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A Training Manual for Precision Hand Deburring, Part 2

By L. K. Gillespie

Published December 1980

Prepared for the United States Department of Energy
Under Contract Number DE-AC04-76-DP00613.

Bendix Kansas City Division

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A TRAINING MANUAL FOR PRECISION HAND DEBURRING, PART 2

By L. K. Gillespie

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A TRAINING MANUAL FOR PRECISION HAND DEBURRING, PART 2

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Part 2 of 4 parts of a training manual to be used by machinist trainees, production workers, and others removing burrs from precision miniature parts. The manuals are written to be self-teaching and are intended to be used with two hours of training each day along with another six hours of bench work in deburring.

WM:GWP

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PREFACE

This is the second volume of a four-volume training manual for precision hand deburring. Part 1 of this manual presents information on looking for burrs, types of tools and their use, basic deburring needs, and deburring techniques for plan and threaded holes.

This portion of the manual describes Bendix standards for edge quality and finish, written deburring instructions, assembly requirements, research on hand deburring, finishing of flat and cylindrical parts, and the use of brushes, files, and rotary burs.

As indicated in Part 1, this material is meant to be supplemented with approximately six hours of practice and test samples for every chapter.

CHAPTER 11

DEBURRING TURNED PARTS

Another family of parts which must be deburred are "turned parts". Probably 70 percent of all parts deburred in the miniature parts department are turned parts.

BASIC TYPES OF TURNED PARTS

The term "turned" implies that the part is basically round and was produced by turning it on a lathe. Turned parts can be simple pins such as shown in Figure 1, very large cylinders having a number of diameters, or parts which start out as round but become machined into a variety of hard to define shapes along the way. If the part has any obvious cylindrical features, then it will normally be called a turned part. Threaded shafts, for example, are turned parts which have the threads on them. Screws, bolts, even nuts are turned parts.

HOLDING PARTS

One of the first requirements in deburring turned parts is to select a method in which to hold them. Four methods are most frequently used:

- Hand holding,
- Holding in a pin vise,
- Holding in an expanding mandrel, and
- Holding them in a bench motor.

