

Work from different directions until there is complete coverage. Note the Jorgenson clamp holding the work, which is itself clamped to the bench. This mount is solid and lowers the work height substantially from the bench vise height, which is much more comfortable for scraping.

I'll start finishing after achieving the results seen in Photo 182, as there is coverage over most of the surface. Photo 183 shows a small Arkansas stone being used to deburr and Photo 184 shows individual bearing points. Look inside the blue areas for the gray, or shiny areas – these are visible toward the center of the block in this photo. These are the high points that penetrated through the blue to make contact with the reference surface plate.

Maybe it's just that my eyes fatigue after scraping for a while, but it is sometimes helpful to switch up from bluing the reference to bluing the work as the surface approaches completion (Photo 185). After rubbing the blued work on a plate, the high spots jump out as shiny points (Photo 186).

When sufficient bearing points are present, we'll turn our attention to the side opposite of side A,



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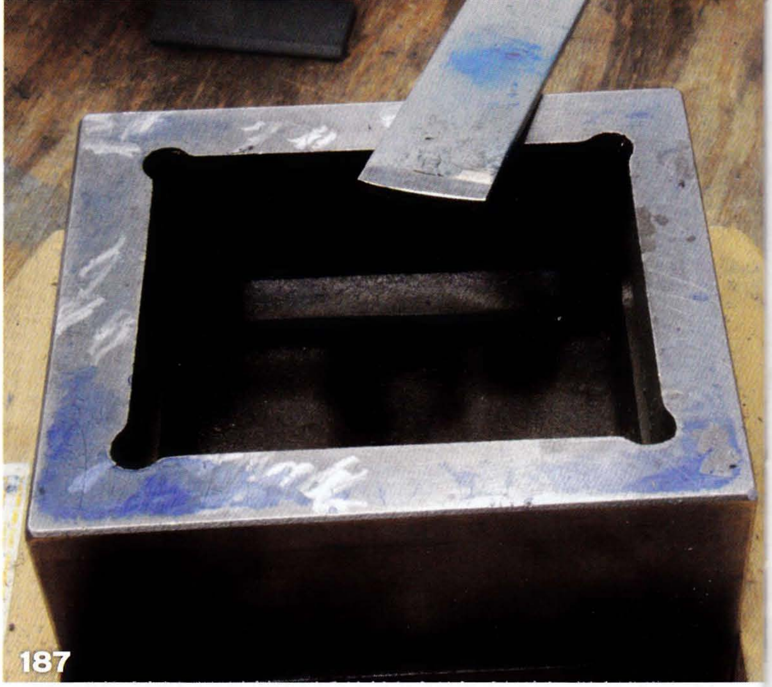

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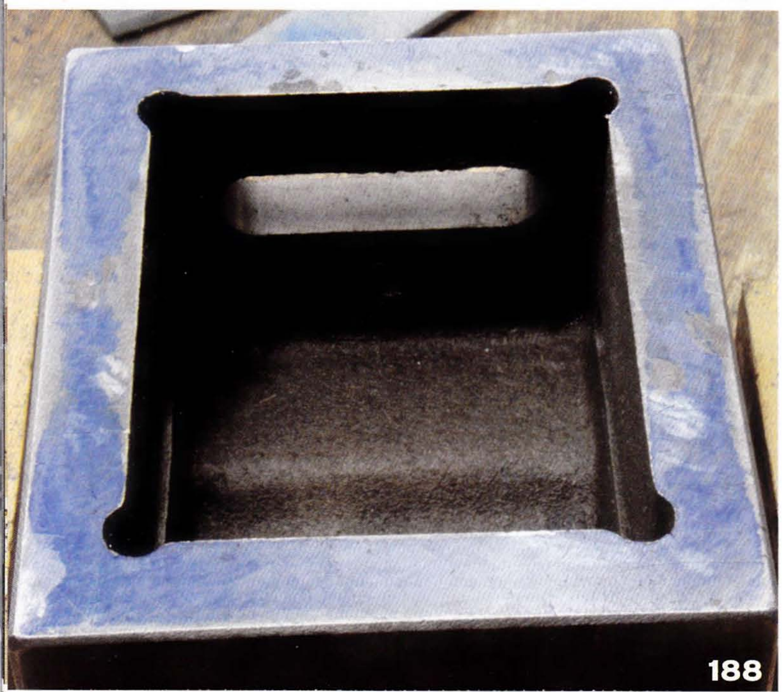

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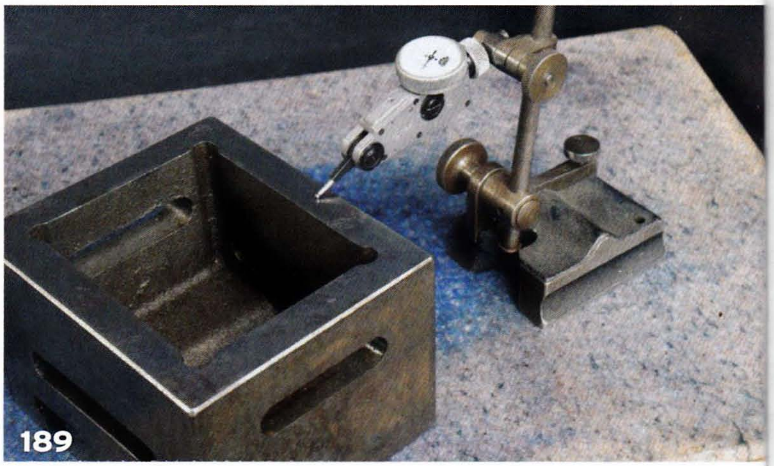

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and we'll call it side "B," as shown in Photo 187. It's no accident that it's the side with the least surface area, hence, requiring the least scraping. Getting side A flat, then getting the smaller area of side B parallel to it, is the quickest route to establishing two parallel surfaces.

In the first look at side B, it looks as though there's some work to do with not much of the area bearing. That proved to be a false alarm. After reducing what proved to be a few high spots from the first pass, we get a very even bearing surface, shown in Photo 188. The take away is to start with a light blue spotting to see where things are at and study what's going on!

Next, it's to the surface plate to get sides A and B perfectly parallel, which we now know how to do (Photo 189). Scrape B to the surface plate such that we get the same indicator readings on each edge.

Now select a third face, any one will do, and call it side "C." It will, of course, connect sides A and B. We're going to scrape side C flat; however, first check side C's squareness to either A or B using a precision square. If it is significantly out, machine side C so that it is milling machine square – in other words, good but not perfect. While we could get things perfect without milling, grinding, or using a square, if there are several thousandths to remove, it's better to avoid doing so via scraping.

Now, scrape it flat. As shown in Photos 190 and 191, this side required the most work of the three. You can see I'm keeping the blue quite thick until roughing creates bearing spots over the entire surface. Work away until our scraping has almost covered the surface, then introduce squareness checks into the process.

The next task is to get side C square to both sides A and B. There is a neat way to accomplish this by using an indicator on a height gauge, or some form of mast, where the bottom of the mast is allowed to contact the work.

Consider Figure 10. From our work so far, we know side C is flat and sides A and B are both flat and parallel to each other. Therefore, if either A or B are not square to C (and they're unlikely to be), the other is going to out of square by an equal amount, but in the opposite direction. This stands to reason, since sides A, B, and C

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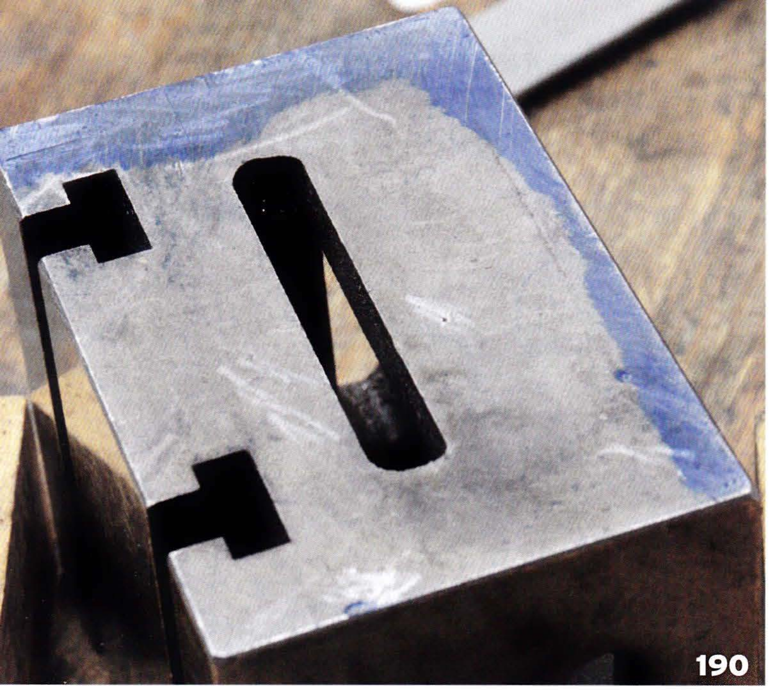
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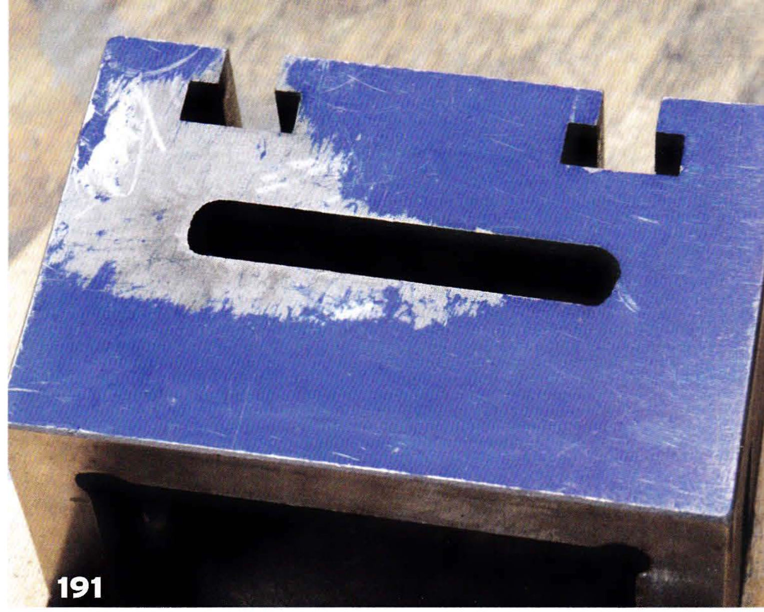
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form 3/4 of a parallelogram. The angle formed by A and C must be equal to 180° - angle C and B.

Our surface gauge was made with knowledge of this little geometrical gem and comes equipped with just the right accessory to use this relationship to measure squareness. By using that sphere on the bottom of the

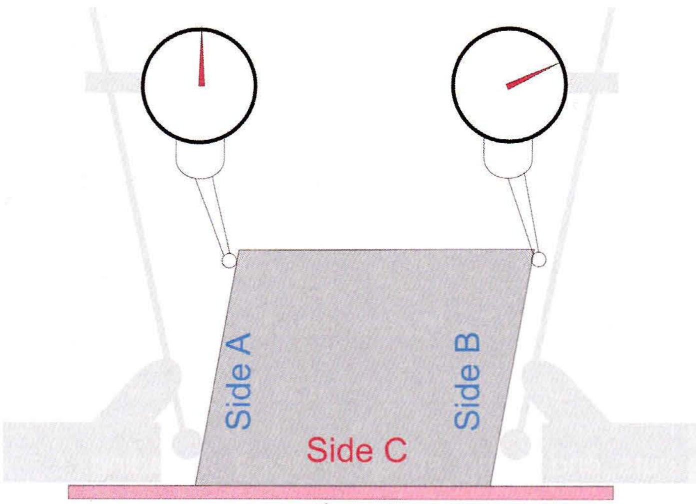


Figure 10

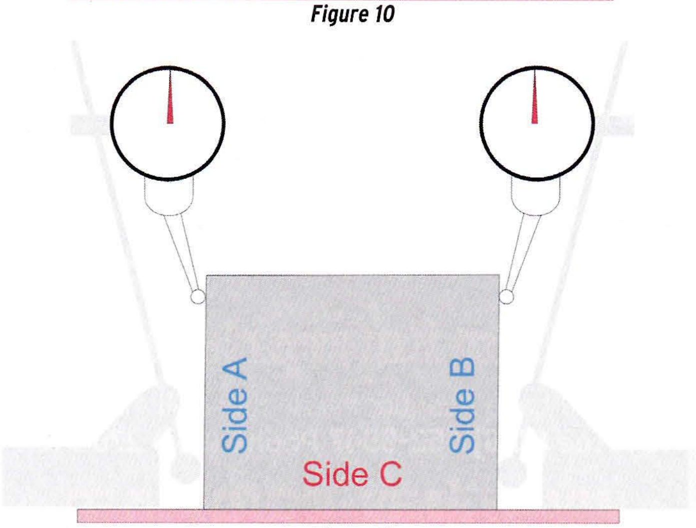
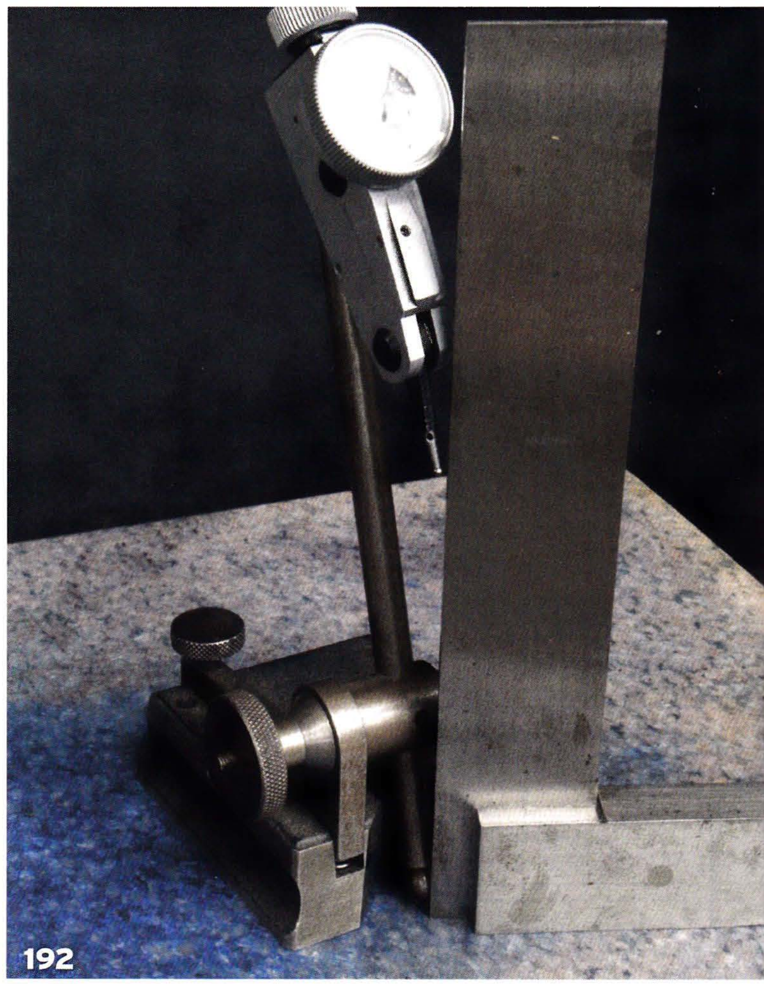


Figure 11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mast (that maybe you've noticed and wondered about) we can bring the base of the gauge into contact with the work. With an indicator touch at the top, we can then detect any variance in a plane touching both the mast's sphere and the indicator point. Another approach is to grind a flat on the front of the surface gauge to make contact with the work.

Figures 10 and 11 attempt to show how square is found. The ball at the base of the mast keeps the mast and indicator a set distance from the block at the elevation of the ball. If the sides are perfectly vertical to the surface

(Continued on page 62)

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plate, meaning they are square, the indicator reading will be identical on both sides.

Photo 192 shows a square being used to set up the surface gauge. I'm simply trying to get the master sphere and point of the indicator lying in approximately the same vertical line. The square was just a convenient way to do so – this is eyeball work, no great precision required.

Bring the sphere into contact with the work, near the bottom, like is shown in Photo 193. Adjust the position of the indicator such that it is picking up the same surface toward the top of the work (Photo 194).

As shown in Figure 10, check each side. The surface gauge is rotated with the ball in contact and the highest reading noted for each side. The amount each side is out is 1/2 of the total indicator needle difference between the two sides.

Don't touch sides A or B, just scrape side C, concentrating material removal to bring the indicator needle movement to zero as shown in Figure 11. For example, in Figure 10, you would concentrate the scraping toward the left hand side of side C.

As we did when scraping for parallelism, we have to keep side C flat as we bring things in line, which is an iterative process; keep checking with the indicator setup between scraping cycles.

Photo 195 shows side C being finished up. Concentrate on removing the individual high spots until you are getting evenly spaced points of contact across the work. Obviously, the higher the density of points (using a very thinned amount of blue), the better the class of work. No, I'm not that pale, I'm wearing latex gloves. These are handy, especially for scraping, where despite best efforts, the blue gets all over things and is difficult to wash up.

As shown in Photo 196, pick one of the two parallel sides we haven't touched yet and rough it in. Our process for checking squareness is slightly easier now (Photo 197). When we get sides A and B square to side C, as shown in Figure 11, we can place the indicator and height gauge against either side A or B and record the needle's reading (if things are square, they should be the

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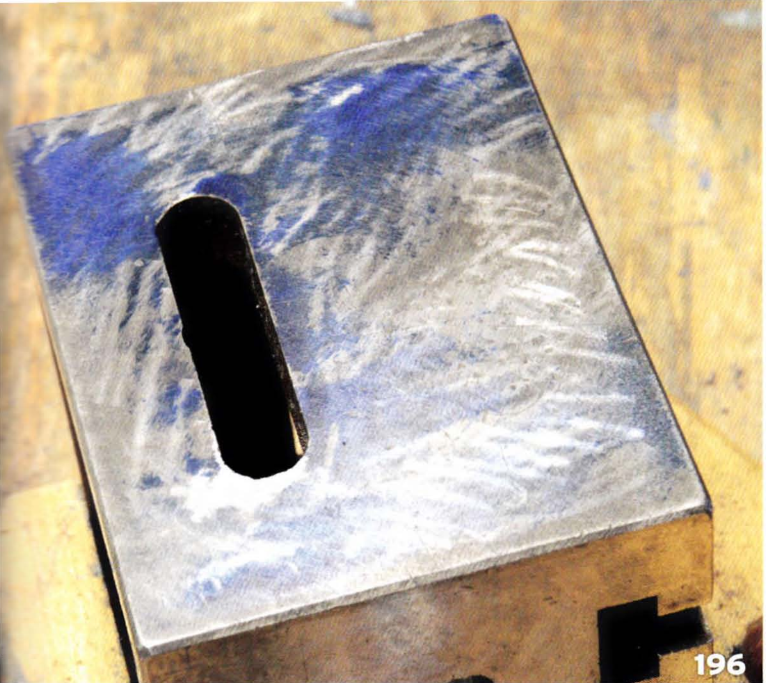


same reading on either). Note the reading.

The indicator setup on the surface gauge can now be used to check squareness on any work piece. Simply bring the indicator and the mast's sphere to bear and the deviance from the noted reading indicates how out of square things are. Note that the reading is an indication, not necessarily an exact amount. As when using a dial test indicator, the nominal reading will differ depending on the angle of the probe.

Scraping on this side is done in the same manner, except the iterative checking for squareness and flatness is compounded as we are now checking for squareness between two surfaces, sides C and A (or B). No problem for us with our rapidly developing scraping skills!

The last step is to scrape in the remaining two sides. I find the easiest way to do this is to scrape them as parallel faces. In other words, scrape them by placing the side parallel to it on the plate and use the indicator on top to check for parallelism.

Photo 198 shows the finished tool makers cube. The very accurate cube is a useful addition to your kit. It can be used as fixture tooling on the mill, or perhaps more appropriately, given how much work we've put into it, as a precision grinding fixture and a surface plate inspection tool and square.

Another very useful application of the cube is as a spotting tool for scraping. You can take all those inexpensive angle plates and in short order, scrape them perfectly flat and to 90°.

HOW TO GRIND SQUARE

Just because we're on the topic of achieving precision squareness, I thought I'd include a little on how it's done with the grinder. Most would assume you'd load the work in a grinding vise or bolt it to an angle plate, and it commonly is. However, both of these options rely on the accuracy of the existing tool, which might not be as accurate as the result you are trying to achieve. This also doesn't account for the challenges of gravity and the magnetic chuck on heavy work such as the ground block.

There is an interesting trick to grinding square, using only the magnetic chuck, that I've tried to describe in Figure 12.

Starting with a block of steel not square or parallel, grind two opposing sides. On the surface plate, using a master precision square and tenths indicator, measure how out of square a side (side C for example) is to sides A and B. I probably should have drawn it with the indicator technique described earlier since it is an excellent way to check squareness and carries the advantage that no master square is required, but the square is easier to draw!

Now here's the neat bit. Return the work to the grinder and place side C on the mag chuck. First, grind all of side D flat except a tiny land next to side B. You have to calculate this depth based on the out-of-squareness measurement. For example, if you used a 6" square, the error is over 6". If you're grinding a 4" block, the error over 4" is 2/3 of that measured over 6". Now flip the block over and grind C flat. Because of the land we left, C will be square to sides A and B! Flip it over, finish grinding, and sides A, B, C, and D, are square and parallel. The process is repeated to get the last two sides square.

Neat isn't it? I included this as it's not information you see everywhere and it gives some appreciation that grinding things perfectly square to a tenth or so is not trivial. Grinding work to that level of precision takes a bit of thought and attention to detail just like scraping. Just make sure that you "block in" the work on the magnetic chuck, as the holding power will be reduced when side D is on the chuck.

Next up, we'll make ourselves a set of matched V-blocks.

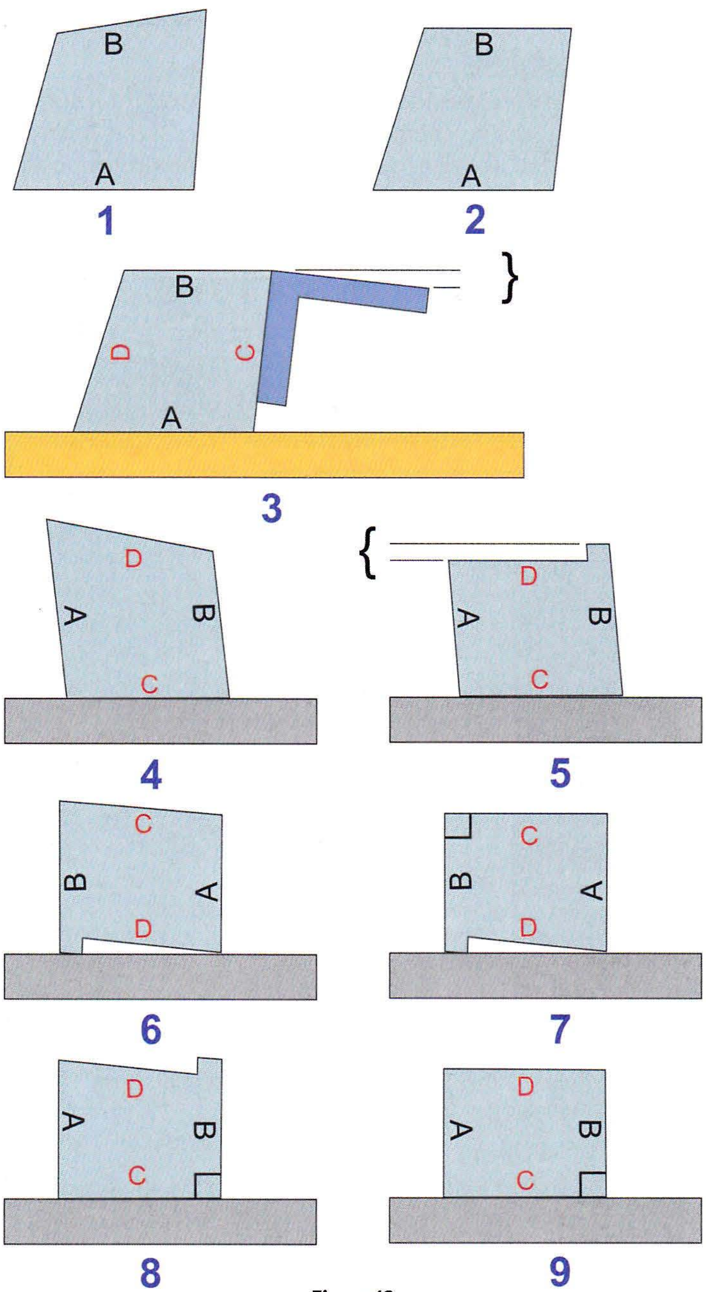
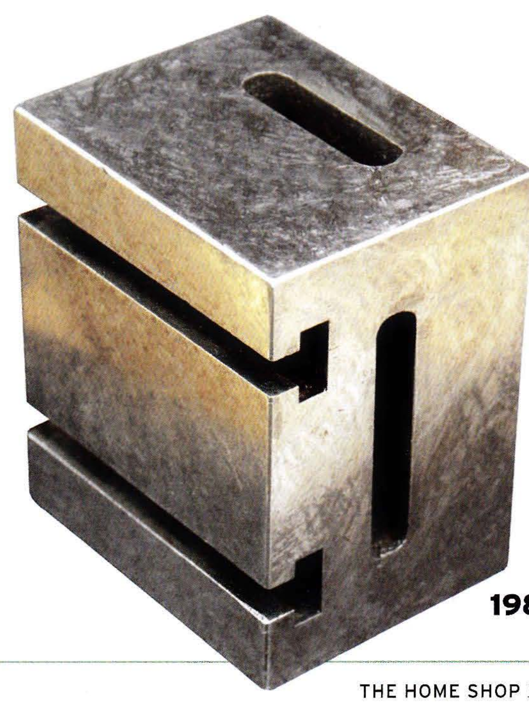


Figure 12

Photos and drawings by Author



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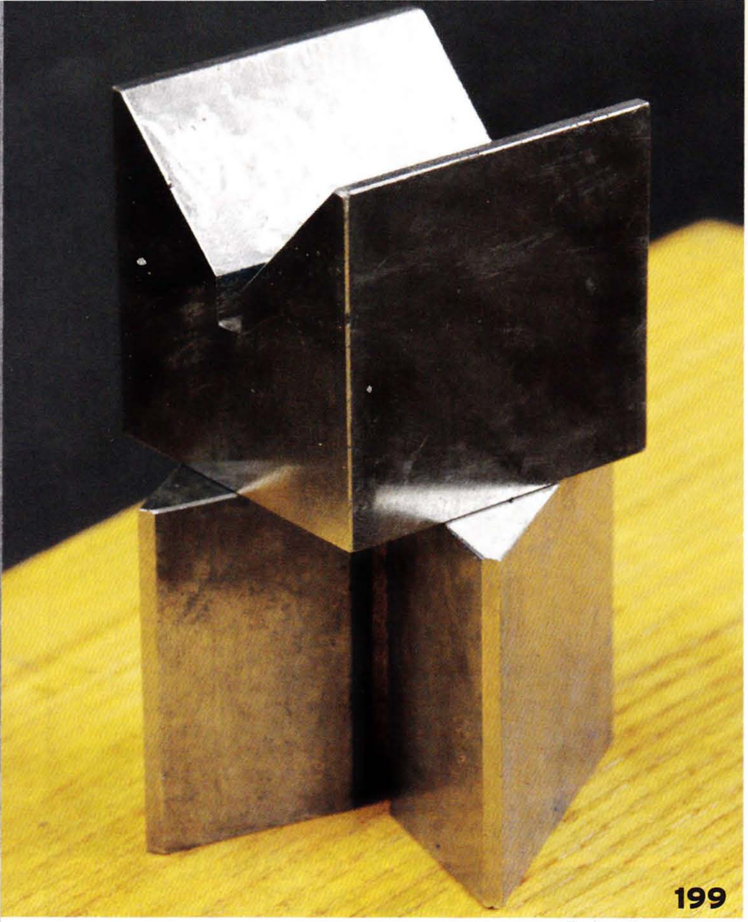
SCRAPING for the Home Shop

Part Seven

BY MICHAEL WARD



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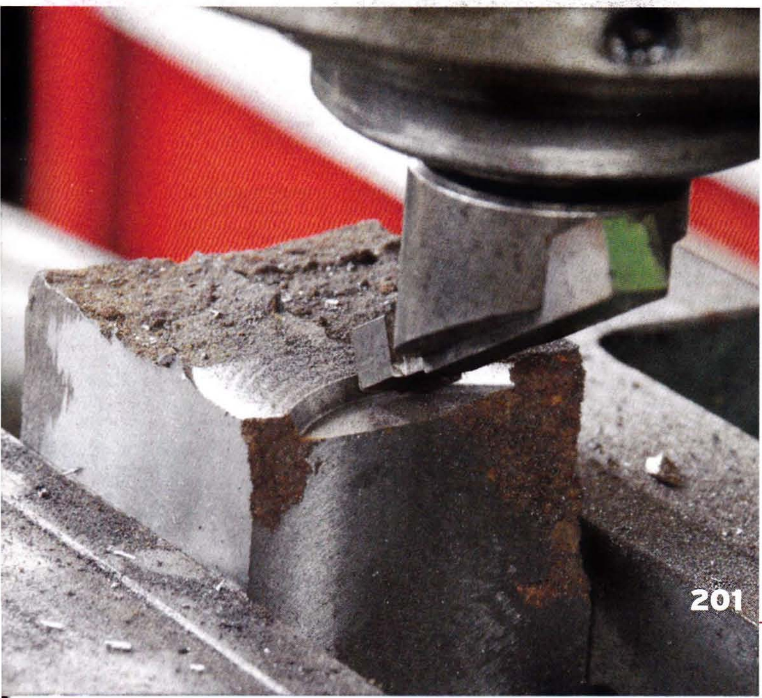
A MATCHED SET OF V-BLOCKS

One of the many projects I had going on when writing this article was the scraping of the ways on a tool and cutter grinder; it will make an appearance in due course. This particular machine has 90° V-ways. When scraping something like that, we need both male and female angle spotting tools.

Like most enthusiasts who have been at it a few years, I have various V-blocks in the tool chest; however, none were quite right for this job. Ground surfaces just don't work as well for spotting and I needed the depth of the V to be the same as the height of the V-ways. A matched set was needed that fit the V-ways ***(Photo 199)***. The reason why will present itself when we look at scraping V-ways in a little bit.

The ideal material to use is cast iron. I had a mystery piece that had one surface so rough it looked like it was leftover from a spill at the foundry ***(Photo 200)***. However, it was about the right size so I took a chance. I caught a break and ended up with a great piece of cast iron that was very easy to work – no chill spots, voids, or surprises.

I aggressively fly cut the pieces square ***(Photo 201)***. I should have used the more beastly horizontal mill (a recent and wonderful addition) but I'm short on sharp cutters (hence the rebuilding of the tool and cutter



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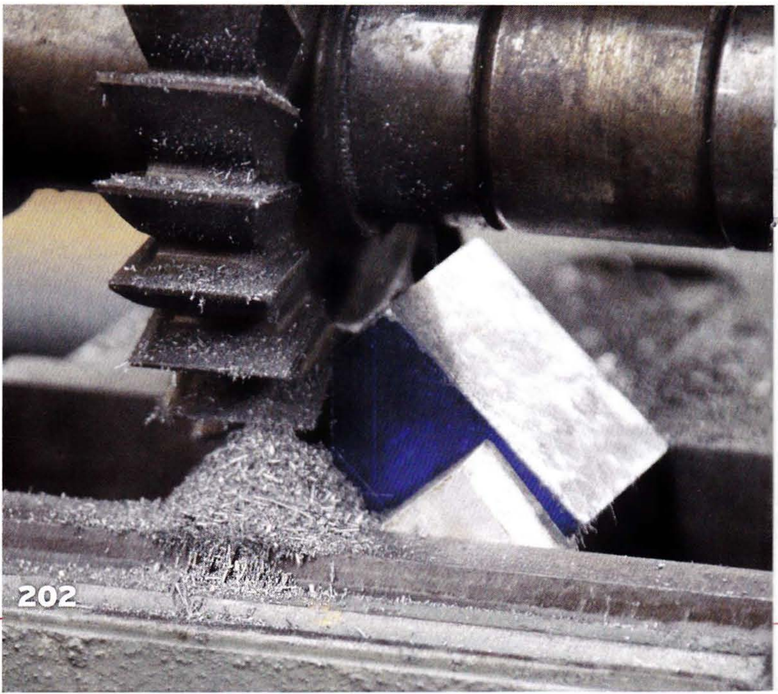

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grinder). I've come to the conclusion that every single thing I do in the shop is somehow connected to another project. I can't remember what started it but if I live long enough, one day I'll finish it, which will mean everything is all of a sudden done. At that point, I will stand there with a dumb look on my face not knowing what to do next.

After squaring the blocks, I cut the V and the bottom relief slot ***(Photos 202*** and ***203)***. I had an appropriate cutter that cut the V in one pass in the horizontal mill, followed by cutting the slot. In the photo, the block is resting on another V-block in the vise. You can do this in a vertical mill, it's just big cuts in a single pass on the new/old horizontal mill seemed like a lot more fun. By the way, the more carefully you have the vise aligned, the less work you will have when it comes to scraping the Vs straight.

Once finished on the mill, scrape three sides: A, B, and C square and parallel, as shown in ***Figure 13***. Use the technique we used on the toolmaker's cube to get A and C parallel. There is an added complication in that we want the dimension between A and C to be exactly the same for the two blocks.

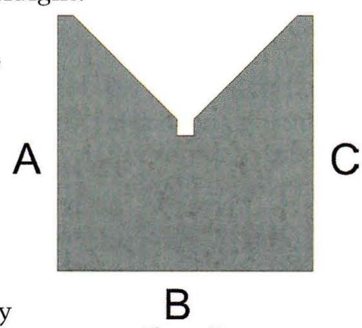


Figure 13

Measure the A to C distance of both blocks and scrape the smaller of the two until A and C are parallel. Next, take the second block and scrape side A flat. Using the indicator method, begin to scrape C flat and parallel to A, but also pay attention to the indicator needle reading. We want to bring C flat and parallel to A and end up with the same indicator reading as we had for the first block. Scraping to a dimension is not as hard as it sounds but you will need to get in the habit of indicating and measuring the surface constantly.

I zeroed a tenths indicator on the first block and was very careful to bring side C on the second block to the same zero reading over its surface. Trying to work to a tenth of a thousandth is quite challenging and a bit of dust or a chip from scraping caught between the block and surface plate will throw things off. I look at trying for a tenth as kind of a stretch goal; it's possible, although difficult. Besides, if we wind up with something that is very close to a tenth, it's still high quality work.

Get side B square either with the indicator, or easier still, by using a precision scraped square (like the cube) to spot it. With the block sitting on side A on the surface plate along with the cube, blue a side of the cube and spot B to it.

A precision V-block needs to have its V exactly in the center of the block and each side of the V needs to be exactly 45° to the V-block surfaces. There is an easy way to do this. As shown in ***Figure 14***, by holding the V-block in another V-block of known accuracy, we can scrape and indicate the V's surface. By swapping the block around so that the AB and the BC corners are alternately sitting in the base V-block and scraping each surface so they have a zero indicator reading, we can get the V as perfect as the V of the base V-block. That sounded much more difficult than it is!

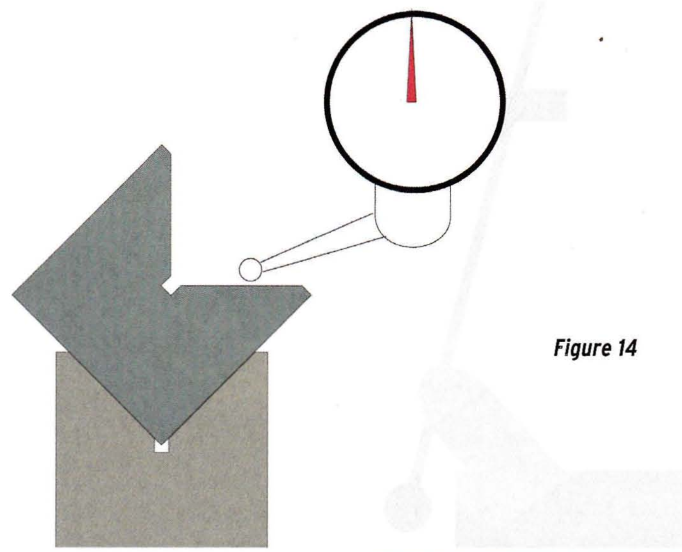
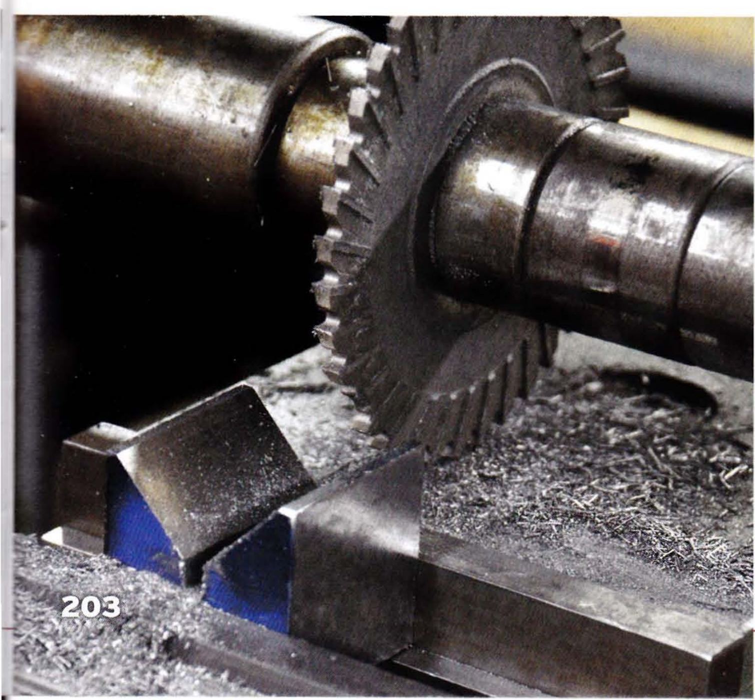
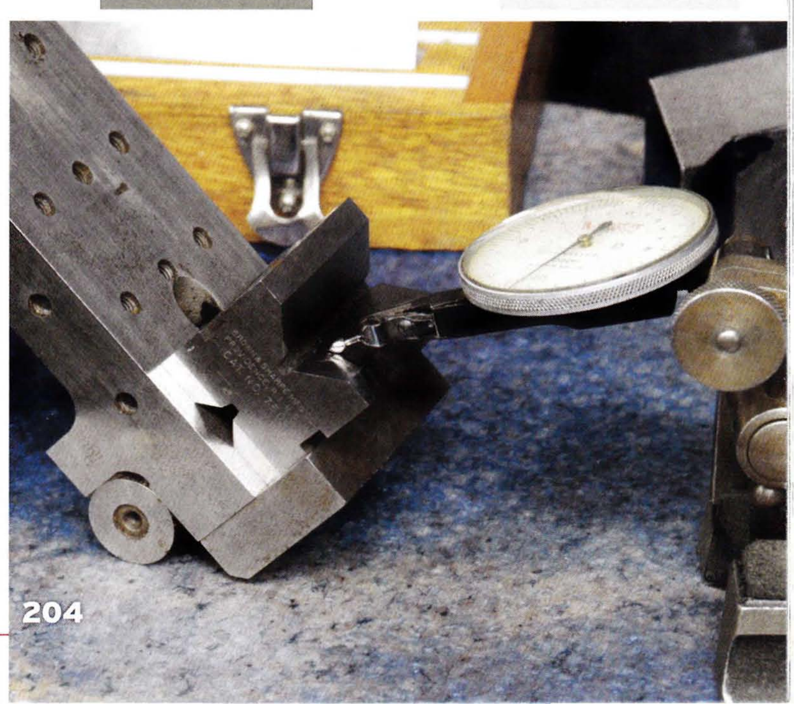


Figure 14

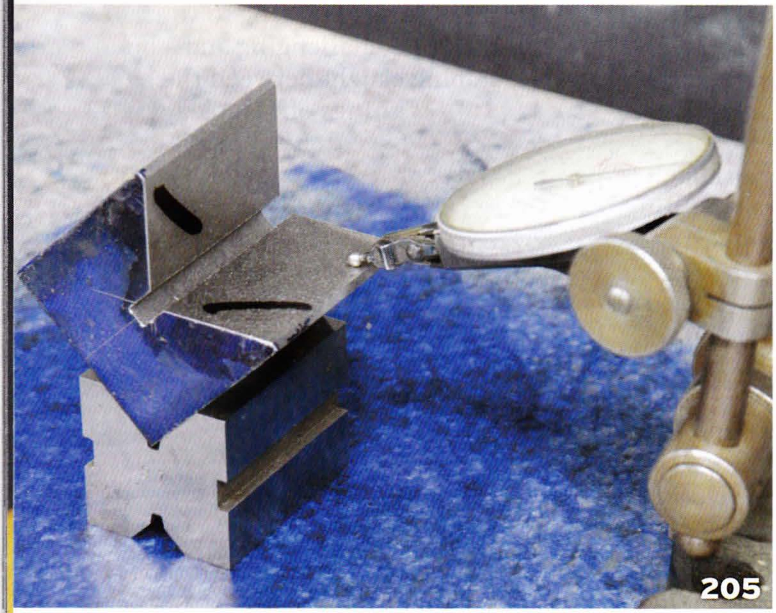




First off, we want to make sure our base V-block is accurate. ***Photo 204*** shows the setup using a sine bar and gauge blocks to do so. If your V-block is from a reputable manufacturer, a tenths indicator needle should barely move through this exercise. In fact, if you don't have gauge blocks and a sine bar, don't run out and acquire one on account of this test; a quality brand V-block should be accurate enough without the need to check with a sine plate. I just wanted to show how this test is done.

Incidentally, this test is also good to know in case you are scraping a V-block to an angle other than 90°. Why would you ever need a V-block that measures something other than 90°? Well, to scrape a V-way that is something other than 90°, that's why! We'll soon see that V-blocks are invaluable for scraping V-ways.

This is a time consuming process. All four V-surfaces on the two blocks have to be brought to the same indicator reading across their entire surfaces ***(Photo 205)***. When you get within a thousandth or two, use both spotting and a check with the indicator to determine where to remove material ***(Photos 206-208)***. The completed, matched set of V-blocks is seen in ***Photo 209***.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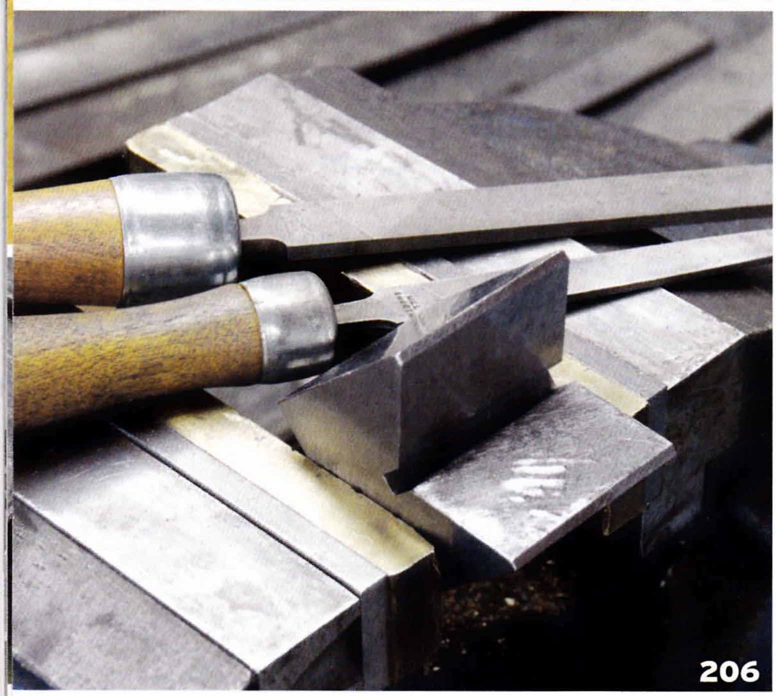
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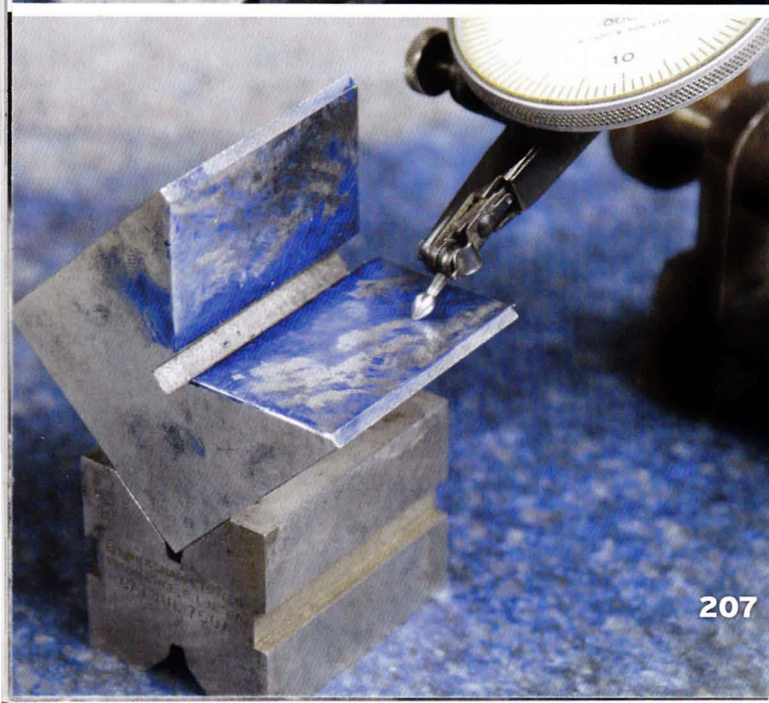
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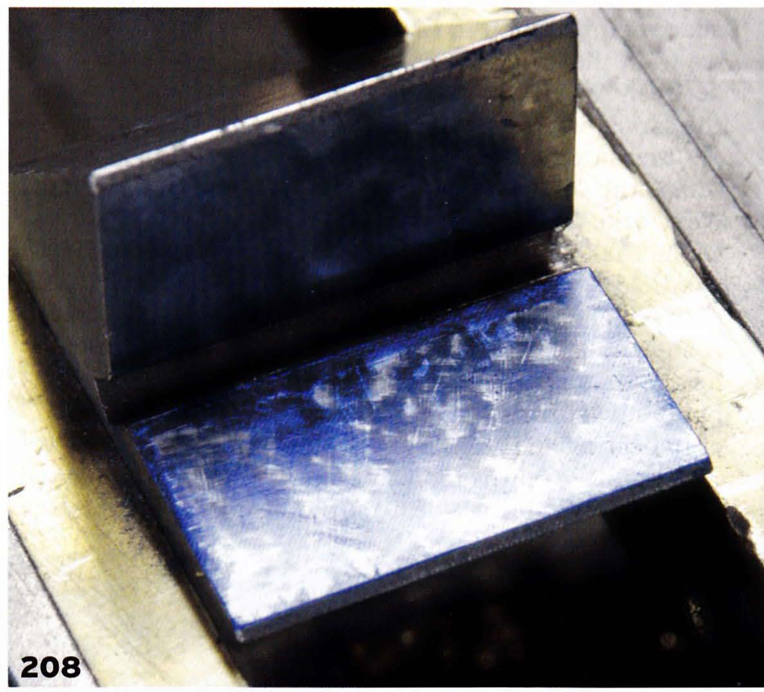
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(Continued on page 44)

SCRAPING MACHINE TOOLS

Fine tuning and reconditioning of machine tools is where many people's minds go when they think of scraping. After all, it seems to be the main application of scraping among professionals and holds a certain lore as we imagine the skill it takes to bring a behemoth jig borer to perfection using hand tools. It also might be the mind's path to the perfect workshop as we dream of shops equipped with all manner of high-end industrial tools, purchased for a song and beautifully restored by our own hands.

Scraping can do that for you; it can be an important part of assembling the ultimate shop for next to nothing. However, that enthusiasm should be tempered with the knowledge that scraping machine tools can be really, really difficult. It takes a very long time, is tedious in nature, and requires more equipment than you've collected so far. If done properly though, the results may well exceed the machine's performance when new.

I just finished scraping a portion of a lathe, the compound's dovetails shown early on in Part One of this series. It is amazing the difference this makes. A lathe, or any machine tool, is basically a bunch of infrastructure designed to provide movement while taking the forces imposed by the cutting tool. When the bearing surfaces are true and perfectly mating, the movement is straight and repeatable. It has the ability to take the applied cutting force with minimal flexing or movement. However, if one part of the bearing surface is only in contact at the ends, with a gap in the middle, its ability to take a load and not flex is severely impaired. Depending on the load, the piece will deflect more or less until it is in full contact. There goes accuracy, repeatability, and rigidity.

In fact, this is a basic test for a lathe: Make a light cut, then go over with a second pass. If the second is removing anything more than fuzz, then the bearing surfaces are a poor fit with the system of ways and the dovetails have lots of flex, as poorly mating parts are prone to have.

What makes machine tool conditioning so difficult is two things: First, the surface areas being scraped are generally quite a bit larger than the bench work we've done so far – each iteration takes longer and is more physically demanding. Second, and the far bigger challenge, is there are so many relationships between numerous surfaces, each of which must be precisely aligned.

In the progression of projects presented here, complexity has increased as we've gone from flat to parallel, to square, and finally, at an angle with the V-blocks. Still, this is quite simple stuff compared to scraping a lathe bed and its mating parts. Each surface has to be in a very accurate relationship with another; perpendicular, coplanar, at the same angle, etc. I concede that scraping a machine tool does somewhat warrant its reputation as a big and complex undertaking.

I have two projects I want to talk about. One is the scraping of a tool and cutter grinder, and the other is the fine tuning of a mini-mill's X/Y table. The objective is to show how to deal with two common situations: the scraping of V-ways and scraping of dovetail ways. The mini-mill is small enough that it is a manageable project; indeed, there are many out there that would benefit from a proper scraping job. While there's more to it than we've seen so far, even the most complex task can be broken into bite-sized chunks. Keep in mind, we are dealing with 50 pounds of castings here, not a 12,000 pound horizontal monster mill. The midsized tool and cutter grinder project is bigger, but still small enough that the castings could be manhandled – barely!

The mini-mill project is a fairly complete write up. As there are so many mini-mills out there, I hope a few people can use the details provided to scrape theirs. However, my goal is basic insight into machine tool scraping, not complete coverage of a topic that's so extensive that the details are as numerous as the machine tool designs themselves. Even if I was qualified to cover all of that, I doubt many would want to read hundreds and hundreds of pages covering all permutations of machine tools and their scraping. Besides, it's already been done: McConnelly's *Machine Tool Reconditioning*. If you want to take scraping to the next level, that book should have a spot in your library.

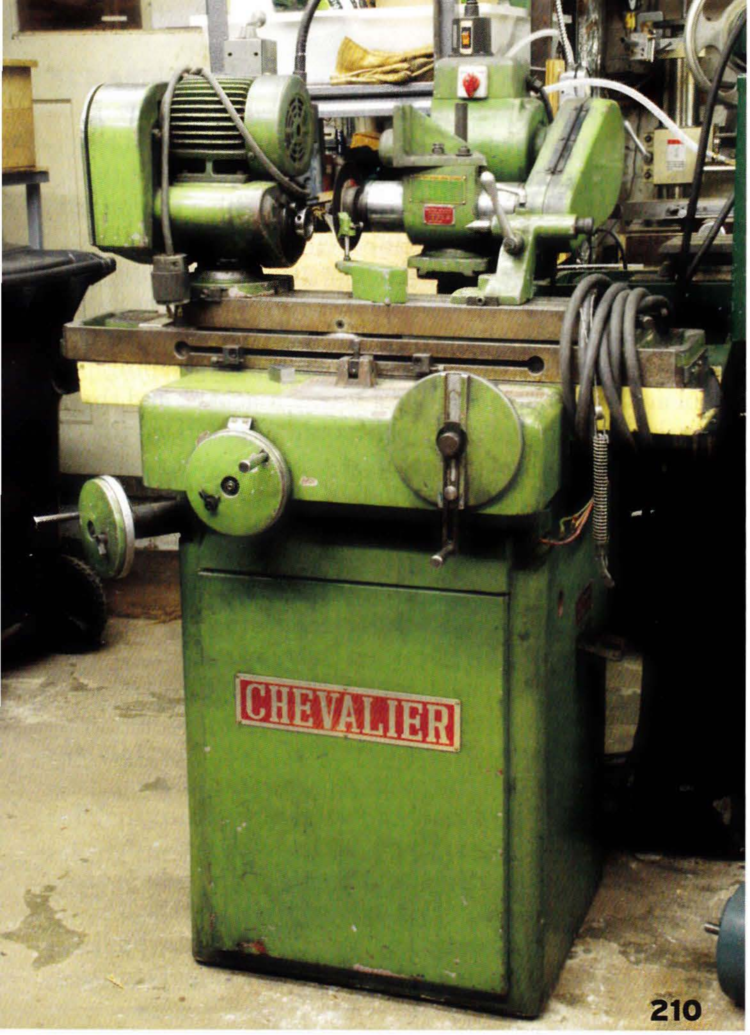
SCRAPING THE TOOL AND CUTTER GRINDER

Before tackling the mini-mill, let's look at the recently acquired tool and cutter grinder shown in ***Photo 210***. This is what I'd call a medium quality machine, made in Taiwan. It was showing some wear, but the spindle bearings seemed okay so I thought it would be worth the effort to do a thorough reconditioning of the bearing ways. This machine also came with a motorized work head that allows it to function as a light cylindrical grinder, as well as a tool and cutter grinder. Wanting to take full advantage of that functionality, I thought it important to start with a solid and accurate set of ways. Finally, while only a few people may end up scraping a tool and cutter grinder, it is a V-way machine and the general approach and principals could be extended to lathes and other V-way machines, which was the primary reason for its inclusion.

Unlike our beginner project, the surface gauge, where simple steps led to achieving the objective of obtaining flatness, here the complexity involved requires a plan. Like most things, coming up with a good plan first requires gathering information.

The objective of the plan is firstly to create a sequence of operations that enables us to get each plane in correct relation to the rest of the planes. Secondly, if there are options on how to do so, we want to organize things such that the amount of scraping is minimized.

To develop the plan, you need to do some inspection: How are things put together and where are things out? Next, think through each step in the sequence – how it's set up and referenced, and which surfaces need to be accurate prior to this step. Don't get



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caught in a "you can't get there from here" trap. For example, we will often scrape a part and use it to spot and scrape its mating part. In those instances, we want to scrape the longer of the two mates and use it to spot the shorter element.

The first step is to determine the starting point. In this case, I wasn't worried about the spindle because it is fully adjustable. I also wasn't particularly worried about the up and down axis of the head. What mattered was that the X- and Y-axes were accurate and had solid bearing surfaces. The bearing surfaces between the saddle and base seemed like the best starting place.

Photo 211 shows the filthy condition of the base and inverted V-ways. It's bothersome that the machine design allowed so much grit and crud to enter. I'm not sure if I can come up with some rubber skirts or something to prevent this from happening again, but it's a worth a try.

In ***Photo 212***, the saddle has been removed by sliding it forward onto a *workmate* style bench and the cleanup is well underway. The two V-ways on the bottom of the saddle ride in the two inverted Vs on the base casting. As the Vs on the saddle are the longest


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part, the strategy will be to scrape them in as close to perfect as we can and then use them to spot the inverted Vs in the base.

Photo 213 shows a close up of the wear pattern on the base ways. There is quite a bit of scoring and the saddle should be bearing on a larger percentage of the way. By the way, the wells are for oil; thin, spring-loaded wheels dip into the oil well, carry it up, and deposit it on the bottom side of the saddle's V as it traverses. The saddle was flipped upside down and work started with a rough scrape to break up the scored pattern ***(Photo 214)***.

An initial spotting, using blue applied fairly thickly to the camelback, shows how far out the way is ***(Photo 215)***. The main high area, toward the apex of the V, is consistent with where we saw the wear areas on the inverted V mate.

Scrape one surface flat as shown in ***Photo 216***. Remember how I said you'll need some additional tackle to scrape a machine tool? Photo 216 shows an old Brown and Sharpe reference flat, or straight edge, commonly known as a camelback. I've never thought the term "straight edge" was completely proper as it's

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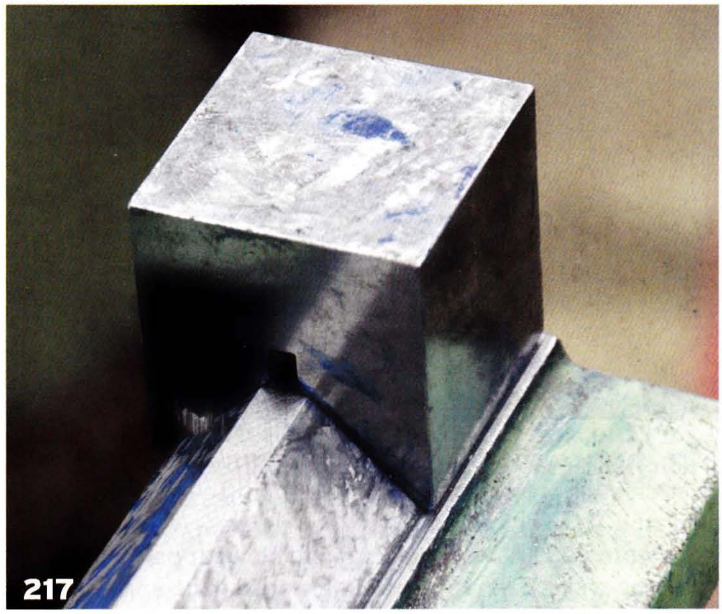
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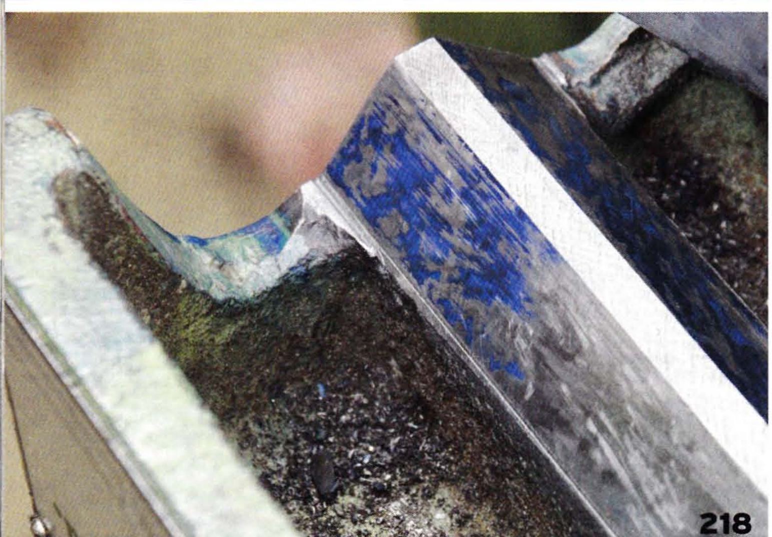
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not an edge, it's a flat surface or plane. It is a carefully stress-relieved casting that is very accurately scraped flat. It's essentially a portable version of the surface plate in that it's a reference source for flatness and is what we use for spotting machine tool ways.

After one way is flat, we need to get the second flat and at the right angle to the first. I made the V-blocks detailed earlier specifically for this project; they are the right angle and right size to exactly cover the V ***(Photo 217)***. Were the angle something other than 90°, we'd make V-blocks for the specific angle required.

In one sense, it does not matter what angle the Vs are, so long as the mate is scraped to match. However, for the process I'm going to follow, it does matter because I will need the V-block to measure parallelism between the two Vs. Getting the second side flat and at the right angle is a matter of spotting with the camelback and periodically spotting with the V-block to check the angle.

To scrape the second side, spot with the V-block to bring the angle in ***(Photo 218)***. I brought two short sections in to the correct angle and then scraped down to them using the camelback. I'm not sure there was much advantage to this except I could go at the initial


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work aggressively without bothering to constantly check the angle.

Depending on what your checks reveal, you can determine where to scrape. For example, I concentrated scraping toward the bottom half after a check with a V-block showed the V-way more obtuse than the block, i.e., spotting with the block left more blue on the bottom of the V than the top ***(Photo 219)***.

(Continued on page 50)

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In *Photo 220*, work is progressing. Keep going until there is a good distribution of bearing points – this is a bearing surface after all. Furthermore, this part will be used to spot and scrape its mate; in that sense, it will briefly be used as a gauge, so we want to do a good job.

THE SECOND V-WAY

So far, things have been a walk in the park, but now we need to scrape in the second V-way. It holds all the fun and joy of the first *and* it has to be scraped such that the two apexes (or the imaginary line that would form where the V planes meet) are parallel.

Having these lines parallel means we have to do checks in two directions; checking that the second V is neither going up or down, nor left or right from the first V. These two checks are where the matched V-blocks will shine. The V-ways themselves are hard to measure; however, using the V-blocks we convert the angled structure to perpendicular and horizontal surfaces that are more easily measured.

We need to introduce a new tool to help with the process: the precision level. It's a big challenge to measure whether these two Vs are going up or downhill from each other directly, but we can readily measure indirectly with the precision V-blocks and a level.

This is not your basic carpenter's level. The level being used is a Starrett master precision level with graduations representing .0005" per 12". These levels are expensive, but purchasing a used one takes much of the sting out. Since we know how to scrape, one in poor shape can be reconditioned, so long as the vial is not broken (the vial is adjustable as well).

Place the two V-blocks along the scraped V-way, as shown in *Photo 221*. Then, place the level across the two blocks. Shim the casting until you get the bubble somewhere toward the center.

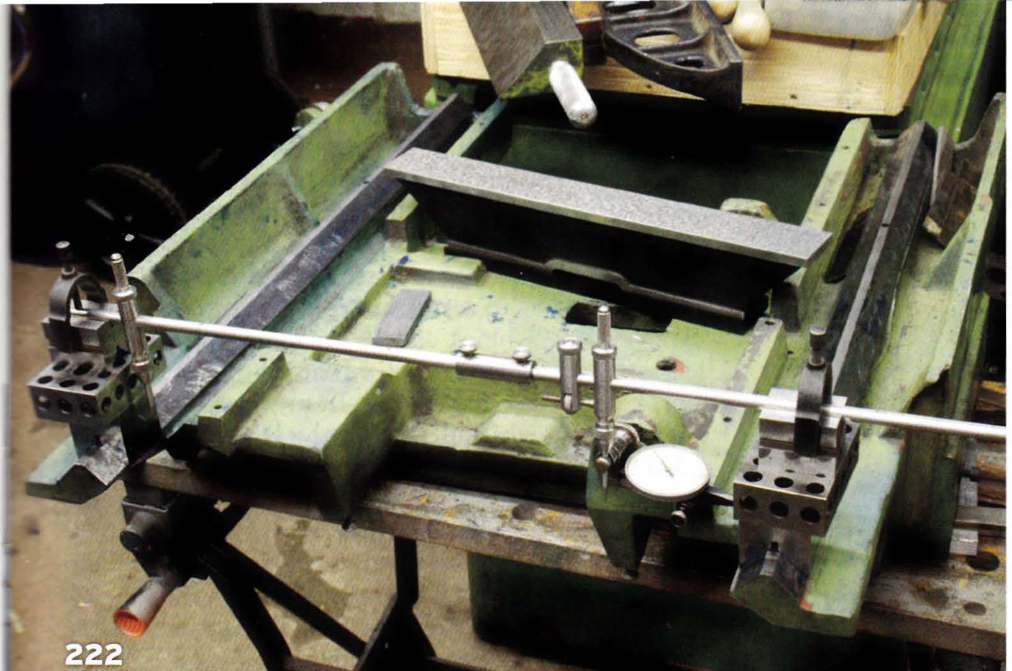
It doesn't matter if the way is perfectly leveled, but note what the reading is. Transfer the setup to the second V-way; if the bubble is in the same position, the two V-ways are not going up or downhill from one another.

The next check is to make sure the two ways are equidistant from each other over their length.

Again, the V-blocks become a very useful and necessary tool to make this check. With a V-block on each way, the distance between the ways should remain constant over the length of the ways if they are not converging.

The setup for this check is shown in *Photo 222*. It looks a bit mad-scientist like, but is really very simple. It is a rig that allows me to indicate the distance between the inside vertical faces of the V-blocks. A more detailed view of the setup is shown in *Photos 223* and *224*. On top of the V-block rests an accurate 123 block, which is just there to provide the necessary height to clear elements of the casting. On top of this sits another V-block, into which a trammel set sits. On one end of the trammel set is a bent leg and on the other is a tenths indicator.

An advantage of this setup is that the V to V distance is measured at a consistent distance from the top of each V-block. As we are taking no steps to ensure



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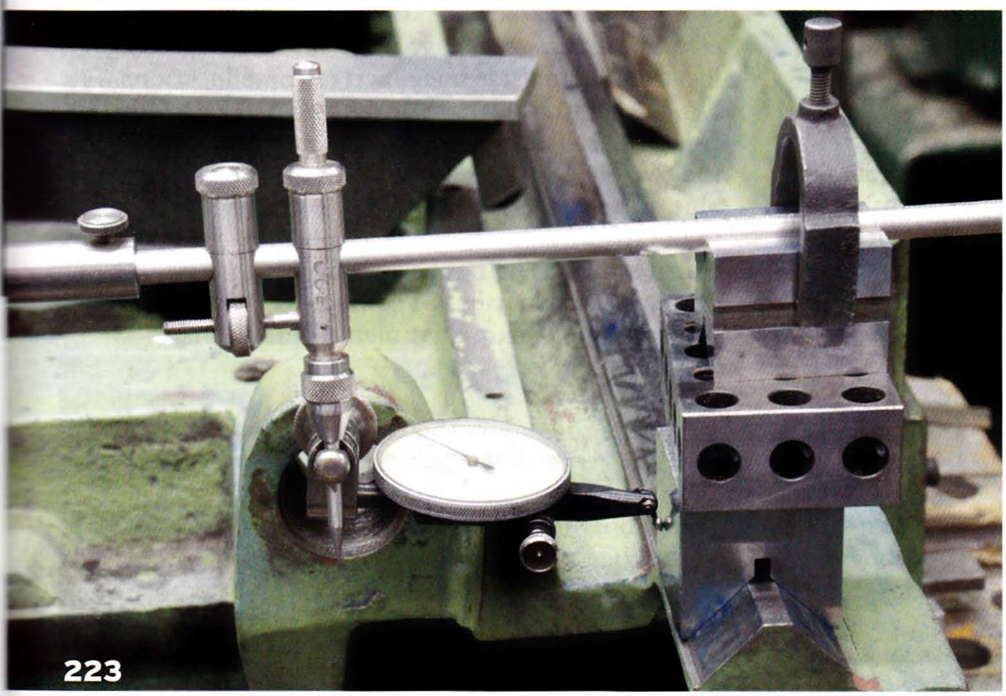

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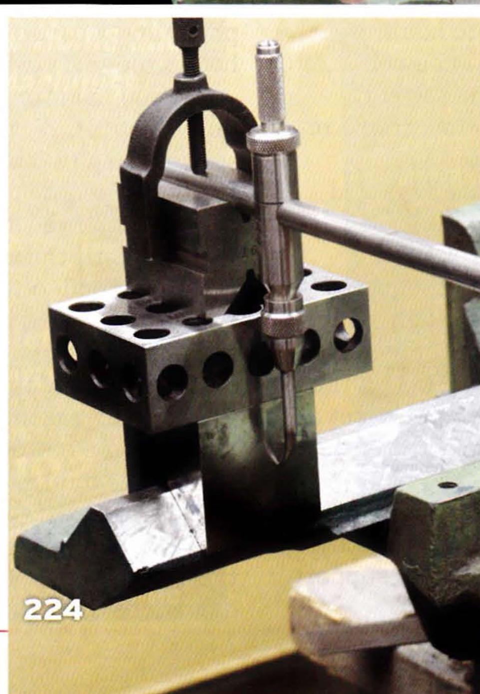
it, it's quite possible that the sides of each V will not be exactly 45° to vertical. You could worry about this and devise a test, but what's the point? This alignment will not matter and will be good to begin with just based on the manufacturer's original machining. I don't think it matters as far as machine tool reconditioning is concerned, but be aware when concocting your setup that the V to V distances may well be different between the top of the V-blocks, compared to the bottom of the V-blocks, because of this.

If you don't have a trammel set (and why would you, since it's



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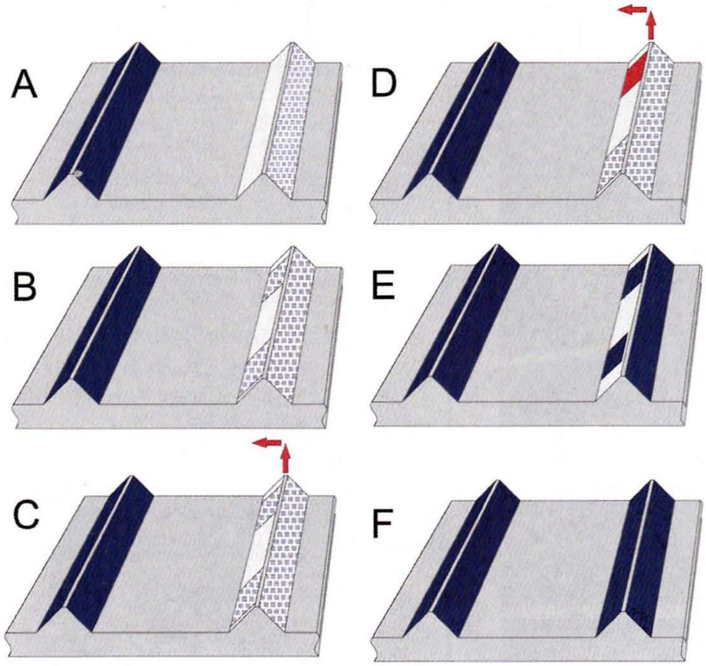

Figure 15

something that gets used once a decade), rig a bar with the indicator somehow suspended from it. All manner of odd-ball sets can be welded up out of steel bar to facilitate machine tool indicating, so be creative with it.

The operation is quite simple. Hold the V-block on the bent leg side and sweep the other, noting the maximum reading. Move the setup to the other end of the ways and compare the readings. Given its gangly appearance, it is surprising how sensitive and consistent the sweep readings are.

This setup for detecting any divergence between the two ways is a weak, precarious setup, full of potential for errors. Aside from the usual culprits, error potential is exacerbated by the flexible nature of the trammel beam and points. Finger pressure anywhere along the setup will move the indicator needle significantly. What to do?

The trick is to practice for repeatability. Train yourself by sweeping the indicator over and over again, paying attention to how and where you are holding things and how much force you use, until you can consistently get the same result. Go to the second location and do the same. Then return to the first: Are you still getting the same reading? With a bit of practice, you will be able to repeat your readings and you will have confidence in the results.

Figure 15 shows the more complex process of scraping in the second V-way. The blue represents completed surfaces and mottled indicates rough-scraped surfaces. Since the tests with the first V-way rely on V-blocks sitting well on two places, the process on the second V-way is to create two spots, get them perfect as per the two tests, and then scrape the rest of the surface down to their level.

Here's the process on how I made this happen:

A. One side of the second V is rough scraped. We want it flat enough, with enough bearing points to support one side of the V-block without rocking.

B. Rough-scrape two pads at a distance apart of about the length of the precision level.

C. Perform the checks illustrated in Photos 221 and 222. These tests quantify how far out of alignment the second way is in two directions. In my case, the second way was high and to the left of perfect, as represented by the two red arrows in the drawing.

D. The trick here is to scrape two places on the second side where the V-block checks are done (I'll call them the spotting locations) to eliminate the error represented by the red arrows. In my case, the error was about .002" up and .002" to the left (it seemed like a lot, and it was!). The determination of where to scrape is based on where the errors are. For example, with my error up and to the left, scraping where the red patch is shown resulted in bringing the V-way down and to the right. Similarly, if there was no left/right error but a vertical error, you'd scrape equally on both sides to bring things down.

E. Finish scraping side one. If, in the effort to correct errors, you had to remove material at the spotting locations, bring side one down to these locations. Finish scraping side two at the two pad locations using the V-block as a spotting tool. Keep performing the two checks noted in point C and make sure the blue areas in E create a way perfectly aligned with the first way.

F. Finish scrape to bring the second side to the same plane as the two pads. Of course, keep checking as you go to make sure alignment is maintained.

THE BASE

Scraping the saddle and getting the two V-ways straight and true is a big undertaking! Scrape to a high standard though, as the saddle will be used as the spotting tool for the base. Similarly, on a lathe, the bed becomes the spotting tool for the saddle and tailstock.

With the two V-ways finely scraped, it's a simple matter to blue the two ways and use the saddle to spot the base rails. It's easy to say, but hard work to do. That's the nature of home shop scraping – you see a photo and a paragraph that represent months of work before moving on to the next step.

If you examine Photo 211, you'll see the saddle rides on two rails fastened to the base. We'll use the saddle to scrape these two rails. This required a lot of scraping on my machine, the difficulty of which was exacerbated by the weight of the saddle casting. It often sat for ages, waiting until the next time I could corral someone to take an end; often it was my son when home from school – an added bonus of Christmas and other holidays. This, no doubt, adds to the confounding eccentric image the family has of me and these crazed garage undertakings!

With the bottom of the saddle scraped, and the base to match, I reinstalled the saddle. However, I first carefully leveled the machine by placing a level on top of the two rails. The reason is that this sets a horizon for the machine that we can then use for some subsequent operations. For example, with the saddle in place as

shown in ***Photo 225***, we can check the inclination of the long, flat, top way. We'll get to scraping this soon, but we need to scrape the table, the longer surface, to spot these ways.
This will be our next job.

A note of caution is due here. Every machine tool bearing surface you will encounter also has a corresponding mechanism to control the motion along it: a lead screw, feed screw, rack and pinion, capstan, power feed, etc. When we scrape, we are changing the dimensions for how that mechanism interacts with the parts we've scraped. For example, if we scrape a lathe bed and the carriage to match, we've lowered the location on the apron through which the feed and lead screw shafts go. If you're lucky, the scraping will be such a minor amount that clearance in the screw will accommodate it, but don't rely on that.

225

Study and plan on how to move and adjust things around so the screw locations will properly align. This may require significant modifications. In my case, I caught a break, as the Y-axis feed nut floats, albeit tightly fitting, in a channel, so no modifications were necessary. The X-axis moves via a rack, which did require adjustment. Be aware of this from project inception and accommodate for it in your overall plan.

In the next installment, we'll get to work on the table.

Photos and drawings by Author

SCRAPING for the Home Shop

Part Eight

BY MICHAEL WARD

THE TABLE

Now that we are done with the base of the cutter grinder, it's time to tackle the table. This is another big job, just due to its sheer physical size (***Photo 226***). Here we have a V-way and a flat-way. There may not be many of you who are ever charged with scraping the underside of a tool and cutter grinder table; however, this configuration is the same as most lathe beds.

My approach was to scrape the V-way straight and true, and at the same angle as the previously made precision V-blocks. I could then use the V-block sitting on top of the V-way to indicate that both the flat-way is parallel to the V's axis (neither going up or downhill) and the front of the table is also parallel to the V's axis (***Photo 227***). First, scrape one side of the V flat, then using the V-block and camelback, scrape the second side flat and to the correct angle.

THE FLAT-WAY

Photo 228 shows the flat-way work in progress. Note the quantity of cast iron chips. Lest you think I'm more industrious than I am, you can make out the handle of the Biax power scraper on the right side. What might strike you about the table work is that the job is longer than the reference (the Brown and Sharpe 30" camelback). This is less than desirable, but it is not uncommon that we are called upon to scrape something longer than the largest available reference.

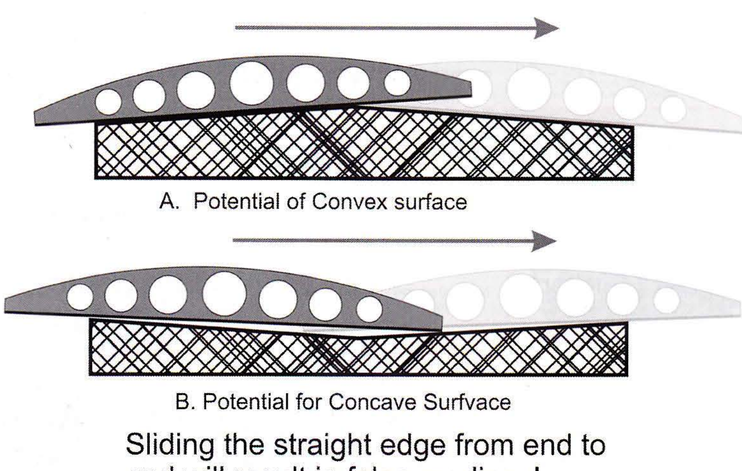

Figure 16

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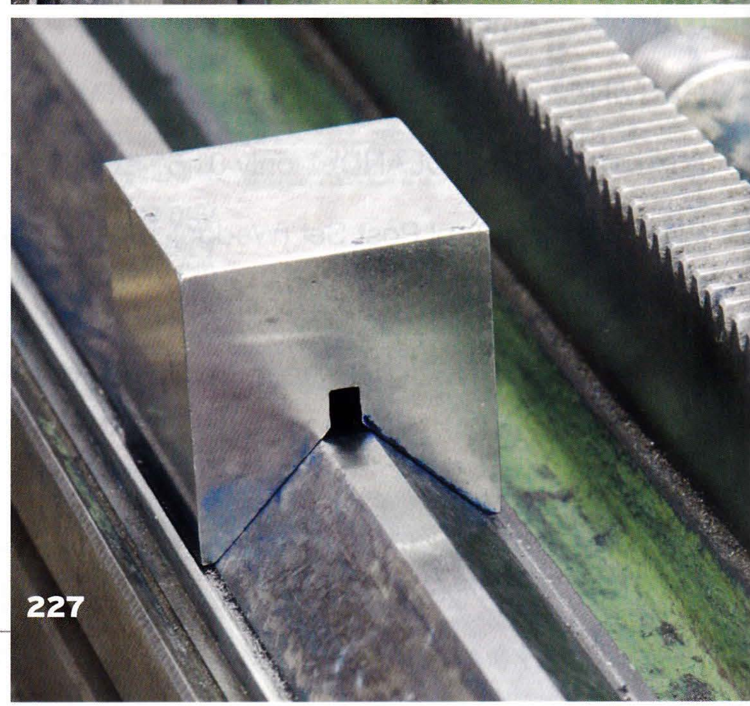

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Standing in the front of this job, there is a compelling desire to place the blued reference at one end and slide it to the other, as shown in ***Figure 16***. Resist the urge! As the drawing shows, in an exaggerated manner, it is quite possible to end up with markings all along the surface yet still have a convex or concave surface.

Figure 17 shows the correct way to approach this situation. Starting from one end, spot the work by moving the reference back and forth a few inches to spot, then scrape things flat. Scrape enough so this now flat section is lower than the remaining section. Then proceed to move the straight edge down the way, overlapping the scraped section by at least 50%. Scrape the flat-way, making sure it is parallel to the V-way's apex using the indicator test shown in ***Photo 229***.

We still have the table front and top to do. I decided the best way to do this was to indicate these surfaces with the table installed. So, with the table bottom complete, we're going to stop work on the table for a few moments while we use it to scrape the top half of the saddle.

There are two tests we want to do when scraping the saddle. One, shown in Photo 225 (May/June 2012 issue, *The Home Shop Machinist*), checks whether the top of the saddle is sloping left or right. The second test is whether the two axes of motion are perfectly square to one another. As is often the case, the square test requires the most complex setups. ***Photo 230*** shows my

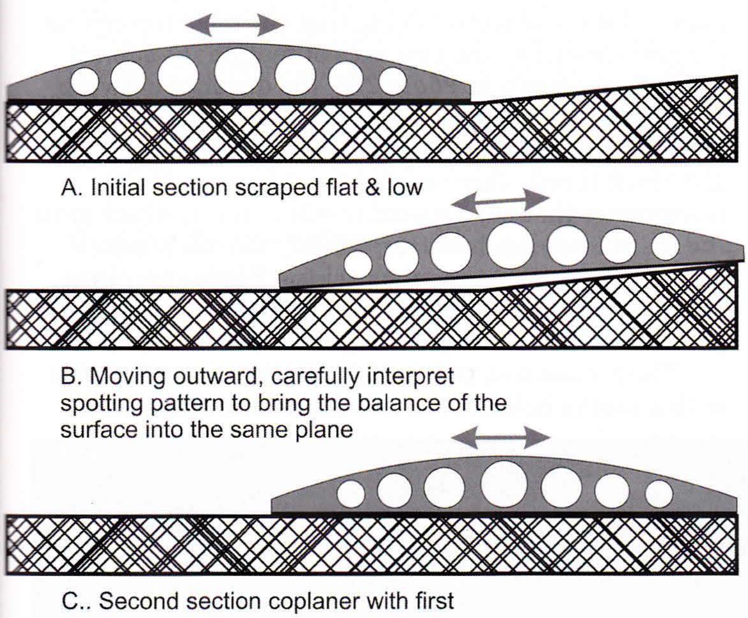
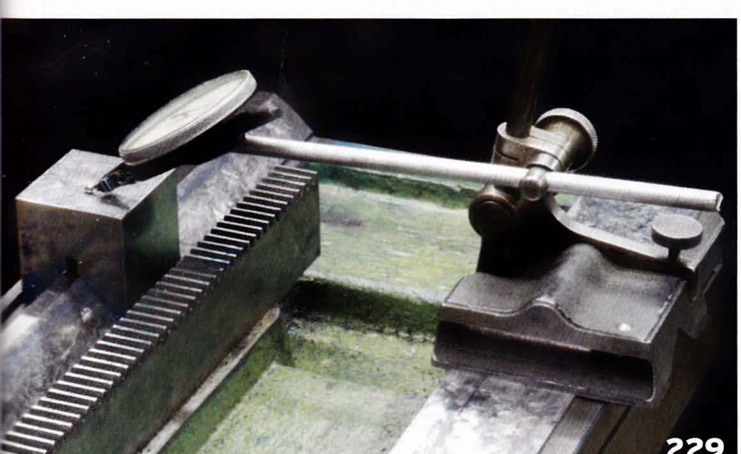


Figure 17



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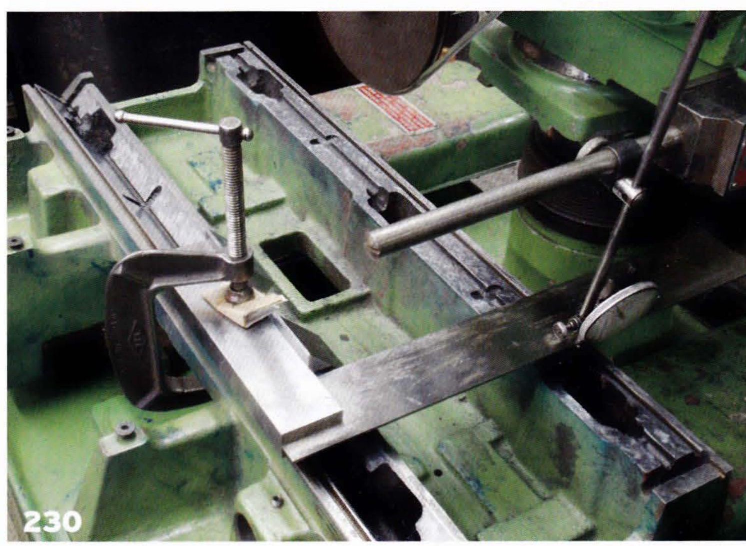

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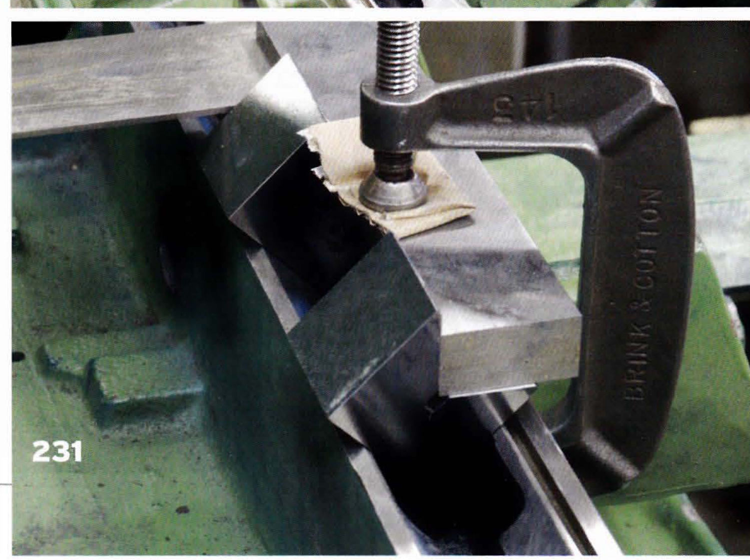

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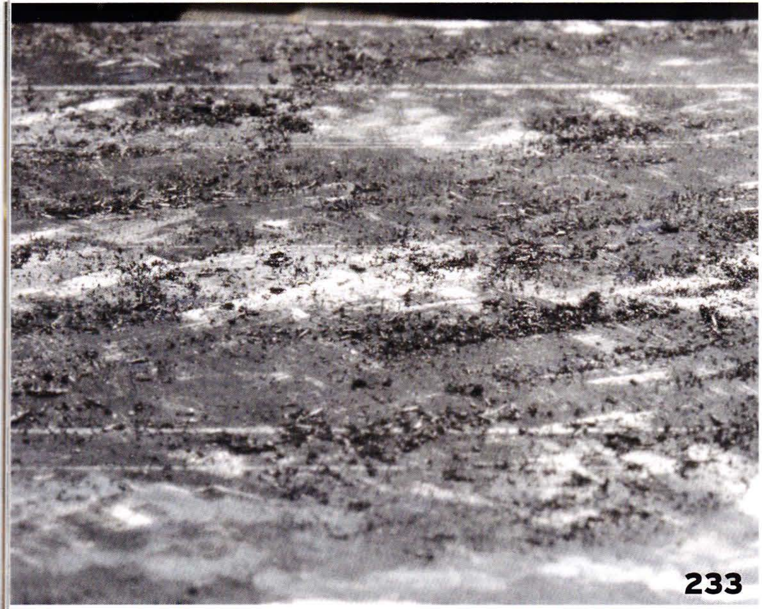

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setup, using a 12" Starrett precision square, two V-blocks, and an indicator. ***Photo 231*** shows the same setup from a different angle. As you scrape the top of the saddle to match the base, keep performing these tests to check for a perfectly configured saddle.

There is a smaller pivoting table sitting on top of the main (sliding) table that provides the primary work surface. As a result, the table you've seen (or perhaps it's more accurately called the sub-table) isn't flat across the top but has three pads to support the table on top of it. These pads posed a challenge as I didn't have a surface long or wide enough to spot them all into the same plane.

To overcome this problem, I made a small surface plate from a piece of cast iron I had on hand. ***Photo 232*** shows it being roughed with a large 6" slab cutter (I may be having too much fun with the horizontal mill).

Photo 233 is included just in case there's any doubt we're doing real work here. After a round of roughing with the power scraper, the surface is covered in chips. It was a fair bit of work, but I couldn't figure any way out of it. Besides, whatever the slab of cast iron eventually becomes, it will benefit from starting with a flat surface. This new surface plate was used to scrape each of the three pads on the top of the sub-table (***Photo 234***).

While scraping these three pads, two tests were done, with the objective being that the table top end up flat and parallel to the two axes of motion it's subject to. First, as shown in ***Photo 235***, the distance between the underlying flat-way and the top surface is scraped to my ability to measure with a tenths micrometer. The 123 block is only there as packing. I have an Etalon micrometer that has squared inside corners, which gave the reach I needed; however, it's a 3" - 4" micrometer, which is too big – hence the packing. Since two of the pads were at the extreme ends of the table, it wasn't possible to indicate them along the Z-axis.

The second test was to indicate the top of the table with a tenths indicator in two directions (***Photo 236***).

(Continued on page 50)

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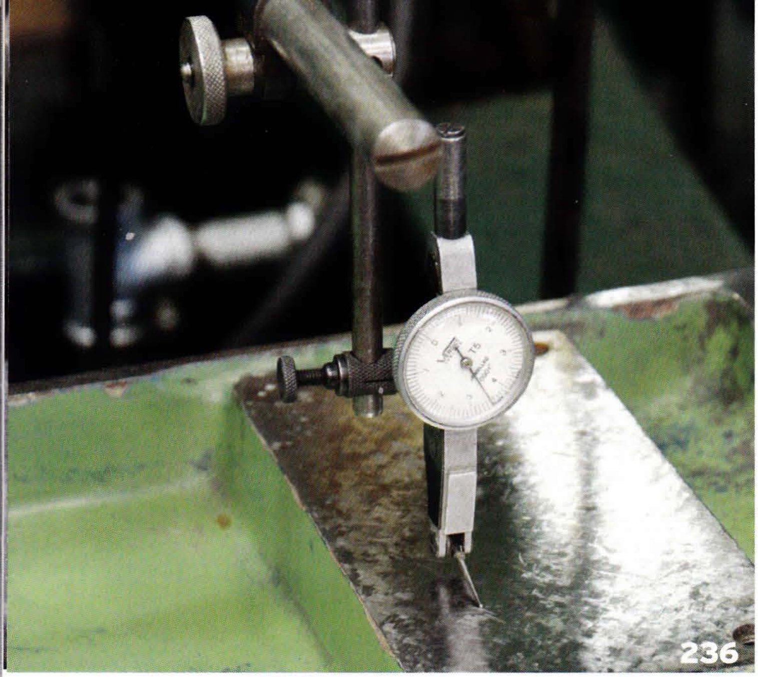

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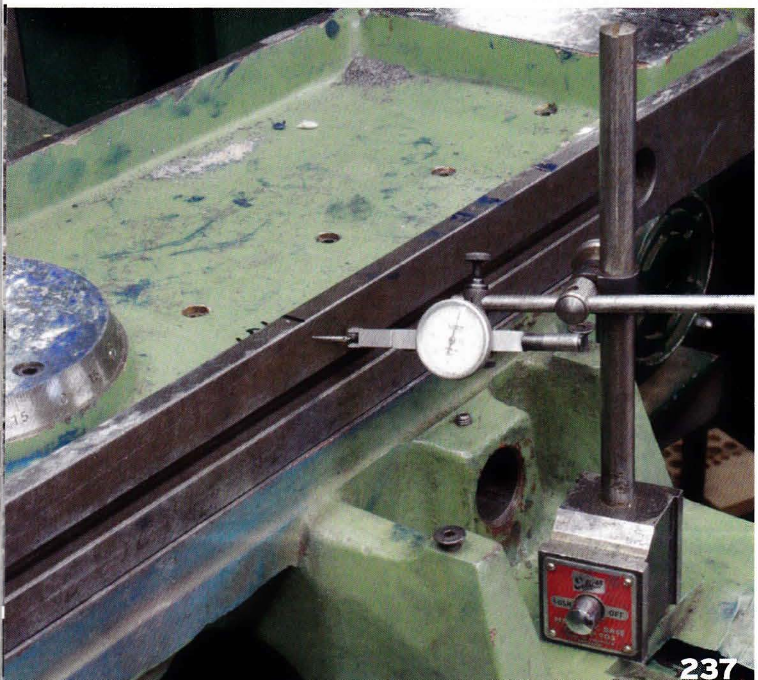

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This should result in the table top being perfectly parallel to the X- and Z-axis of motion (in and out, and left to right). The final scraping job on the sliding table was to scrape the front square to the top and parallel to the axis of motion.

Photo 237 shows a tenth indicator mapping the front surface of the table. This had to be done in two steps, as obviously it's impossible to set an indicator in a spot such that the entire surface moves past it. The table was out .0016" over its 3' length. In scraping parlance, this was a football field away and I knew I had some work ahead of me. The pros will chuckle perhaps at that, but for us amateurs, that's a good sized surface to lower that much. I scraped away, concentrating on the high end while using a precision square to bring it perfectly square to the table top surface as well.

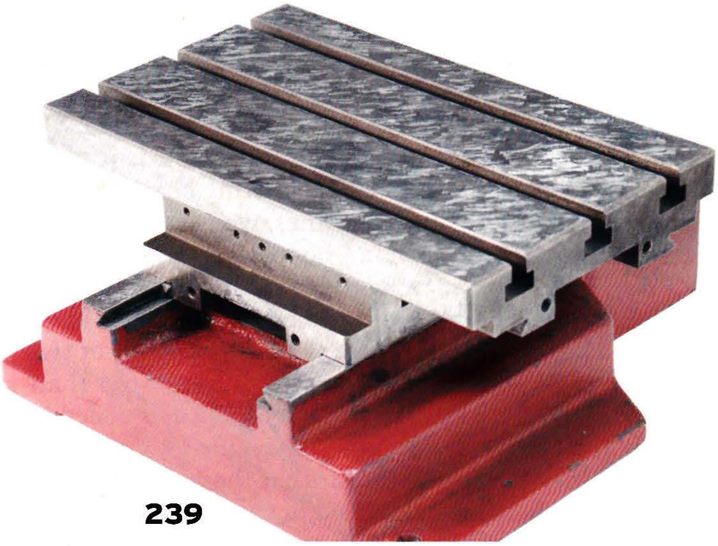
One of the features of a tool and cutter grinder is that the top, or pivot table, can be rotated relative to the sliding table and the axis of motion. (The pivot table isn't shown; what you see is the sub-table.) The table sits on top and can be pivoted via a pin in the center hole in the sub-table. With a motorized head, this makes the tool a light cylindrical grinder and the pivoting table enables it to grind tapers. That, and even setting up simple parallel jobs, would seem to benefit from having an accurate datum surface parallel to the axis of motion, so I thought it worthwhile to accurately scrape this surface.

Aside from scraping the pivot table, which I won't bore you with as its repetitious techniques have already been shown, the last order of business was refitting the rack. The table motion is driven from a rack mounted under the table engaging with a gear, which is connected to a hand wheel. As mentioned, whenever we scrape, we have to be aware of how changing the geometry might affect other components.

In this case, the scraping was heavy enough that the engagement of the rack and gear now lacked the necessary clearance. In fact, the table was riding on the gear instead of the way. None of this was detected before, nor did it interfere with scraping as the hand wheel assembly wasn't installed. The way to deal with this is to skim a bit off the back of the rack.

Some checking with feeler gauges confirmed there was a gap, but it was not immediately apparent how much to take off. I could fit a .002" feeler gauge in the V-way, but it was in the V-way. I could have done the math, but the V-way is offset somewhat from the rack so I elected to go with the trial and error method. I set the rack up as per ***Photo 238***, and milled .003" off using a sharp fly cutter. The rack height in the setup was determined by two pins resting on parallels and bearing on the angles of the rack's teeth. The clamps are holding the rack to angle plates bolted to the table.

This went a long way toward fixing the problem; however, there was still a cogging feel to things, suggesting a bit more needed to come off. I went back to the mill again and .002" was taken off, which resulted in a perfect fit.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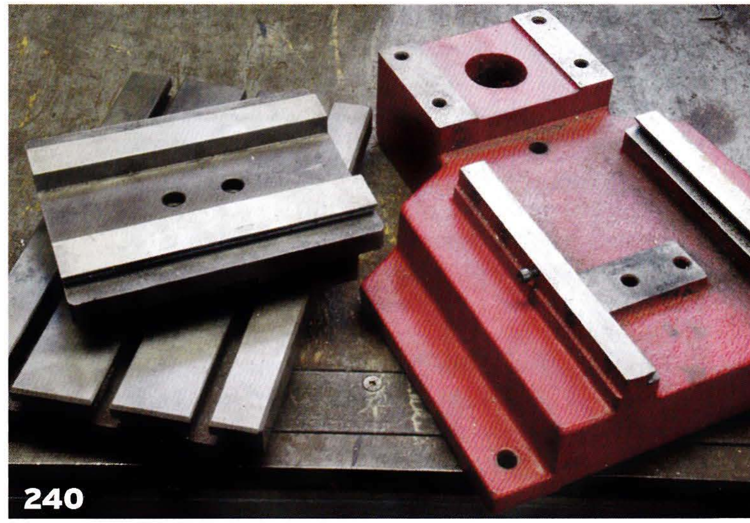
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SCRAPING IN THE MINI-MILL

The availability of low cost, imported, bench top machines has added milling capability to many home shops. While the low cost and small size give accessibility, they've often been faulted on quality. They seem to suffer from poorly fitting slides and bearing surfaces. This is not surprising given that the more accurate and finely finished a part needs to be, the more expensive its production becomes.

The next project we're going to tackle is the scraping in of the X/Y components of a mini-mill (***Photo 239***). It's a great project as it captures the techniques and challenges of dovetail scraping, but is performed on castings small and light enough to fit in a knapsack (which is exactly how they arrived – on the back of the motorcycle riding vendor).

I don't own a mini-mill but one day, while cruising the online classifieds, I came across this set of castings for the table, a saddle, and a base of a mini-mill at a reasonable price (***Photo 240***). Deep into writing this series, I thought they'd make a great practical example of dovetail scraping. Since there are so many of these mills out there that could benefit from this treatment, this was the perfect home shop entry point to machine tool scraping.

These parts were acquired without the rest of the mill for no other reason than to scrape for this writing – that's either dedication or an affliction. After they'd aged under the bench for a while, it struck me there were some exciting, practical outcomes possible beyond just scraping instruction; the completed assembly could become either a high-end X/Y drill press table or a very solid and accurate base for a do-it-yourself CNC machine. No matter what its final use is, I hope its treatment here is of interest.

The good news is that scraping is the technique to bring the linear bearings and movements of these little mills up to best-of-class standards. Traditionally, scraping is the technique used to bring the best machine tools into perfect fit and alignment, and is still the approach to the first-class restoration of a machine tool. Our little mini-mill castings can be viewed as roughed out pieces and, similar to a worn out machine, ready to be scraped to bring about a perfect fit and alignment.

For many in the home shop, surface or way grinding is an academic subject; without a grinder there is no choice but to scrape. In fact, unless you are a machine tool rebuilder, possessing a large way grinder capable of carrying a precision grinding head(s) over 10, 20, or even more feet and at various angles, it's academic for most any shop.

High quality machine tools are made, or are commercially restored, by completing one part with large precision way grinders and then its mate is scraped to match. The reason is that, while the way grinder can handle the complexity of a lathe bed and its various V- and flat-ways and surfaces, it's very difficult, especially given the angles involved, to perfectly replicate the opposite shape in its mate. Scraping overcomes that difficulty by using one part to shape the other. Perhaps one day incredible grinders will be inexpensive enough to completely eliminate scraping on newly manufactured machines, or perhaps everything will go toward box ways, which are more easily done on automated grinders. Either way, for now scraping is a part of how the best machine tools are finished or reconditioned.

I suppose my point is that if scraping is in decline in new machine projects, it's because it is labor intensive and expensive, not because it suffers any inadequacies in the accuracy department. In fact, the results you can, and indeed should achieve are world class bearing surfaces.

LAPPING THE MINI-MILL?

I have read accounts of people misled into thinking that rough spots in their machines can be improved by lapping. The advocated process is to place some lapping compound on the bearing surfaces between mating parts and rub them together to "loosen things up." I would discourage this approach in strong terms as it is the wrong methodology and will do more damage than good.

Why the strong statements? The use of an abrasive compound will loosen things up and create the impression of very smooth action. However, this is accomplished by indiscriminately abrading away material. The motion is now smooth and without tight spots simply because the abrasive has created more clearance between the parts; more slop is present between what should be precision fitting bearing surfaces. To improve our machines, we need better fitting bearing surfaces, not a sloppier fit.

We've looked at lapping twice in this series so we are aware that lapping is usually considered to be a cutting action between a workpiece and a lap – not two workpieces. We want the lap material to be softer than the work so the abrasive particles become embedded in the lap and cut the work. If the lap and work are the same hardness, there's a danger that these abrasive particles can become embedded in the work. There are lapping compounds that claim to break down and avoid this; however, if you built the rotary lap, you know how readily abrasives can be pressed into metal, making it a very effective cutting tool. The result is that the work potentially becomes a lap, and will continue to cut once the machine is together.

The fundamental objection to lapping between two machine parts is that there is no control over where material is removed. If you are just rubbing two pieces together, like in the two castings of a mill, there is no control. You could lap away only to have created a convex shape in one and concave shape in its mate; this is not what we want for our machine bearings.

Scraping is the correct way to improve a poor fit in a machine tool, whether it's because of wear or less than satisfactory original production. Maybe the decision to lap rather than scrape comes from the knowledge that scraping is more work and also from a bit of wishful thinking that lapping will work. Hopefully, most of the decision to lap was from a lack of knowing how to scrape properly, which we can rectify! Bringing a thorough understanding of how to really improve these machines will hopefully make the hobby more enjoyable.

With scraping, not only is the location for material removed specified, the process is based on comparisons to reference standards and hence, the shape and form of machine tool bearings end up mimicking the flatness and accuracies of that to which they were compared. What we want from our bearing surface is a broad area of contact and minimal clearance between moving parts, both of which increase rigidity and accuracy.

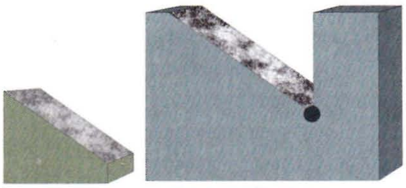
DOVETAIL SCRAPING - OVERVIEW

There are a few ways to come at dovetail scraping, as there a few different acceptable results – we have some forks in the road. The first thing to realize is that perfectly serviceable dovetails can be produced without regard to the exact angles of the surfaces. For the dovetail to function, two things matter: that the two horizontal planes are parallel (they don't even have to be coplanar) and that the two apexes of the four angled surfaces are exactly parallel. In other words, two pins placed in the Vs of the dovetail are equidistance apart at each end.

(Continued on page 54)

The dovetail might be nominally 55° but if you scraped it in at 54° and 17 minutes, it will still work perfectly, so long as the horizontal surfaces are parallel, the apexes are parallel, and one mating piece is scraped to the other.

The other approach is to set out to make the angles exactly to a reference, or even more challenging, to an exact degree measurement. To do so involves some gauge making. Gauges of the specific angle are required and are used to spot the work and check its angle. ***Figure 18*** shows two angle spotting tools – one for internal angles and one for external angles.



Angle Spotting Tools
Figure 18

EQUIPMENT

We, of course, need a scraper, which has been covered in previous issues; however, you will likely need to make a narrower version to get deep into the dovetail. The sides of this dovetail are only a frustrating 1/4" or so wide. This is difficult to scrape and I would have liked for it be a larger surface, but you'll see this on all manner of machines, so we must cope with it.

Some of the smaller tools I used to get into the constricted dovetails use .071" thick carbide. They started as nominal 1/16" pieces of carbide but they seemed to be manufactured oversize. A very slight radius was ground on them to make it easier to reach into the corners using the corner of the scraper. Unfortunately, this was still not enough and even thinner instruments were required. Dentistry must be easier, but we cannot relax our diligence because the going gets tough. We need to be able to access this awkward surface with the same ability to precisely remove material as we would do for a flat surface.

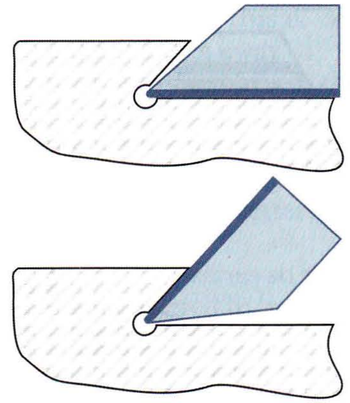
Along with the basic accompaniments of a surface plate, parallels, an indicator, and a surface gauge, we need a specially shaped reference flat that will fit into the restricted space of the dovetail shape and an angle reference so that we can keep a consistent angle along the dovetail.

Another necessary piece of equipment is an adjustable arm task-light. It can be tricky to see into the dovetail to identify the areas marked with blue; being able to direct light at the exact angle needed really helps make the job go more smoothly.

THE DOVETAIL REFERENCE FLAT

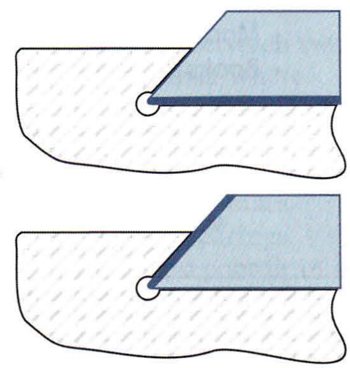
Like all scraping projects, we're trying to get something flat. In the case of dovetails, the restricted access created by the angled surfaces means our surface plate or straight edge won't work. We need to make a spotting tool with a flat surface that is of a profile that will fit into the dovetail's angle. In Part One of this series (May/June 2011), Photo 11 shows a couple of dovetail reference flats, or straight edges. The main feature of these items is that the acute angle on one corner permits the reference to be used in the confined space of the dovetail.

The easiest reference tool to make uses a single-sided spotting tool with an acute angle less than the dovetail angle. An example of this is shown in ***Figure 19***. The work is in grey and the spotting tool is in blue, with the straight edge surface shown as the thick blue line. The only requirements are that the spotting tool has one finely finished and scraped surface and the angle is acute enough to get into the dovetails. Note that such a spotting tool does not preclude scraping the dovetail for a specific angle. We'll address that when we look at angle gauges.



Dovetail - Single Surface Spotting Tool
Figure 19

The other approach is shown in ***Figure 20***, where a dovetail straight edge is prepared that has the exact angle and two reference surfaces. It is more work to make the tool but it has a couple of advantages. The angle of the dovetail will be perfect, which may not matter much for our home shop activities where one piece is fit to another. The second advantage is it is easier to use to spot the diagonal surface. What I mean by that is the diagonal surface of the dovetail is often very small, sometimes less than 1/4", and it can be difficult to hold a straight edge and get good contact as shown in the bottom image of Figure 19, especially when the straight edge is large and heavy.



Dovetail - Two Surface Spotting Tool
Figure 20

Also note that only one surface of the work is scraped at a time, as is indicated by the dark blue line in Figure 20. The point of the two scraped surfaces on this style of spotting tool isn't that two work surfaces can be scraped at once (they're not!), it's that it allows the second surface to be scraped both for flatness and at the correct angle at the same time while the spotting tool rests on the firm footing of the horizontal surface for spotting.

As your scribe in these matters, I felt duty bound to demonstrate the most complex route – the dovetails scraped to a specific angle using a two-sided dovetail scraping tool. It's not that I advocate making things more complex than they need to be; if the simplified approach without angle gauges and using only a single-sided spotting tool will work, then that should be pursued. However, presenting more complete coverage will hopefully make for a better job on my part. With the context of what matters and why, the reader can

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decide to tone it down as the job permits. Also, my view is that the two-sided reference, while more work to make, is worth the effort given the difficulties in spotting the narrow diagonal surface like we had on the mini-mill's dovetails. On the other hand, making the style shown in Figure 19 makes it somewhat universal since dovetails come in a variety of angles.

MAKING THE ANGLE GAUGES

The first step to scraping the two-surface dovetail spotting tool is to make accurate angle gauges (***Photo 241***). The easiest way to make the inside, or female, angle gauge (right side of the photo) is to make the wedged shaped gauge first and use it as a spotting tool to make the inside gauge.

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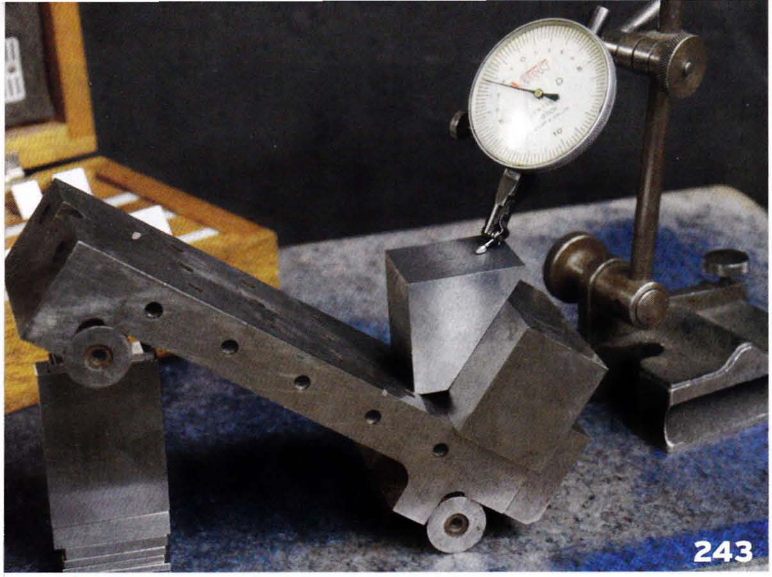
A common way to make the angle gauge is to spot the tool against an unworn section of the dovetail. In the case of the wedge shaped internal angle gauge, a perfect result can be obtained as the two surfaces are scraped for flatness using the surface plate and checked against the dovetail for the correct angle.

However, I'm going to make this angle gauge without using the existing dovetail. One reason is that it adds to our overall abilities to know how to make a precision angle gauge. Another is that the very narrow surfaces of these dovetails don't give me confidence in using them to spot the angle. I'd like this tool to be a little wider than required just for this job and exactly 55° so it has a life beyond this project. In any event, it's a minor deviation in process; whether you make the wedge from an existing dovetail or not.

To start in on the wedged shaped gauge, square up a piece of cast iron and scribe a line at 55°, and then set it up in the mill as shown in ***Photo 242*** to cut a small notch. The block is then clamped to a plate and mounted in the band saw. The notch is only there to help the blade start its cut.

After cutting the angle on the band saw and smoothing with a file, scrape the long side of the wedge shaped spotting tool. Do the highest class job you can on this interior angle spotting tool. We need to be aware of cumulative error in that we're using one tool to spot another to spot another. This has a small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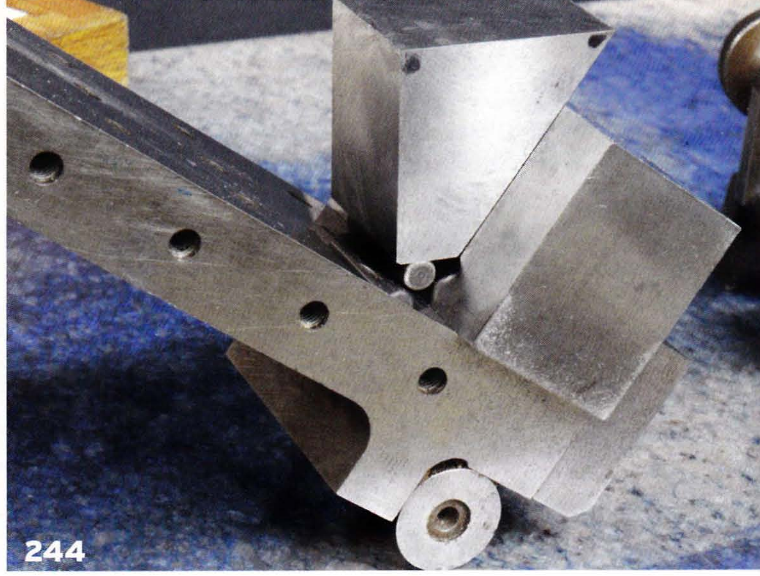
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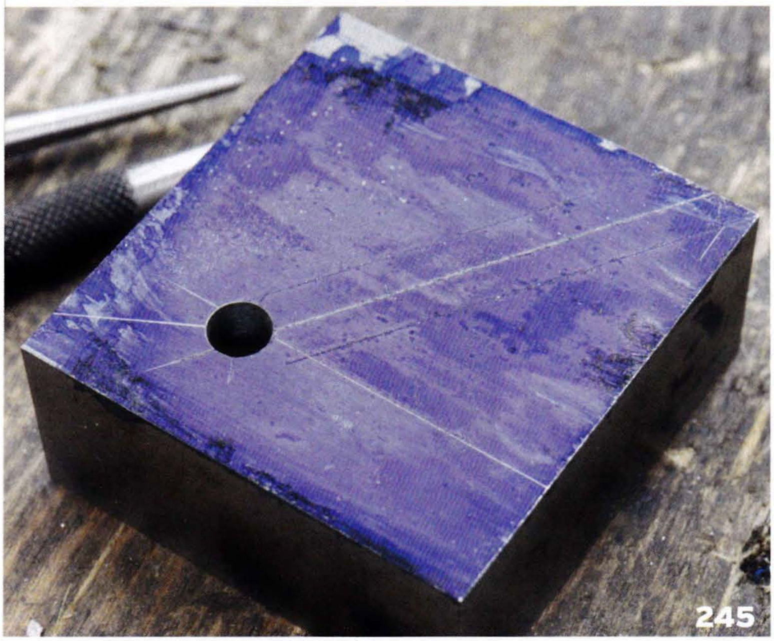
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surface so it shouldn't be too time consuming. With the long side done, we can bring the shorter side in to it, but without the dovetail to spot to, how do we get the angle for the second surface?

The best way to do accurate angle work is with the sine bar. To get the second surface 55° from the first, I set a small sine plate up at 35° degrees and used a precision ground block to support the well scraped, long edge of the block. The accuracy of a sine bar fades as the angle becomes larger. Rather than creating a gauge block stack to produce 55°, I used an accurately ground block so I could effectively rotate the plate's reference surface 90° (***Photo 243***).

After taking this picture, I realized that the position of the spotting tool was depended on the scraped surface (which is good) and an edge (which is not good). A small ground dowel pin placed as shown in ***Photo 244*** makes for a solid and repeatable setup.

Don't get discouraged if you don't have sine bars and gauge blocks. One of the joys of this hobby is being able to collect a wonderful assortment of high quality tools, but that happens over time. If you don't yet have a high quality assortment of tools, perhaps you can derive equal pleasure through ingenuity and creativity. I've read accounts in early hobby magazines of IC engine builders doing their work on treadle lathes, without the benefit of a micrometer (an unaffordable luxury). In contrast, I see people today who've not built much of anything buying sets of gauge blocks. I suppose it's only about having fun so it's all good, but there seems a bit a skew nowadays towards acquiring everything. Hopefully this doesn't discourage the newer, less equipped practitioner. Most of the gismos are more about convenience than fundamentals.

You can usually make or innovate around what you don't have and the shiny, quality brand tools will come with time. A quite serviceable sine bar can be hobbled together at home. One of the things that makes a sine bar convenient is that the round bars are set at 5" (or 10") apart. However, this just makes for a convenient calculation; trigonometry cares not whether the hypotenuse is 5" or 4.992". As for stacks of gauge blocks, machine a block of steel to the right height and check with your best micrometer – better yet, scrape it.

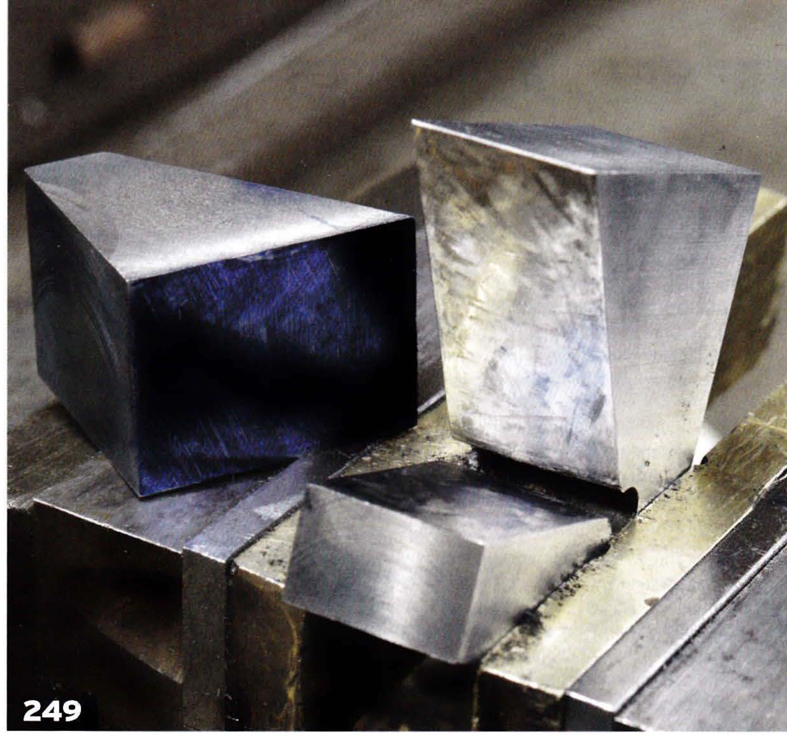
That might not be what they do at the jet propulsion laboratory but it will get great results in the home shop until some of the more expensive and esoteric items can be acquired. I'll be the first to admit there is enjoyment in collecting quality tools; however, it's often for its own sake rather than a real need demanded by our work.

Oh yes, how would you make an engine without a micrometer? By comparing items with calipers and making things like plug gauges to be able to compare OD's to ID's. Quite incredible work can be done with outside calipers and shop made plug gauges as it's really not important that the piston is 1" diameter, only that it properly fits the bore.

When you have the wedge shaped 55° angle piece scraped to perfection, which will be second nature by now, put it aside and start on the exterior angle gauge. This gauge is also a piece of cast iron and is first roughed out on the mill. (By the way, if you are going the route of the one-sided dovetail scraping tool you may not need the exterior tool.)

Scribe two lines, creating a 55° angle between them and then draw a third line at a 27.5° angle bisecting the first two. Center punch for a 1/4" hole such that the intersection of the lines will fall within the hole (***Photo 245***).

Now, set the block up in the mill with the 55° line vertical and make a small notch for the band saw blade



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to start in. You've seen my band saw fixture many times (simply a plate with drilled and tapped holes), ***Photo 246*** shows it being using vertically. Clamp the work to the fixture, align the scribed line to vertical and clamp the assembly in the band saw vise.

Photo 247 shows the work fresh from the saw. I tried to cut as close to the lines as possible, and by band saw tolerances it looked pretty good. The part of me that was thinking about filing was less impressed. You'll need some knife edge files; half round ones also work well at getting into the end of the angle. In retrospect, I should have drilled the center of the hole closer to where the lines meet. Making it as tight as I did makes it quite difficult to file and scrape.

I had the mistaken view that a better job would result from trying to have a very small area of V intersect with the hole. I say it was a mistaken view because this gauge is to check angles; reference flats are used in conjunction with this gauge so the work partially being in the clearance hole shouldn't matter.

In ***Photo 248*** you can see the wedge and interior angle gauges and the collection of scrapers used. Knowing how small the dovetails are, I made a couple of special scrapers with the carbide measuring .0625" × .3125" that saw service in the gauge making process as well. While I haven't seen short style scrapers like these, commercially or otherwise, in my opinion they are greatly preferred for benchwork.

The process should be straightforward at this point; blue the wedge to spot the exterior angle gauge. ***Photo 249*** shows the finished female and male angle gauges.

Now that we have the angle gauges all done, we can move on to the construction of the dovetail reference flat, which we will do in the next part.

Photos and drawings by Author

SCRAPING for the Home Shop

Part Nine

BY MICHAEL WARD

THE DOVETAIL SPOTTING TOOL

With the angle gauges completed, I was able to start work on the spotting tool. I chose a 1-1/2" × 1-1/2" piece of continuous cast iron about 1′ long. The first task was to square it up on all sides. I cleaned it up on the horizontal mill; a fly cutter in the vertical mill will also do (***Photo 250***).

A recent addition to my shop is a nice horizontal mill; can you tell how much fun I'm having with it? It's a real power house at material removal. For those newer to metalworking, this is a good example of getting the vise off the table and creating a setup for larger pieces. The work is clamped via homemade machinist clamps to a large angle plate bolted directly to the table. Two stacks of 123 blocks provide support under the work. The masking tape along the left side of the table keeps the cast iron (machined dry) out of the coolant return system.

A better setup still would have been to reverse the angle plate – the setup shown has the milling cutter's helix pushing the work away from the angle plate. This force has to be taken care of by the toolmaker's clamps, whereas a more solid setup would have the helix pressing the work against the angle plate. An improvement further still would have been to use heavy duty C-clamps. I recall trying them but found they fouled part of the setup. Depth of cut was only 1/8" so it didn't matter; I'm just noting it for posterity.

It's a good idea to take at least 1/8" off a piece of continuous cast iron, as there can be surface cracks in it. ***Photo 251*** shows the roughed out bar and quite a pile of cast iron chips. I like machining cast iron, good cast iron that is; not tractor wheel weights, barbells, or window sash weights where a glass-hard chill spot can turn the air blue. Many lament the mess as machining cast iron creates some black dust. However, machining Dura-Bar produces mostly chips, as can be seen, and the dust tends to stay confined to a small area. This bit of mess is offset by just how easily it machines, takes a good finish, and maintains its shape.

***Photo* 252** shows my setup for roughing out the 55° angle. Essentially, we want to remove about half of the bar. There are a few ways you could come at this. There is enough material left between the two opposing sides that you could use the same setup in a vertical mill with the head tilted.

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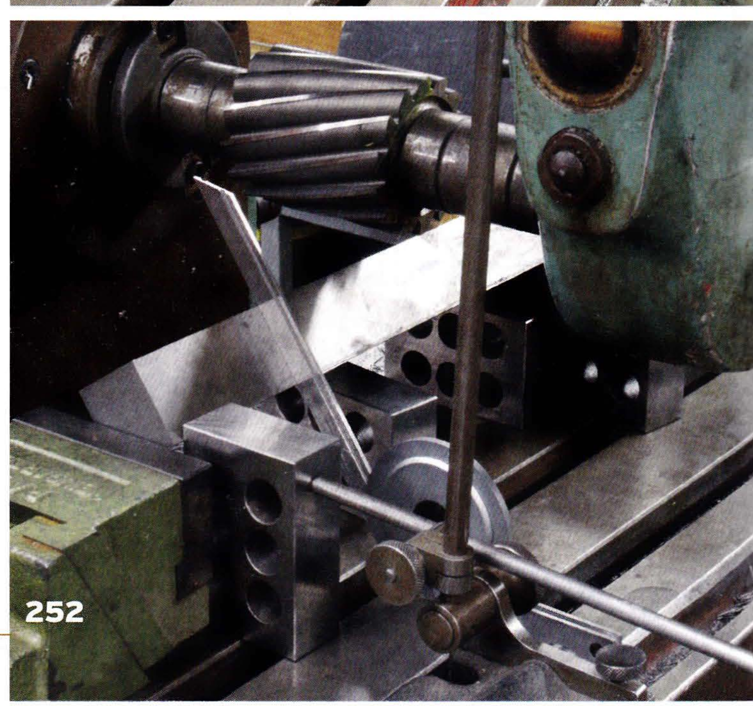

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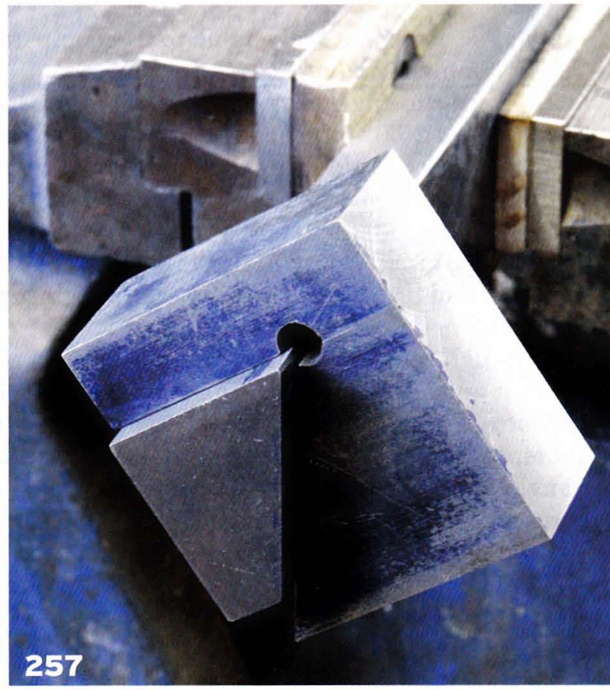
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Another option would be to drill and tap the ends of the bar and bolt it to a couple of angle plates, similar to ***Photo 253***, but using angle plates instead of the vise clamps I used. Set up as such, cutting could be done in a vertical or horizontal mill.

While my mill has the power to make this cut in one pass, the setup does not. If I recall correctly, I did this in several light 1/8" cuts.

Not surprising with this setup, the work bowed slightly, resulting in the initial pattern seen in ***Photo 254***. In fact, you'd be surprised to have something come directly off any mill setup and blue out well because, unless the work was perfectly flat to start, the warps and twists will return after the clamping force is removed.

After the fidgety bits of scraping the internal angle gauge, this wide open, flat scraping job will be a treat. Most of the work in this series has been hand scraping because hand scrapers are what the majority of readers are going to have access to. Wanting to complete this series within the current millennium, I grabbed the power scraper to speed up the roughing work. I suppose some highly skilled practitioners can finish things off with a power scraper; however, I view it as a time and arm saving roughing device, still requiring fine hand work to finish things. In fact, when I do attempt a finer finish with a power scraper I tend to take more of the weight of the scraper in my arms, which makes it tiring.

Photo 255 shows the pattern typical of the mechanical scraper. Passes are done at 90° to each other on about a 45° angle to the work. The 45° helps since it's best to approach an edge at an angle.

Work continues with hand scrapers. Almost every scraper I've seen, either commercial or made by others, has a long (12" +) handle. My guess is that this is a legacy of machine tool scraping where the jobs were large with lots of material to remove and required a whole body effort. For bench top work, especially in the vise, which positions the work higher still, these long


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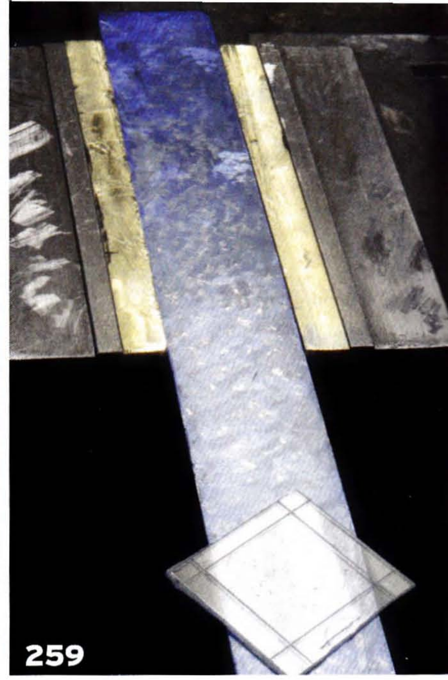
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handled scrapers are miserable to use compared to the shorty shown in ***Photo 256***.

I used the angle gauge to check the dovetail spotting tool (***Photo 257***). The second side is scraped flat and also to the correct angle using the angle block to check. Like almost all scraping jobs where we're trying to do more than just get things flat, you've got to read the patterns of the markings left by both the angle gauge and the surface and figure out where to scrape to bring things both flat and to the correct angle.

Rough scrape the surface using the surface plate to spot it and also keep checking with the angle gauge (***Photo 258***). You know what to do now; carry on and scrape the second surface until things are at the right angle with lots of bearing spots spread evenly over the surface (***Photo 259***). The angle can be checked anywhere along the tool; if both sides are flat (no twist) and one point is at the correct angle, all points will be at the correct angle.

This is the type of scraping that can be the most relaxing. It's not hard work and it tends to command your attention such that it becomes fairly absorbing. Don't stress about how long it takes or that we're working to extremely precise limits, just do it and enjoy the quiet shop time.

Maybe the biggest trick to scraping is judging when to transition from roughing to finishing. Finish scraping is time consuming work, but because roughing runs the risk of blasting past where we want to be and leaving new low spots, we tend to start finish scraping early, in order to creep up on the desired surface slowly. The time consuming part comes from the lack of 20 years of experience that goes with our amateur scraper status; we do 20 iterations of finish scraping that accomplish nothing as we creep up on things. It's sort of like switching from running to crawling while still half a mile from the finish line. Rest assured, things will improve with experience.

The good news is the difference between professionals and amateurs isn't the quality of work, it's just how long it takes us to complete things! The general strategy is to rough scrape until all regions get at least some coverage. ***Photo 260*** shows the completed gauges resting on the table they're about to be used on.

One thing I probably should have done was to drill a hole in each of the spotting tools for some round handles. The two scraped surfaces are literally so smooth that they are slippery. There is also an argument to be made that heat from the hands will change the shape of the gauge and handles of wood can prevent this heat transfer. While true, I wasn't overly worried about that in this instance, as the tool is small enough (the amount of movement from heat depends on the material, the temperature change, and the size of the item in question) and I keep handling time as short as possible.

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THE SCRAPING PLAN

Beyond getting something flat, parallel, square, or to the right angle, complexity is dramatically increased as you put more and more of these dependent relationships in sequence. It makes sense to puzzle through the sequence and how we're to get each surface flat and correctly constrained. We need to list out these relationships between surfaces and then come up with a way to check each to ensure that we aren't developing a sequence of operations that paints us into a corner.

Here's what needs to be done, not necessarily in order:

- **Table Top**
  - Front of table 90° to table top.
  - Front of table parallel to the T-slots.
  - Both horizontal dovetail surfaces flat, in the same plane to one another, and parallel to table top.
  - Both angle dovetailed surfaces flat, a constant distance apart, and aligned to the front of the table (this puts the front of the table parallel to the axis of motion and to the T-slots).
- **Saddle**
  - Upper two horizontal dovetail surfaces flat and coplanar.
  - Upper angled dovetail surfaces to match the table's.
  - Lower horizontal dovetail surfaces flat and coplanar and parallel to the upper horizontal planes.
  - Lower angled dovetailed surfaces a constant distance apart and aligned exactly 90° to the upper dovetails.
- **Base**
  - Two horizontal dovetail surfaces flat and coplanar.
  - Angled dovetail surfaces to match the saddle's.
  - Column mounting surface parallel to horizontal dovetail surfaces.
  - Bottom mounting surface parallel to horizontal dovetail surfaces.

Now that doesn't sound too bad does it? We'll add in making the gibs as well as we go.

When we're contemplating removing material, especially from a machine part or casting, always spend some moments in thought and inspection to develop a plan. Where are the constraints (i.e. the immovable reference points) that everything else must be brought into alignment with? Also, assess where things are close and where they're not; when deciding between two sequences or choices, which will require the least material removal?

Another important consideration is where will one part be used to scrape another? In those cases, we always want to use the longer pair of the bearing assembly to spot the shorter. The opposite, using the short to spot the long, is fraught with error.

I've not scrapped a horizontal mill; however, from examination prodded by Connelly's instruction, it seems clear that the immovable object is the spindle. If that were the scraping project, you'd start by ensuring those elements that must be perpendicular to the spindle were so, and proceed in sequence from there.

As this project is not yet part of a machine, I cannot identify that immovable element and hence I think we're free to either go bottom up or top down.

SCRAPING THE TABLE

Let's get started on the table. As the table is the largest surface we're faced with, it minimizes scraping by starting with it as our datum surface or original reference point. In other words, if they are out, it's a lot less scraping to bring the flat bearing surfaces of the dovetail parallel to the table rather than the table to the dovetail, just because of the relative surface area of each.

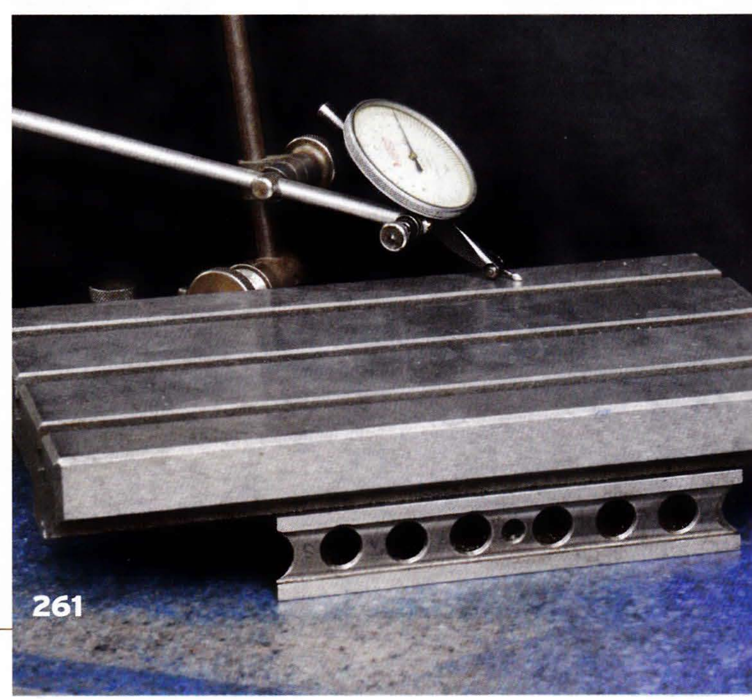
Our order on the table will be:

- Get the table top flat.
- Get the front of the table parallel to the center T-slot and square to the table.
- Get the flat bearing surfaces parallel to the table and coplanar to each other.
- Get the dovetail bearing surface flat and equidistant from each other and the front of the table.

Complications come from trying to achieve more than one objective at a time. It's like the old routine of the handyman trying to get the wobble out of a four-legged table, in which he keeps removing too much until the table is almost on the ground! We're not going to be a vaudeville act so working a plan, paying attention, and exercising care is the order of the day as we start tasks that require us to scrape to more than one objective at a time.

Let's start by figuring out what we are dealing with. I wanted to get a sense of alignment between the two horizontal ways and the table top (***Photo 261***). Check that your parallels are dead on with an indicator first. If you don't have a set that won't move a tenths indicator's needle, by this point in the series you are well equipped to bring about their manufacture!

Map the surface, looking for any areas that stand out. Ultimately we want the ways and the table top parallel. While of less area, the ways are trickier to scrape, as access is restricted and you can end up



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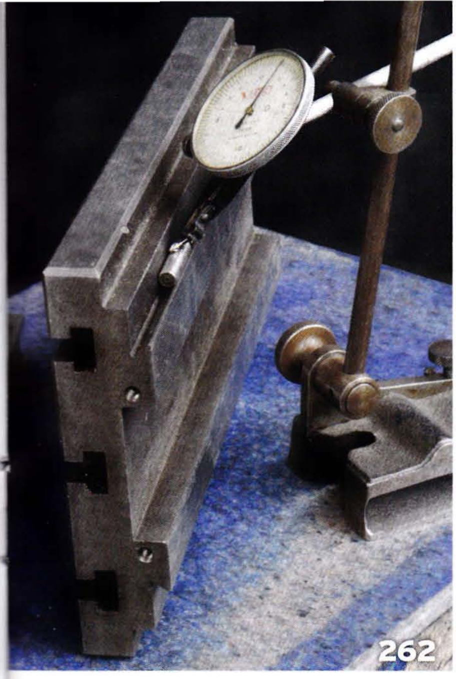
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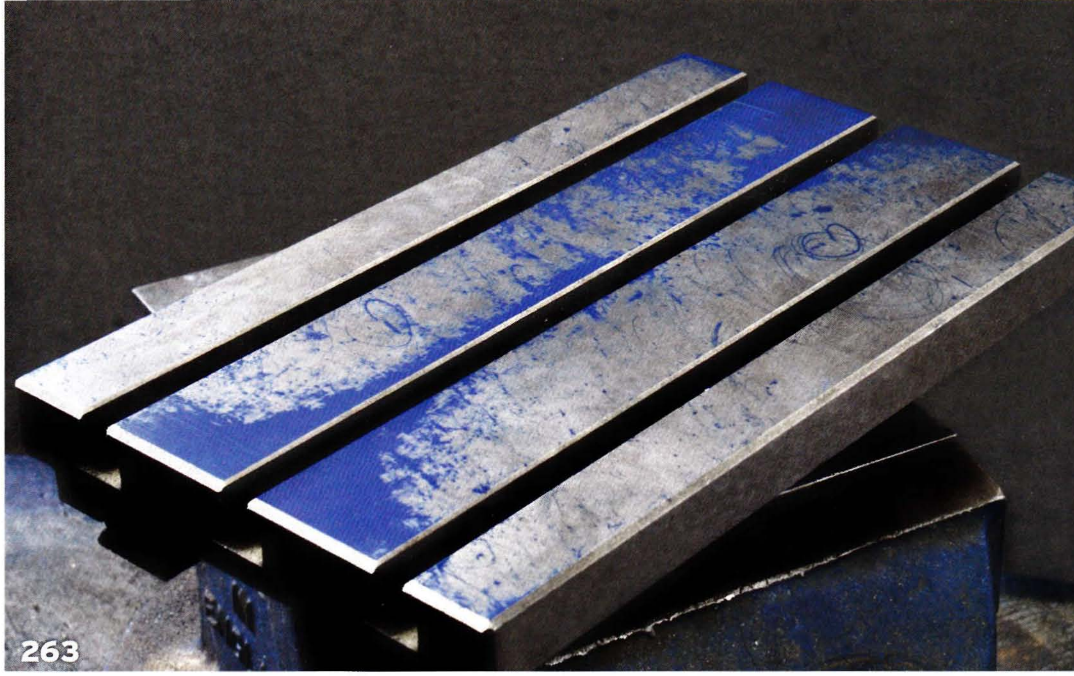
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changing the axis of the dovetail, but the table top is a larger area. What you find here will help in deciding whether to scrape the ways or the top first. If you are really paying attention, you might notice in the photo that I have the wrong surface of the table resting on the parallels (not the bearing surface). I corrected this but neglected to retake the photo.

For example, if most of the top is close to being parallel with the ways except for one end, it might be less work to scrape that end down. If, on the other hand, the ways and top are mostly flat but diverging over the length of the table, it might be easier to scrape the table top first then correct for parallelism via scraping the ways.

We also want the dovetail ways parallel to the front edge of the table and the center T-slot. ***Photo 262*** shows one way to check this. With an accurately ground pin (dowel, ejector, or wrist pin, depending on the size of what you are checking) placed into the dovetail angle,

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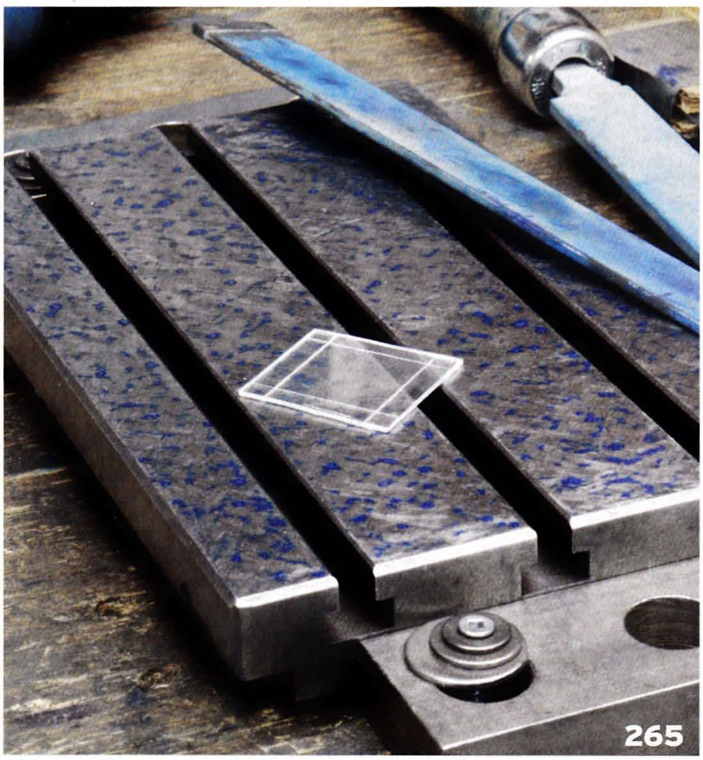

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it is easy to indicate the pin's relative height to the edge in contact with the surface plate. A better setup, which I did subsequent to this picture, is to lightly clamp the table to something square like the toolmaker's cube that was scraped earlier. After assessing things, I ended up going with what was intuitively the starting place: the table top. It's easy work on the brain, but tough on the arms.

Photo 263 shows the table top after a first spotting using a heavy layer of blue on the surface plate. As can be seen, there's some work to do.

After several iterations with a power scraper, the top is almost past the roughing stage. Almost all regions of the surface have at least some areas that are picking up the blue (***Photo 264***). This is definitely an instance where "zone roughing" works well; overlapping passes across all areas except those devoid of blue.

The roughing was done with a power scraper for expediency; hand scraping will get you there just as effectively but will be slower. Apply the scraper such that the direction is diagonal to the long axis so the edges are approached at a diagonal, and continue by alternating the direction by 90°.

The table shown in ***Photo 265*** is almost finished. It is not a sliding or gauge surface so at 10+ points per square inch, it is ready to go. To explain the work holding, the bench is a sheet of sacrificial plywood I keep as a protective layer over a woodworking bench. I've screwed two parallels to it and with the use of a wedge, jam the milling table between them.

The final step is a quick rub down with some WD-40 and a hard Arkansas stone (***Photo 266***). The WD-40 stops the stone from loading up, while the exceptionally fine abrasive action of the Arkansas stone removes small burrs and puts a polish on the bearing spots.

Next up is the front edge of the table. This surface serves several functions, both operationally when using the mill and as a datum or reference surface for the scraping. Operationally, if the table edge is parallel to the axis of motion we can set work or a vise up on the table using a square or other tooling. The ability to square things to the front edge makes it a convenient and accurate reference for setups.

We also want the T-slots to be aligned with the dovetail motion so that if, for example, our vise is keyed accurately with the T-slots it will result in the vise jaw being parallel to the axis of motion. The table edge will also be used as a datum to compare and get the T-slots parallel to the dovetail.

First off, the edge has to be square to the table. If it wasn't, then we couldn't rely on the depth measurements we're going to make between this edge and the dovetail and T-slot. ***Photo 267*** shows the inspection of the edge using a hardened bevel edge square. These squares, this particular one a Schweitzer from Germany, are well-made precision instruments. They must be handled with care, ideally with a soft cloth or gloves to keep hand heat away and are only used for the inspection of precision parts. For less demanding work, a machinist square is used, which is checked for accuracy with the precision square.

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Aside from being very accurate (about .0001" square over its length), its advantage is the bevel edge, which allows great visibility on the area of contact between the square and the subject. In the photo, the visible triangle of light clearly shows the surface is out of square to the table top. While this might look like a lot, a .0015" feeler gauge cannot be inserted; the gap is probably around .001". It's generally accepted that most people can see light through a gap of .0001". With that in mind, we'll inspect again after some scraping.

In ***Photo 268*** you see one way of inspecting the distance from the table's edge surface to the T-slots. A small adjustable parallel is wedged in the T-slot and a depth micrometer is used to check the measurement at each end of the table. After this photograph, I switched to checking the center T-slot, which is much more relevant as it's the one that the vise is likely to be keyed to. Meanwhile, the photo is included to demonstrate the technique.

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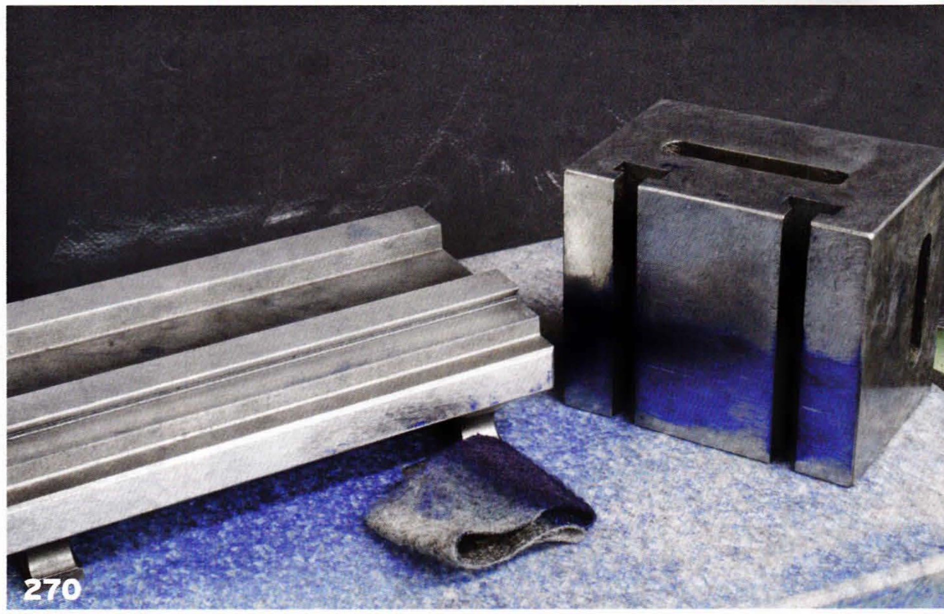
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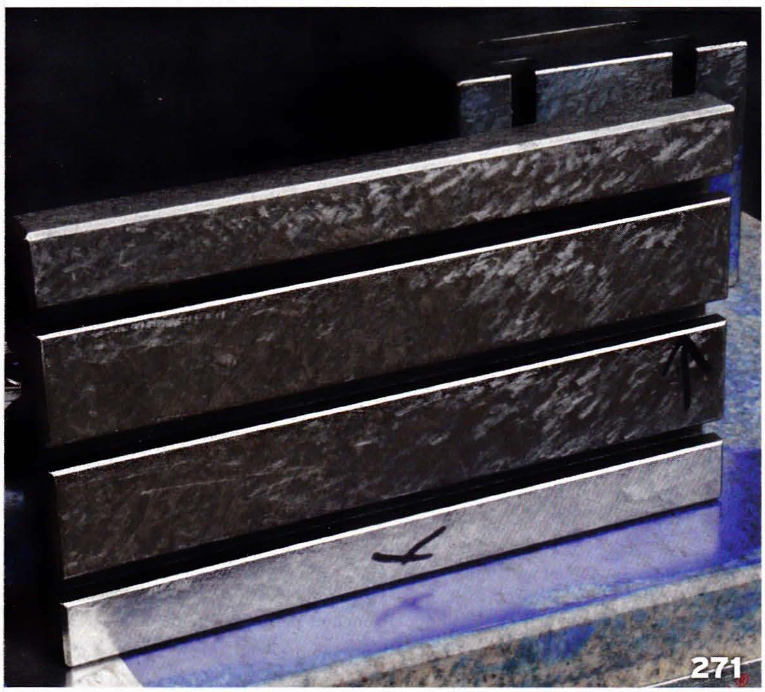
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Photo 269 shows one method to check the alignment of the edge of the table to the dovetail. Using a depth micrometer, the distance between any ground pin seated in the dovetail and the table edge is measured from one end of the table to the other. This is important, as we want the front edge of the table and T-slots to be parallel with the axis of motion.

This inspection showed that the front of the table and the T-slot were out by about .002" and that the front of the table was not square to the top. The dovetail was also out; however, as scraping the T-slot would be next to impossible, it makes sense to work from the T-slots outward. We'll use the T-slot to scrape the edge, then use the edge to scrape the dovetail. I used the toolmaker's cube to spot the front edge of the table square to the top (***Photo 270***).

In ***Photo 271*** I am in the process of spotting the front surface of the table. A black marker is handy for making notes on the work so you can keep track of which surface needs to be brought towards which direction. You can see a piece of .001" thick shim stock under the left side of the table so that my spotting, using a thick coating of blue on the surface plate, is concentrated toward the end that is high.

After a while, I managed to get the table edge within a couple tenths of an inch to the T-slots using the inspection method shown in ***Photo 268*** and quite square to the table surface as shown in ***Photo 272***. With only a small bit of light on the far left-hand side of the area being checked, I believe we are square to .0001" over most of the surface. The test for parallelism to the T-slot was within a couple of tenths (my depth mic only reads thousandths but I can estimate a quarter of a thou on the scale). This is more than accurate enough given that the T-slot itself is a milled, non-precision surface.

Now for the bad news: You probably haven't

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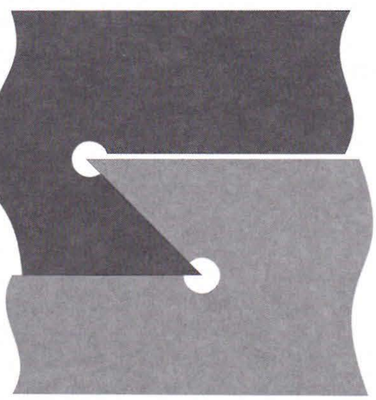
realized it yet, but scraping as you know it has been a blissful, relaxing exercise with the enjoyment of accessible, wide open surfaces. An appreciation for these wide open plains will soon develop as we take on the frustratingly confined and narrow dovetails.

SCRAPING DOVETAILS

Like all our work, it's never particularly difficult when broken down into its constituent operations; however, scraping the mini-mill's dovetails certainly registered with me as the most frustrating and time-consuming job in this series. I have scraped the dovetail ways of a full-sized vertical mill and, while the work inside a narrow angle is less convenient than wide open flat surfaces, it is comparatively quite doable. What makes these dovetails so frustrating is that they are so small.

As work progressed through the dovetails, I became rather critical of the mini-mill's dovetail design. The angled portion of the dovetail is around 1/4" wide. As clearance is required at the apex of the surfaces (***Figure 21***), the geometry is such that there is approximately only 1/8" of contact between the mating parts on the angled dovetail surface. You will definitely need some narrow scrapers if you take on this task. I made the small scrapers (shown in ***Photos 276*** and ***277***) specifically for this job, utilizing a small piece of carbide 1/16" thick.



Dovetail corners should have reliefs

Figure 21

Another amusing discovery is that while there are ground surfaces, they are the wrong surfaces. ***Photo 273*** shows where I am just beginning, on the table's horizontal section of the dovetail. The surface marked "+1" (meaning that dovetail element is .001" high at that end) is nicely ground; however, it is the rough, tool mark scarred and scored surface just below it that is the bearing surface!

Start with a rough scrape of the two dovetail horizontal elements (***Photo 274***). Once you get these somewhat within a plane, take the table to the surface plate, top surface down, and check these two surfaces with an indicator.

I run the risk of the following statements sounding like conflicting advice. In the sense of what's required to make a perfect working dovetail, we don't much care that the two surfaces are at the same height; the dovetail way will work perfectly without them being coplanar. However, they absolutely must be parallel. We want no difference in indicator reading from all four corners on either side. This will ensure that the table doesn't bind and that one end of the table is exactly the same distance to the spindle as the other along the X-axis of movement.

When it comes time to scrape the saddle I'll rely on the horizontal elements of its two dovetails to be coplanar to get things right. If the saddle's horizontals are coplanar, then so must be the table's.

The point is, as you are working your way through a scraping plan, you need to be aware that certain things are needed to affect the bearing and certain things are need as datums to permit the sequence. Let's look at and carve out what is required for a dovetail without, for a moment, worrying about the rest of the sequence.

Each set of dovetails (two mating parts) involves eight surfaces. Assuming the mate is a perfect match, examining just one part (half of the dovetail bearing) involves four surfaces – two horizontal and two angled surfaces.

We know it is critical that all four surfaces are perfectly flat. We don't want any twist or curvature to them. Also, the two horizontal elements can't be going uphill or downhill relative to each other and the table top – they have to be parallel. I think that is fairly intuitive. A check for this is readily done with the

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surface plate and indicator.

Finally, the apexes, where a horizontal surface meets its corresponding angled surface, must be parallel to each other and to the part's axis. If this were not the case, the dovetail would be narrower from one end to the other, leading to a sloppy fit in one position and a tight fit in another. Again, this is intuitive. This is conveniently checked by placing a ground pin (I used appropriately sized dowel pins) in each dovetail and measuring the distance across them.

Beyond those two items there exists a lot of different conditions that will still produce a workable dovetail. Consider ***Figure 22***. In the first image (the stylized dovetail part "A") the horizontal surfaces are coplanar and the angular surfaces are at exactly the same angle. This is the ideal construction and what I've strived for.

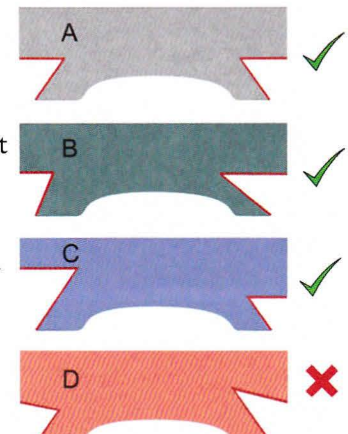


Figure 22

In image B, the horizontal elements are coplanar but the angled surfaces are not at the same angle. This produces a perfectly fine, working dovetail. I went with a dovetail spotting tool accurate on two surfaces so I am able to produce dovetails as per image A, although it is a lot of work. A single surface spotting tool of a smaller angle than the dovetail used without an angle gauge might produce dovetails with different angles, as shown in image B, but will create a dovetail every bit the functional equivalent of the one shown in A.

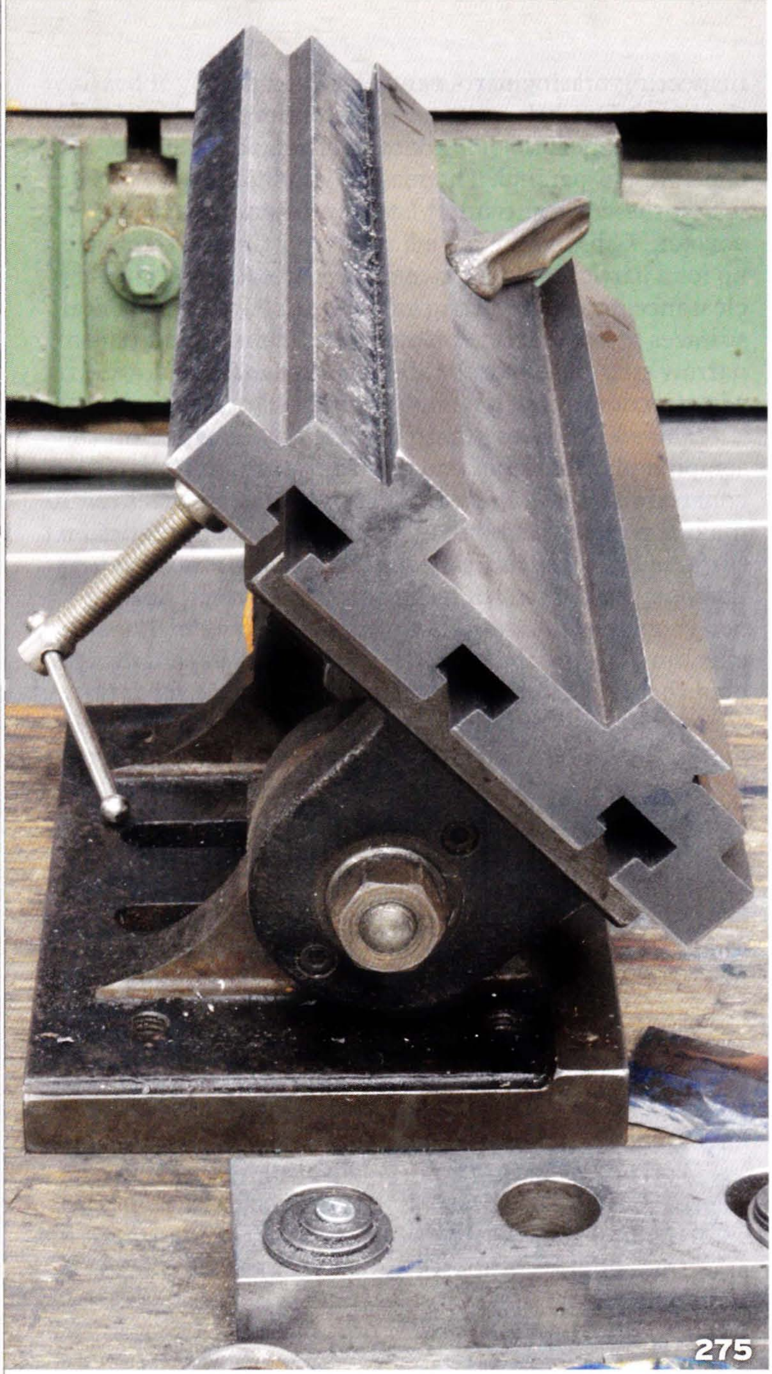
Image C has the horizontal surfaces parallel but not coplanar. While in the image the angles are the same, they don't have to be. Image C can work, producing perfect linear motion. In my opinion though, this is less than ideal. If they're not coplanar, scraping and inspecting mating parts can be challenging.

Image D, while quite exaggerated is not acceptable. In this instance, the horizontal elements are neither coplanar nor parallel. The reason why this doesn't work is that there is some small lateral movement with the dovetail. Gibs, which are adjusted over time or tightened up for a particular job, move things laterally and alter the clearance between the angled dovetails. If the horizontal surfaces aren't at least coplanar, the binding of a very narrow strip of support would result in making dovetail adjustment (or even assembly) impossible.

The point for including this is that the ideal scraping plan incorporates the minimum number of constraints of surface relationships to one another to make a perfect mechanism and also the required datum surfaces from which to check/measure those constraints through the sequence. For example, a dovetail doesn't need coplanar horizontals to work but how I'm checking later surfaces in the sequence does; create a plan that does both while minimizing the number of constraints. On the other hand, scraping a tool bit feed mechanism on a shaper probably wouldn't require the horizontals to be coplanar and simply being parallel would suffice.

In scraping the dovetails, you are essentially trying to see and work into a groove. Being able to constantly change the position of the work depending on what part of the surface you're scraping is a significant advantage. In ***Photo 275*** I've deployed an adjustable angle plate as a movable work surface on which to scrape the dovetails. An adjustable light, the type with spring-loaded parallel beams, is very handy. To do these small dovetails you have to position the work so you can get at it and you have to be able to clearly see the spotting marks.

Work always begins on the dovetail by scraping in the two horizontal surfaces. While I made the dovetail spotting tool accurate in two planes, only one is used at a time. ***Photo 276*** shows rough work on the horizontal plane.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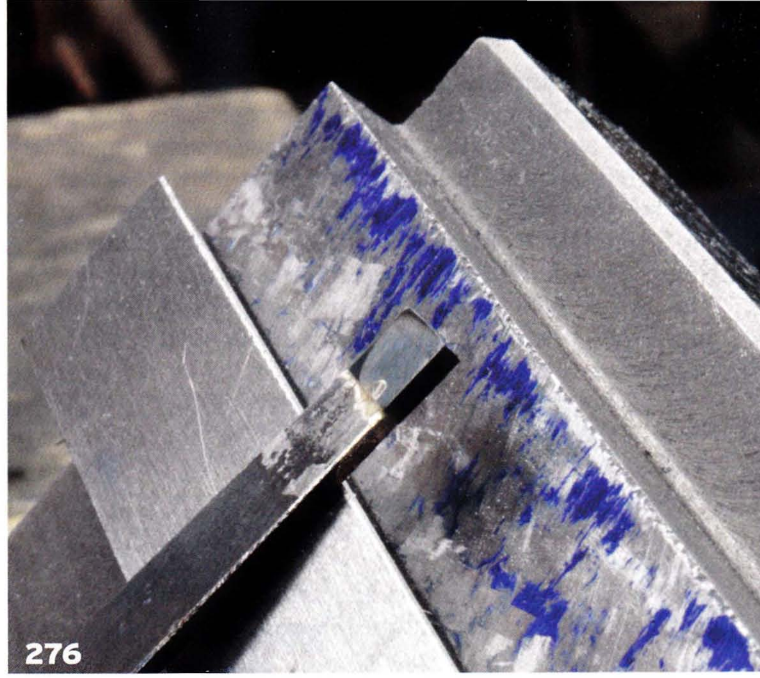
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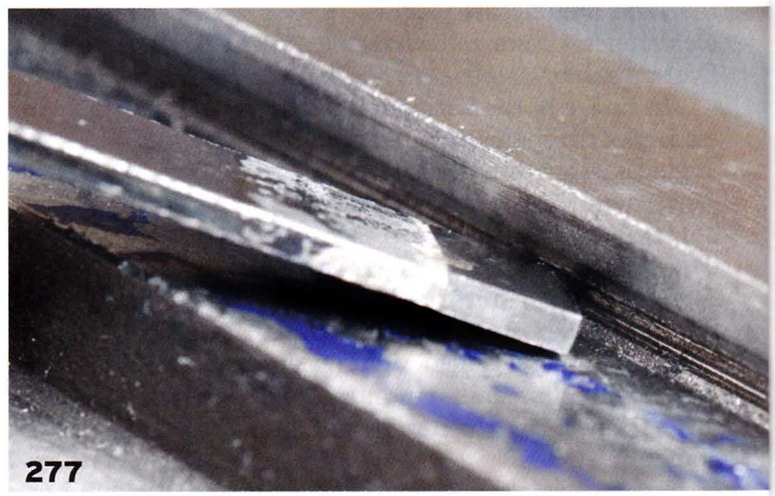
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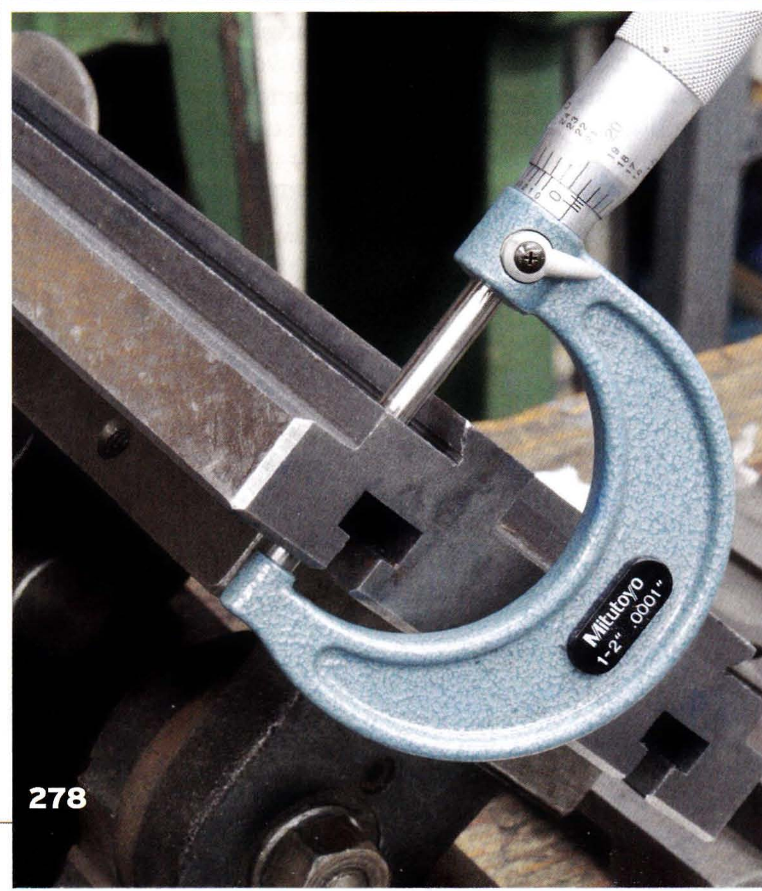

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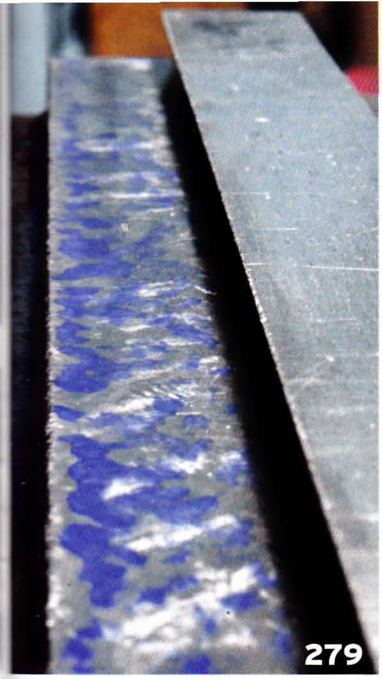
What makes this such a tedious task is that rough work is a misnomer – you want to do roughing but the constricted space and small scraper make the action more like finish work right out of the gate. ***Photo 277*** shows the smallest of the scrapers I made reaching into the corner.

Photo 278 shows a check of the horizontal surface to tabletop dimension. Keep performing this on each end of the dovetail horizontal surface as you go along as an on-the-fly check. However, the final arbitrator is a tenths indicator on the surface plate. The reason for this is that the mic will show the difference end to end but the wide area of the anvil makes it less revealing side to side on the surface.

These small parts are readily lifted onto a surface plate to indicate for parallelism. If you're working on a full size machine, this is not so easily accomplished. In that case, all manner of ingenious devices to hold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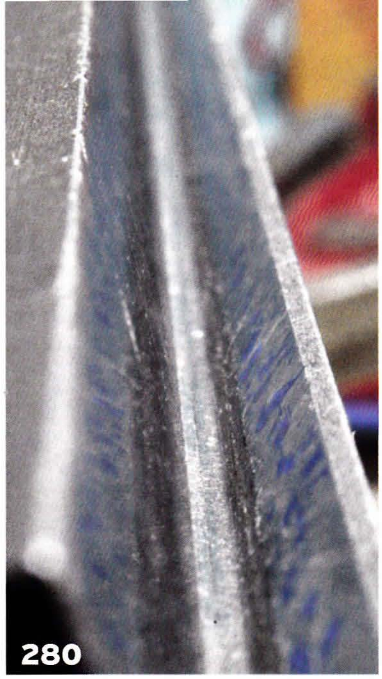
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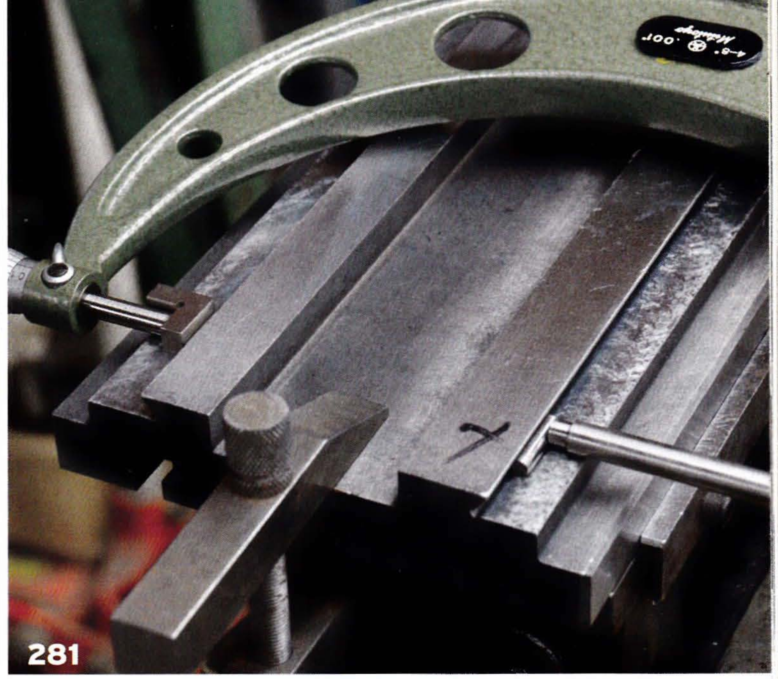
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indicators can be deployed, a great number of which Connelly details. For simply getting two surfaces coplanar you can mount an indicator in a sturdy surface gauge with a long arm. Place the base on the completed horizontal element and with the long arm's reach, indicate the other.

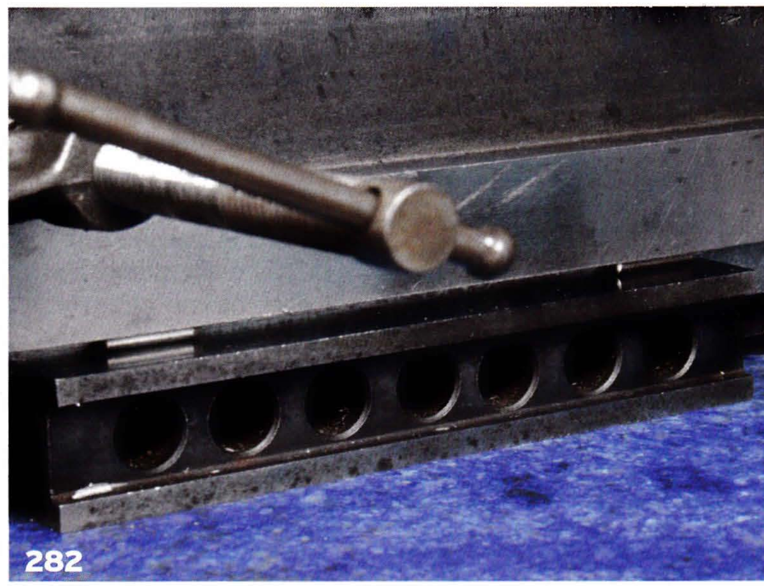
Work is just about complete in ***Photo 279***. Work then shifts to the two angled dovetail surfaces. Start with the angled surface next to the scraped front face. Using the methodology presented in ***Photo 269***, scrape this narrow surface flat and equidistant to the front of the table using a ground pin to check. The spotting tool is rested on the freshly scraped horizontal surface and used to spot the angled surface. As mentioned, the very narrow surface is only about 1/4" wide and would be difficult to spot without being able to rest the tool on the larger horizontal surface.

This is not an easy operation, scraping this finicky, constricted area. However, with perseverance, this too shall pass and you'll get to a similar state as shown in ***Photo 280***, with the angled dovetail surface almost complete.

As work begins on the second angled surface, it is important that it is exactly the same distance from the first along the axis of the part. We now have a T-slot parallel to the front of the table and parallel to one side of the dovetail. Scraping the second equidistant from the first is a simple matter of measuring across pins placed in the dovetail. This will serve to not only have smooth, non-binding motion of the dovetail, but all that motion will be perfectly parallel to the T-slot and front face.

Photo 281 shows this check in progress. The small ground "L" shaped piece on the left is just there as packing. The micrometer frame would otherwise foul on the horizontal surface.

Checking with the micrometer is a good way to monitor the work in progress, but a more accurate inspection is done on the surface plate with tenths indicator. I set the table up on two pins and then indicated along the mating dovetail (***Photos 282*** and ***283***).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283

With the table done, we'll start in on the saddle in the next, concluding part.

Photos and drawings by Author

SCRAPING for the Home Shop

Part Ten

BY MICHAEL WARD

THE SADDLE

With the table completed, let's set it aside and focus on the saddle (***Photo 284***). As well as two sets of dovetail geometry to scrape in, the saddle carries the additional challenge in that these sets need to be scraped perpendicular to one another.

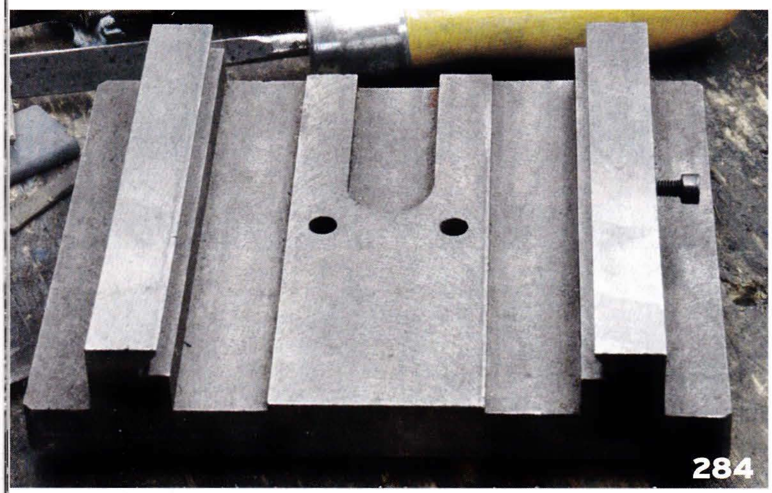

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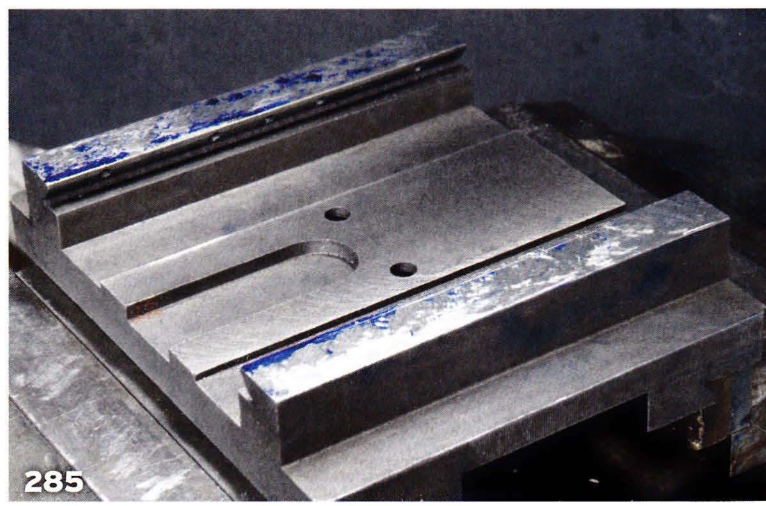
Photo 285 shows the roughing out of the two horizontal surfaces that mate with the table's. It's a treat working on these open surfaces after the last operation; however, our respite is brief.

I rough scraped these surfaces using the surface plate for convenience and then finished them by using the table as a spotting tool in scraping them to the table. The reason is that, while I'm satisfied that the table's surfaces are coplanar to a tenth or two of a thousandth, the surface plate is more accurate than this over a small distance. In other words, we could scrape these surfaces to the plate and not necessarily get a good bearing against the table's surfaces if one of the table's surfaces happens to be a tenth or so higher or lower. Final scraping of the two surfaces was done by smearing a thin layer of blue with the felt pad to the table's surfaces and using it as a spotting tool.

Photo 286 is a close-up of the saddle's angled surface. Of course, there are two angled surfaces; however, we are not going to bother scraping the angled surface on the side of the gib. As hopefully is conveyed in this photo, the surface is very rough. When you get close-up to the surfaces you can see the temptation to throw a little lapping compound in to smooth things out. Things



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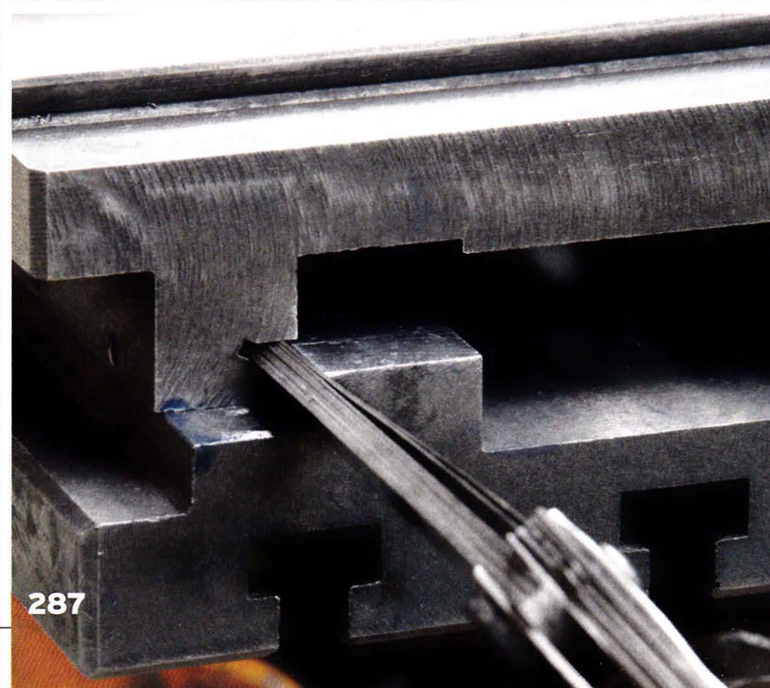

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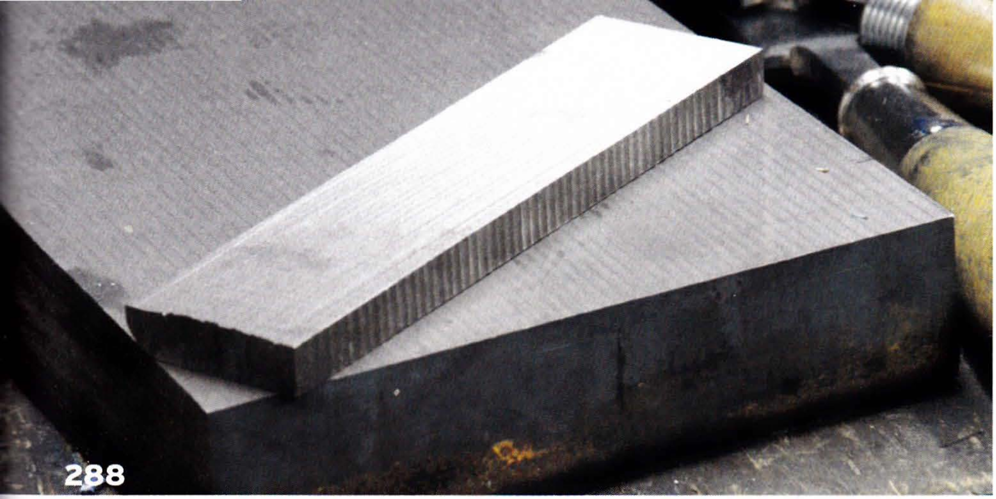
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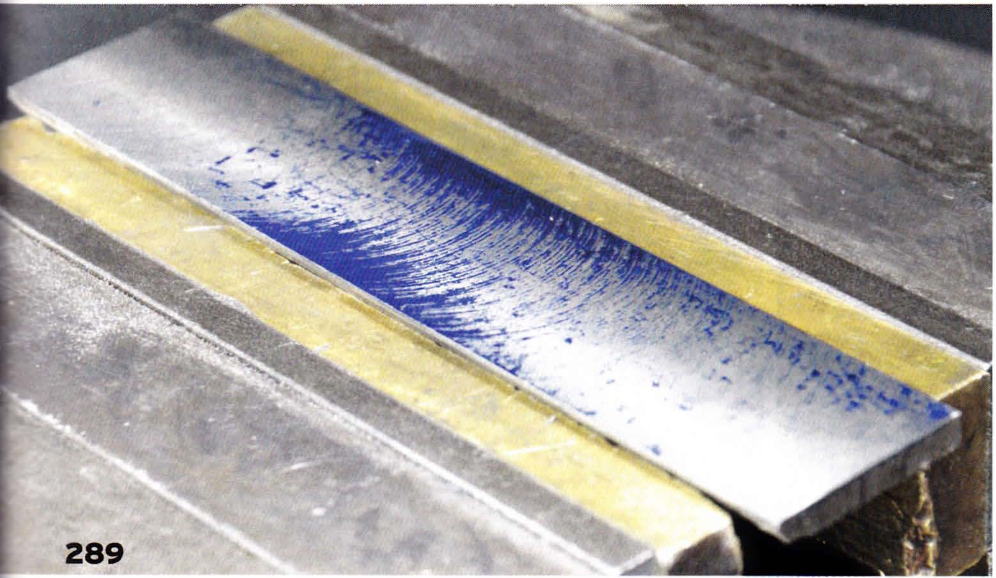
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would be smoothed out, but it would be at the expense of accuracy. Scrape this dovetail flat and to as high a number of bearing spots as you have patience for.

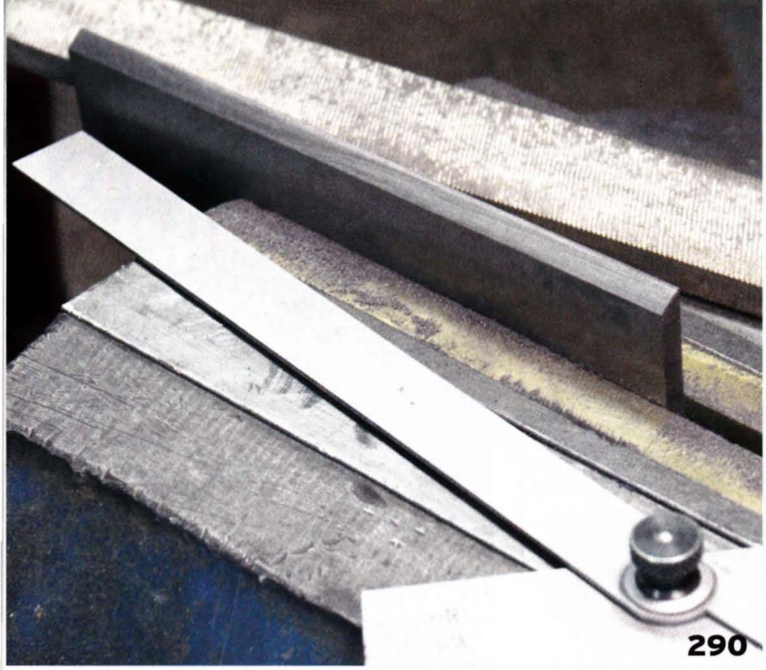
MAKING A GIB

Three of our four mating surfaces are done and in direct contact with each other. The final surfaces though have a gib as an intermediary. The gib gives the ability for lateral adjustment. This provides for everything from a way to lock the slide, adjustability for different machining operations (tight is needed for some operations, but makes things wear more quickly), a way to take up wear, to making assembly easier by providing greater temporary clearance.

As there is a gib on one side, we need only to scrape one angled surface on this part of the saddle. Go ahead and put a little oil on the bearing surfaces and see how beautifully smooth the motion is between the parts. With the parts placed as such, we can measure the thickness of the required gib using feeler gauges (***Photo 287***). Fortunately, I had a set of feeler gauges whose ends come to a taper and were able to fit the very small gap.

It's at moments like this when I take comfort in having large blocks of cast iron cutoffs lying about. I suppose it takes a unique personality to find comfort in idle blocks of cast iron, but I'm sure a great number of readers can relate. ***Photo 288*** shows a small slice from which I'll make two gibs – thank goodness for band saws.

I milled and fly cut the burgeoning gibs to approximate size and then scraped one surface flat. I've just done the first spotting and am about to start roughing in ***Photo 289***. As described earlier, it can be challenging to get a piece such as this flat; even surface grinding is quite challenging, as the magnetic chuck will



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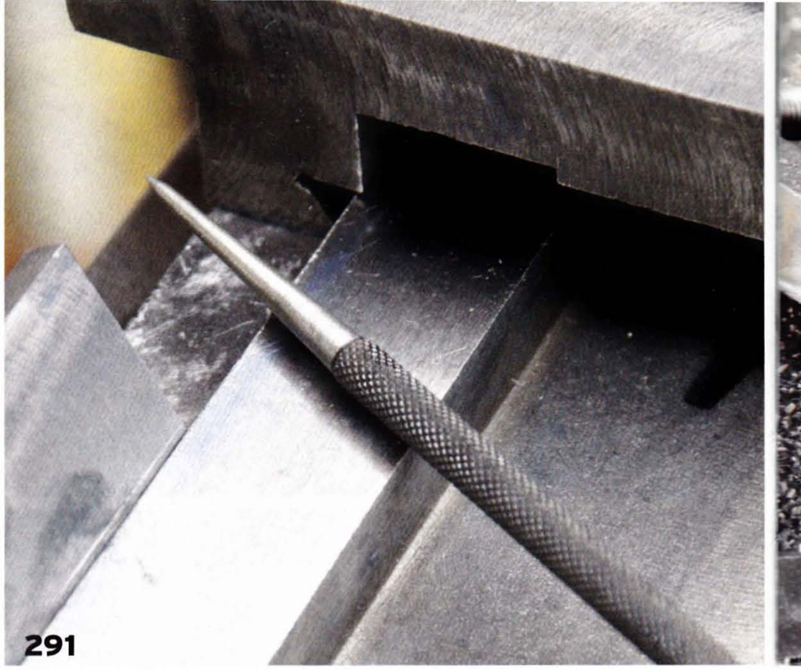

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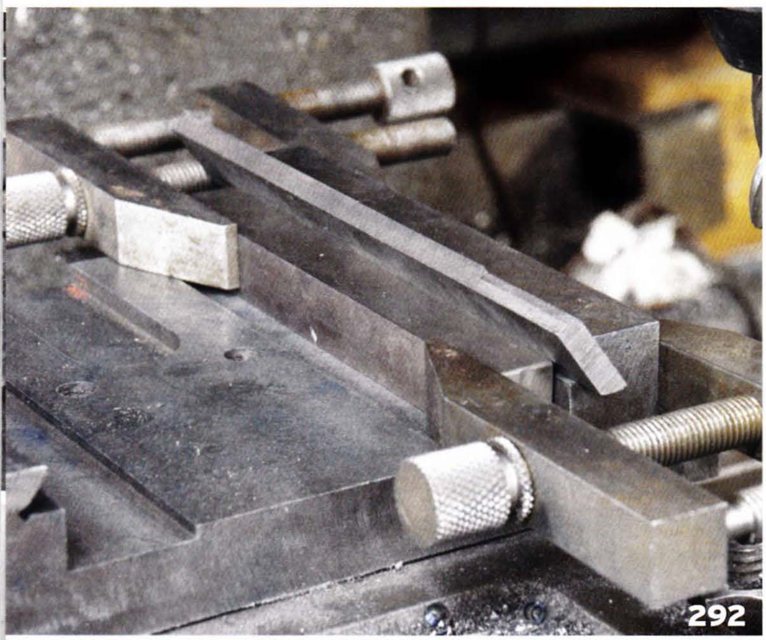

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temporarily pull a curve out of the piece only to have it return when the force is released.

Using a file and protractor, one edge of the gib was tapered (***Photo 290***). This is approximate work only; the final angled surface will be accurately milled.

Using the saddle as a guide, I marked where the gib blank needed to be ripped in two. The width of the gib is marked with a scriber (***Photo 291***). This is just to gauge where to cut the piece in two lengthwise to get the two necessary gibs out of it.

The angles on the gibs are easily manufactured if we use the female dovetail itself as a fixture. In ***Photo 292*** you can see the saddle being held in the mill's vise and the gib next to the angled dovetail surface. A rectangular piece of steel, selected such that one of its edges engages the gib at about the halfway mark, makes part of a clamp. Using the machinist clamps (homemade of course) the gib is held in place against the angled edge of the saddle.

Photo 293 shows the milling under way. Take one pass to set the correct angle, remove the machinist clamps and flip the gib over. Mill the second side and we now have a gib in a perfect trapezoid profile. The final pass should be about .001" lower than the horizontal scraped surface. Be careful to set the end mill over just at the edge of the gib so that it does not cut into the horizontal surface.

Take the gib to the surface plate and on the surface that contacts the table, put on a fine scraped finish (***Photo 294***). ***Photo 295*** shows the gib in place. Obviously, if the sharp corners of the trapezoid foul the clearance grooves in the corners of the dovetail, file them back to suit.

Prior to this project, all the gibs I've worked on have been tapered or larger shapes and have been made of cast iron. I have no knowledge of what is normal for these smaller trapezoid gibs, as this is the only minimill I've worked on and the castings arrived without gibs. However, I recently heard mention that this style is frequently made of steel. A proffered reason was that


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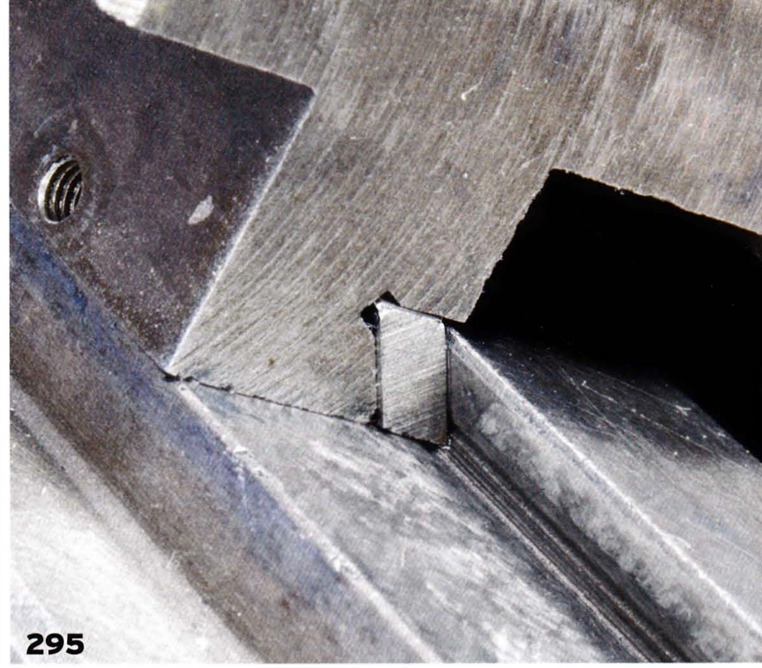
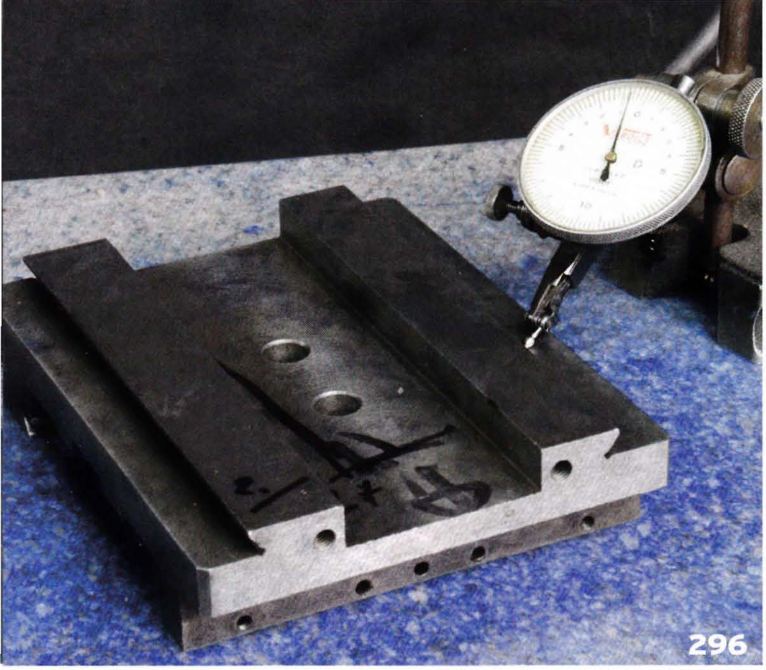
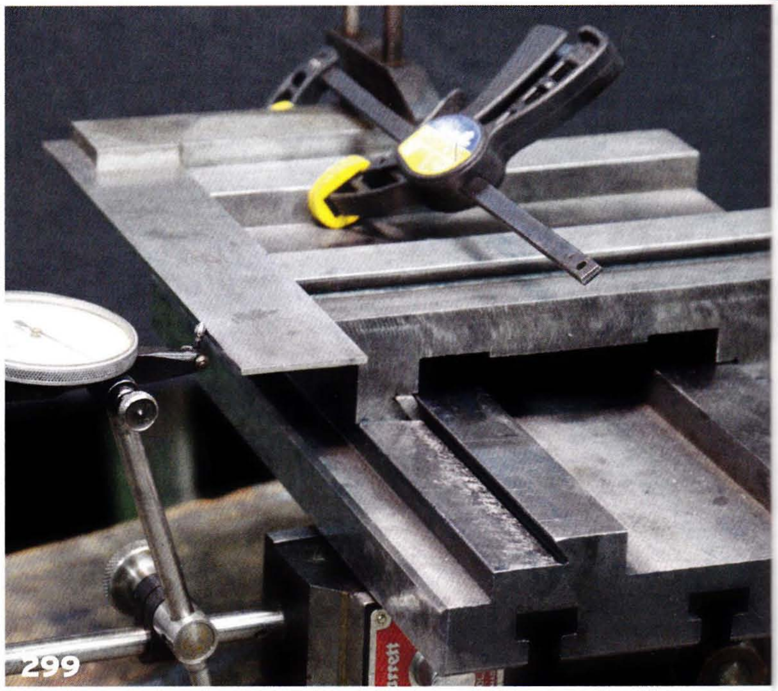

295

the thin section of cast iron is subject to breaking, cast iron being more brittle than steel. I haven't had a problem with mine (yet!) and suspect a large part of the reason steel is used would be that these mills are built to some pretty amazingly low price points, but that's not to say the point is without merit and that the comparative brittleness of cast iron isn't an issue. With the gib fitting properly, the point of stress would be the point loads exerted by the adjustment screws. Perhaps round brass pads with their ends angled could sit in the hole between screw and gib and would diffuse the point loads such that the cast iron is safe. It does seem like a rather crude arrangement having the end of the screw pressing against the angled surface of the gib.

The next operation is done on the horizontal surfaces of the saddle that mate to the base. As mentioned earlier, this is an example of a part that would be difficult to check if the bottom set of





horizontal elements were just parallel and not coplanar.

As always, work commences with an assessment of what we're up against. ***Photo 296*** shows these surfaces being checked for parallelism with the horizontal dovetail surfaces on the opposite side of the saddle via surface plate and indicator.

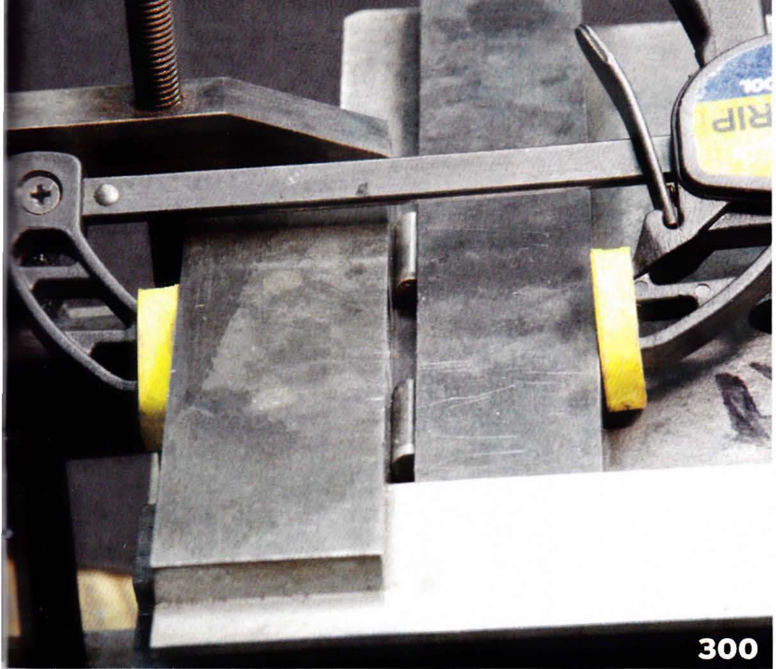
Photo 297 is a close-up of the saddle's second set of horizontal surfaces. Again, incredibly, the nicely ground surface is irrelevant and in contact with nothing. It is the very rough surface, with the roughness highlighted by my first few scraping strokes, that is the dovetail bearing surface.

For working on these two horizontal surfaces, task lighting, an adjustable angle plate, and small scrapers are the order of the day (***Photo 298***). These two surfaces are made flat and coplanar, which is well covered ground by now.

What is new territory though is getting two perpendicular dovetail ways square to one another. While we can do origination, the two basic conditions we are constantly trying to create or check, namely flatness and/or squareness, come essentially from comparison. The surface plate is used for flatness and the precision machinist square is used for squareness.

The idea then in checking machine bearing surfaces is to somehow register one blade of the square such that the other blade is parallel to a second axis of motion. ***Photo 299*** shows one such setup. The saddle is on the inverted table. As shown in ***Photo 300***, dowel pins keep the edge of the square aligned with the recently scraped dovetail. As the square is quite a bit larger than the dovetail itself, I had to use a small machinist clamp to hold the square to the horizontal dovetail surface while a padded quick-grip clamp holds the square against the dowel pins.

A regular blade precision square is shown in favor of the bevel edged square. The bevel edged square is great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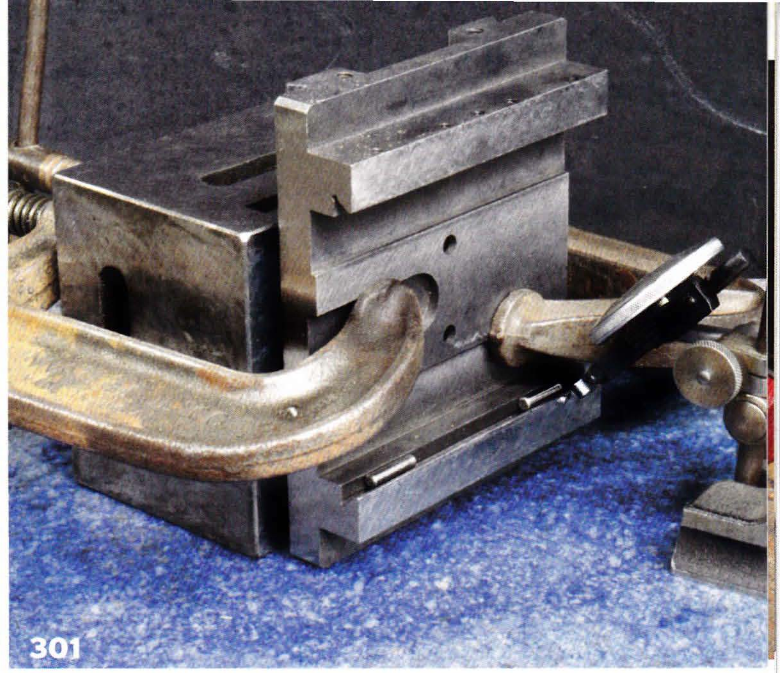
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at revealing where there is contact but we need the wider surface the regular blade provides to run the indicator against.

As the saddle is moved back and forth along the table, an indicator mounted to the table reveals any change along the square's blade. This was the worst area on my mini-mill, with the two dovetails being out by about .002" over the length of the 6" blade.

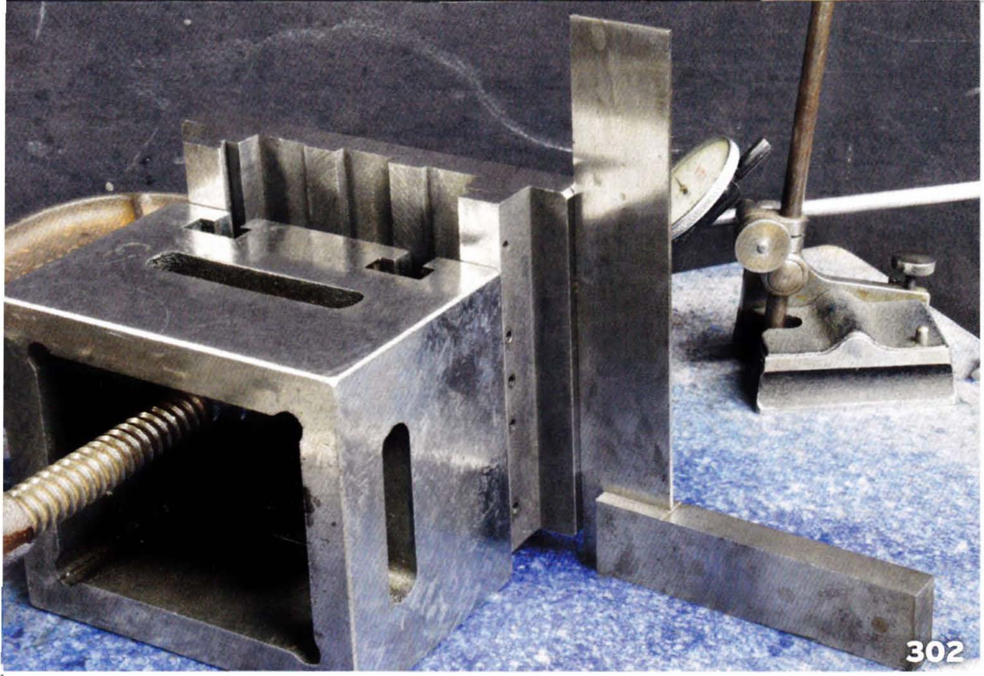
This is fine and good, and on large machines you will often have no choice but to indicate squares held in relationship to those surfaces being checked; however, it is a lot to set up for each iteration of scraping. As the parts involved are small, there are some shortcuts we can take. I decided to finish the two outside edges of the saddle to be exactly 90° to each other and such that one of them is parallel to the dovetail mating to the table. Bear with me and hopefully this will make sense.

Photo 301 shows the saddle clamped to our very accurate toolmaker's block. It is clamped such that the two ground pins resting in the scraped dovetail (that mates with the table) are exactly the same height as read by a .0001" indicator – it is gently tapped into position until it is so.

I then mounted the block on the surface grinder and ground the top. Lacking a surface grinder, a very light and fine cut with the mill should produce an accurate datum surface. This, of course, is easy to check with an indicator using a setup similar to that shown in the photo.

This gives us one saddle end surface ground parallel to the table's dovetail, which has been scraped in. Set the saddle back up on the block, but indexed 90°; use a precision square on the surface plate and against the just ground/milled surface (***Photo 302***).

We now have two convenient datum surfaces perfectly square to each other and one parallel to the first set of dovetails. Getting the second set of dovetails that mate with the base perpendicular to the first was a simple matter of measuring the dovetail's distance from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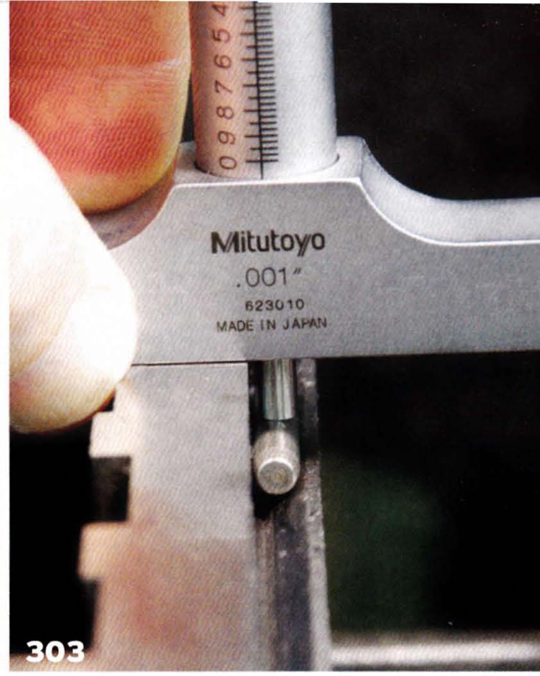

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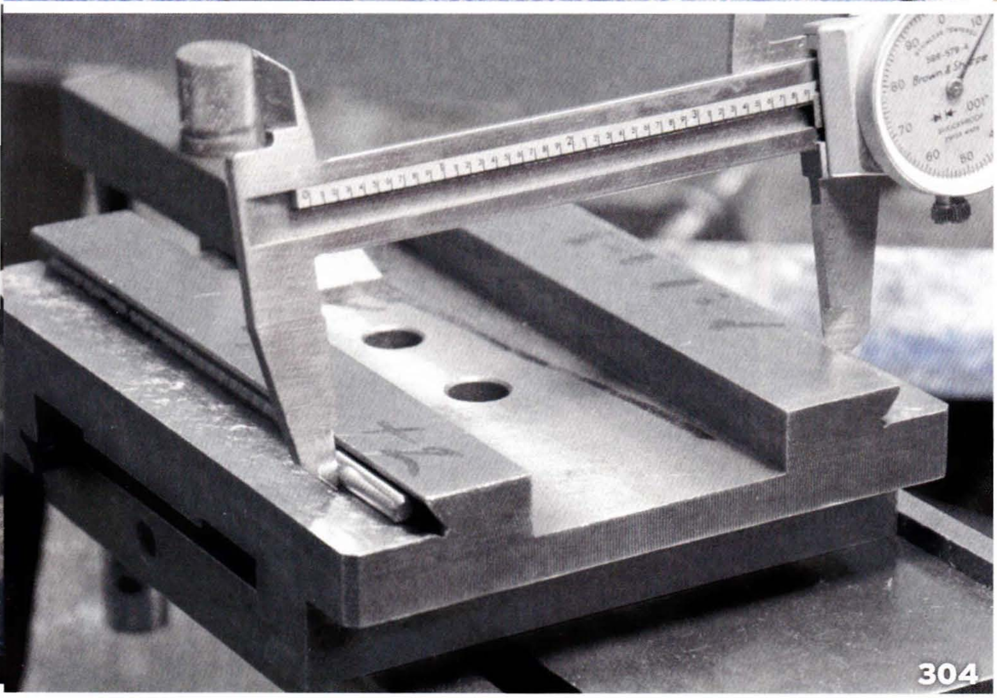
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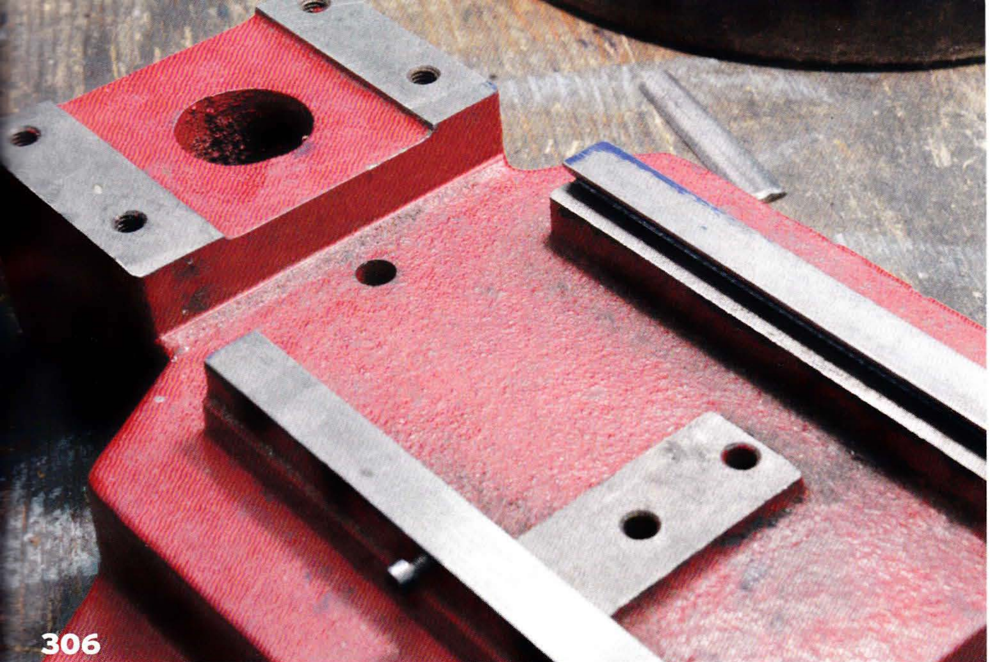
305

this datum surface (***Photo 303***).

It's worth doing the test shown in ***Photo 299*** first though. If you are only out a few tenths it might not be worth grinding/machining the two datum surfaces. Of course, there's no reason you would have to create the two square datum surfaces at all, it was just a convenience. The square/indicator setup shown in ***Photos 299*** and ***300*** is time consuming to set up, a bit precarious, and would have to be done constantly throughout all the iterations required.

The second dovetail is brought into alignment with the first by the now familiar technique of measuring across the pins (***Photo 304***). If you do not have a large micrometer, don't despair. First off, on a small job like this the final arbitrator of accuracy is an indicator and the surface plate. For occasional checks as you go, a caliper will suffice. While calipers are not nearly as accurate as a micrometer in terms of measurement, in this instance the measurement matters not; we simply want to compare the distance at both ends of the dovetail. As a comparative device, with a bit of practice, the caliper does a reasonably good job. Take several samplings until you can get consistent readings and I would hazard to bet that you are then getting quite an accurate comparison.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Out of curiosity, I also tried comparing using a sprung caliper, imagining myself an early 19th century machine builder (***Photo 305***). The dial caliper is definitely preferable and I doubt I was able to sense more than a couple of thousandths difference with the sprung caliper. Those 19th century mechanics were good and had the touch!

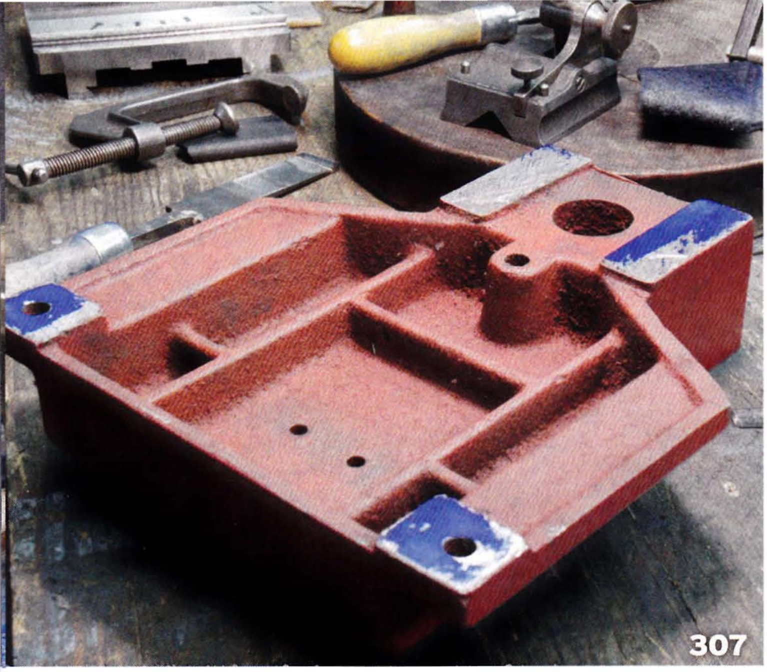
The most accurate test is that shown in ***Photo 283*** (September/October 2012), where any distance across the pins is sensed via a .0001" indicator on the surface plate. The micrometer, dial caliper, or sprung caliper tests are on-the-fly progress indicators and the more precise checks are done on the surface plate with an indicator. If the job is large and can't be put on the surface plate, rig an indicator to sense the distance between the two pins in situ. This could be as simple as an indicator on a surface gauge with the front of the surface gauge ground flat and pressed up against one pin, while the needle makes contact on the other side of the dovetail with the other pin.

THE BASE

My thoughts for using the base (***Photo 306***) have ranged from a super accurate XY table to be used on the drill press or on top of the rotary table, to a small CNC setup. Were I to use the column mounting area, or if you are scraping in a mini-mill, this area needs work. The manufacturer tried to grind the four surfaces (the two dovetails, and the two pads for the column), but they didn't go deep enough; the right column pad is fully ground but the left is lower and still shows mill tooling marks. To correct this, get the four feet flat, then mill/grind/scrape the two surfaces that the column joins to such that both sides are coplanar. I feel for the guys out there trying to tram the head by shimming to make up for this shoddy workmanship. We won't suffer that affliction however, and we are very close to completing a very accurate and smooth mini-mill base and table.

I decided it made sense to get the base's feet parallel to the dovetail surfaces. If used as a bench mill this won't matter; however, mine may see service on top of a rotary table or drill press table, so parallelism here would be good. Start by rough scraping the feet. A heavy coating of blue on the surface plate shows the results (***Photo 307***). Keep going until all four areas show a good amount of bearing.

Check the dovetail horizontal surfaces for parallelism with the feet in accordance with ***Photo 308***. Using the surface plate, bring the two dovetail surfaces to a fine scraped finish parallel to the feet. This is easy work for us at this point, with the part clamped to a bench (***Photo 309***).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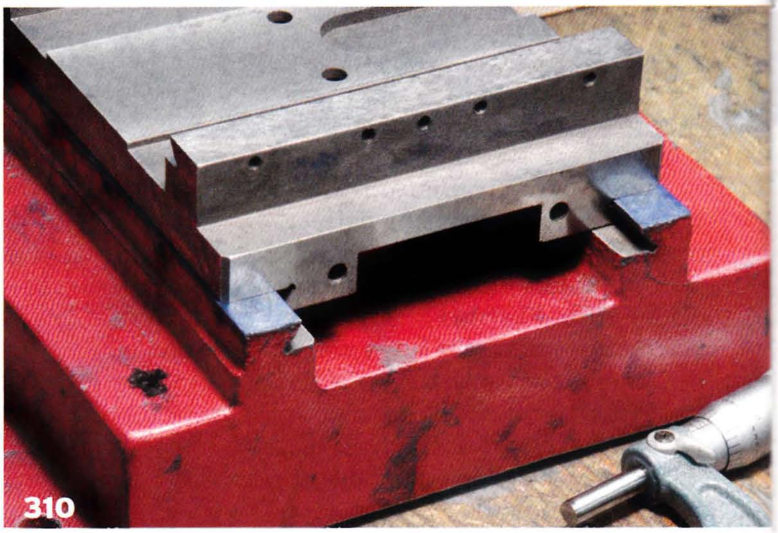
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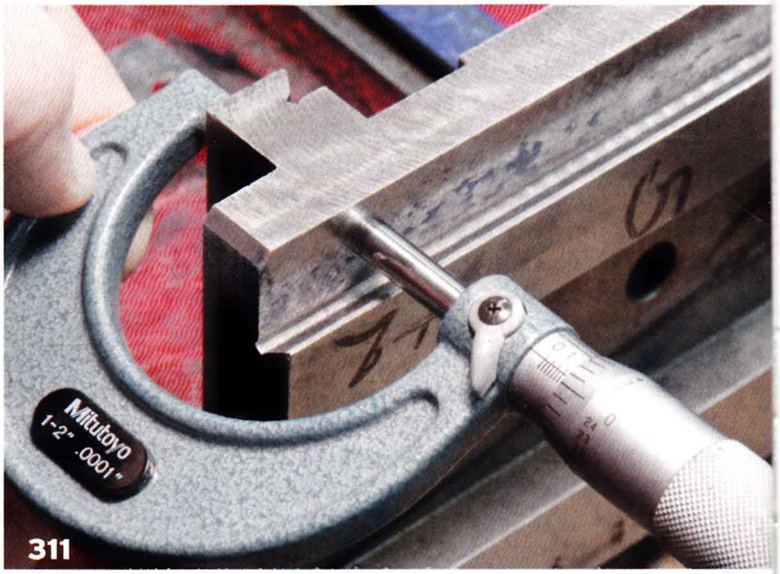

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Photo 310 shows the completed base horizontal dovetails being test fit to the saddle. I was not entirely happy with the area for contact achieved, as revealed by a bit of blue.

I carefully checked the dimensions between the horizontal surfaces with mics and indicators and determined the saddle was well scraped (***Photo 311***). While the surfaces are scraped such that a tenths indicator shows almost no movement, this is still potenitally not as precise, or at least the same, as the surface plate over the small area of the part. I concluded that a very slight difference in height between the horizontal surfaces of the saddle, so slight that it passed a tenths indicator test, would cause the saddle surfaces to be not quite as perfectly coplaner as the base's, which were scraped directly from the surface plate. Some finish spotting of the saddle using the base as a gauge corrected things.

The angled elements of the base's dovetails were spotted using the saddle as a spotting tool (***Photo 312***). You want the longer element scraped first and used to spot its mate; these two were almost the same length so it did not matter which was done first. The angle spotting tool can't be used here, as the horizontal surface forming the other half of the acute interior angle is nothing; i.e. it's not bearing or mated to anything or even machined with any accuracy. We would have to do some work to ensure it was parallel to

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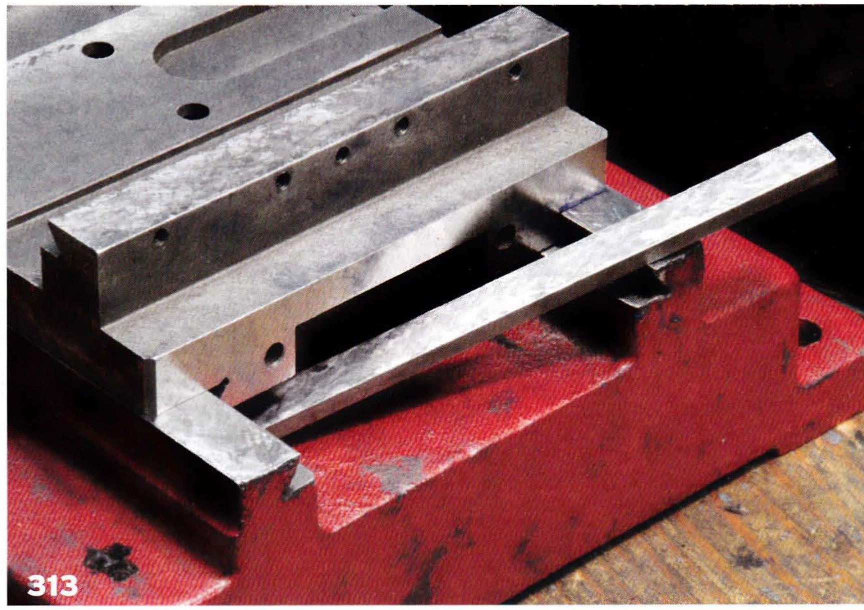

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the horizontal dovetail surface (the upper horizontal surface on this part) before it could be used as a datum for the dovetail spotting tool. The saddle worked perfectly well to spot it.

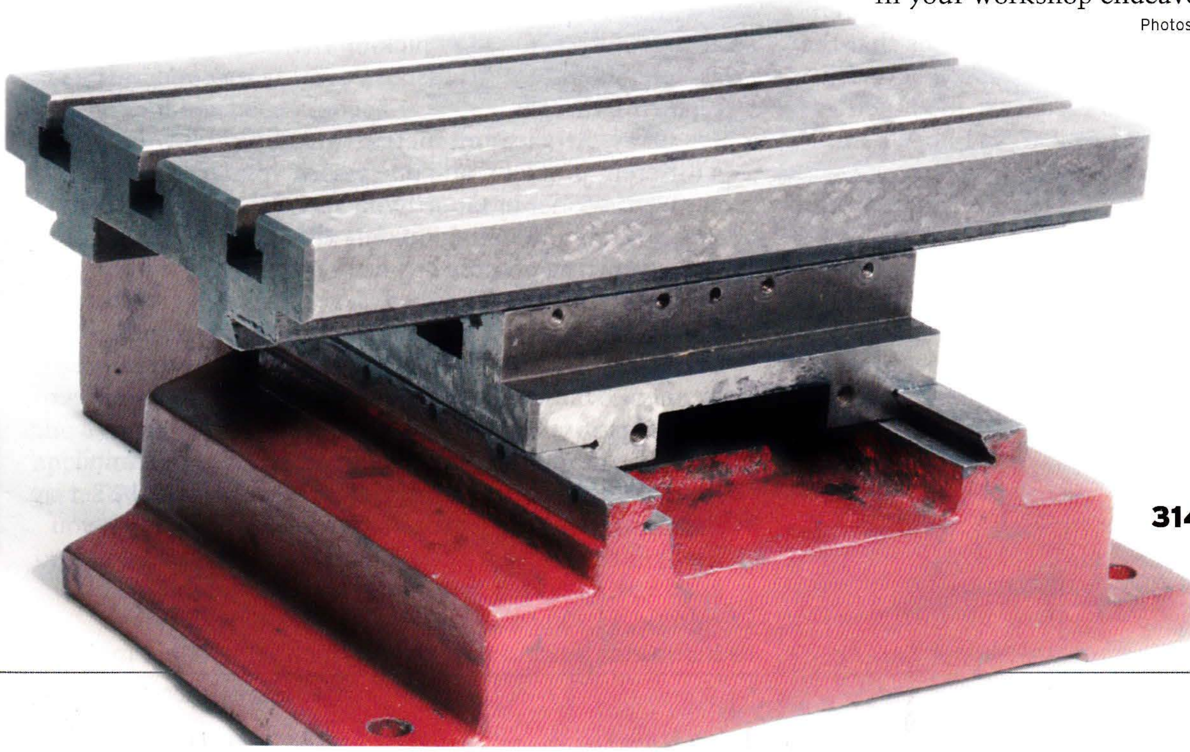
A gib was made and fit exactly as was done previously for the other slide (***Photo 313***).

Photo 314 shows the completed mini-mill XY components. Completed at least in terms of scraping. I still have lots of machining to do: hand wheels, graduated collars, screws, nuts, etc. Another important aspect is proper engineering of lubrication; so much work has gone into this project we don't want it to wear out quickly. What is needed are oil cups and holes drilled, and channels milled over the bearing surfaces so that oil can get to all the surfaces.

With the completion of the XY table, that concludes this series on scraping. This work certainly grew in scope from my first "why doesn't someone explain scraping so everyone can use it" idea. As each item you see here was scraped "live" in preparation for these writings and photos, it's been a considerable undertaking.

My objective was to remove the mystery that seems to often surround the subject, to show how to do it, and how to equip oneself for scraping. I also wanted to demonstrate with practical projects that it is a technique that can be called upon for numerous tasks other than machine tool scraping. Finally, I wanted to show some examples of machine tool scraping, perhaps to get some of you started or maybe just to remove some of the mystery of it for others. I hope you've gotten something from this and are able to use scraping in your workshop endeavors.

Photos by Author



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