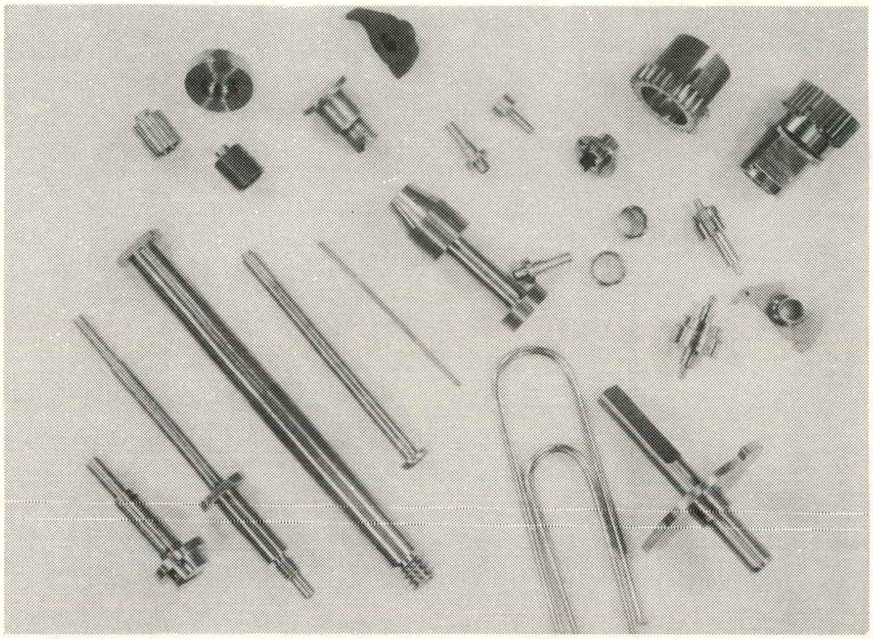

Figure 1. Examples of Turned Parts

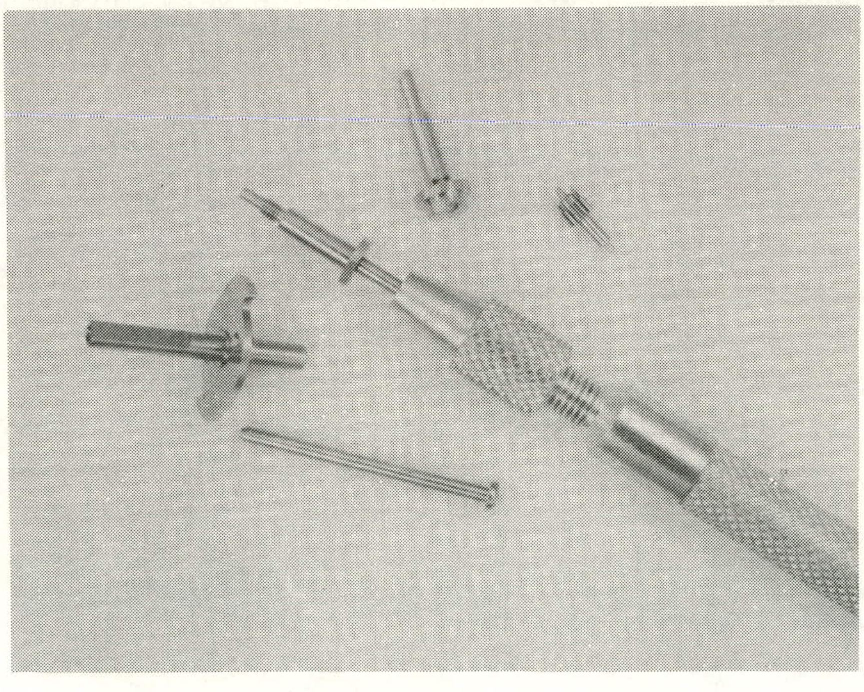

Figure 2. Pin Vise and Cylindrical Part

Note in Figure 2 that a pin vise is designed to hold cylindrical objects; thus, it is the ideal holding tool for many of the smaller turned parts. Expanding mandrels such as shown in Figure 3 have a small shaft which expands outwardly radially when the mandrel is tightened. These are used to hold parts which have a hole in the center (Figure 4). Also, the part can be placed in a bench motor (Figure 5) provided the part is not squeezed too tightly. In this case, the deburring tool is hand held against the part rather than hand holding the part against the rotating tool.

BASIC APPROACHES FOR DEBURRING

The basic approach for any turned part is to rotate the part, since all of it can be finished in this manner. Frequently, small pieces of sandpaper are used and held against the edges. In this case, a large sheet of sandpaper is cut into 1 inch squares for more convenient use on the miniature parts. An operator will begin with a large stack of these 1 inch squares, perhaps even folding them into four smaller pieces for use on very small parts. Abrasive filled rubber products are also widely used on this type of part. Brushes are widely used to provide a final blending and remove any particles left on the part. The deburring of threads has already been discussed and as previously mentioned is one feature of many turned parts.

APPROACHES FOR SPECIFIC SIZES

Assuming a very large turned part is 6 inches in diameter, a typical approach would be to perform the following operations:

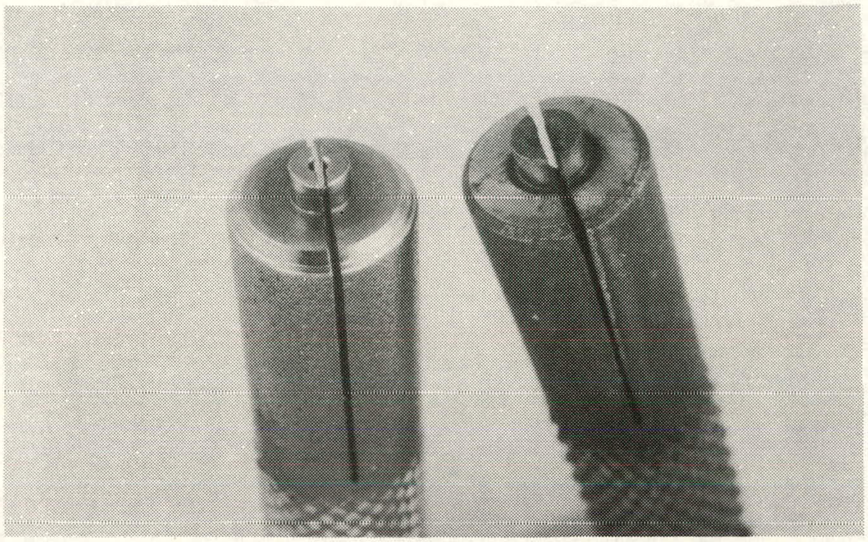

Figure 3. Expanding Mandrel

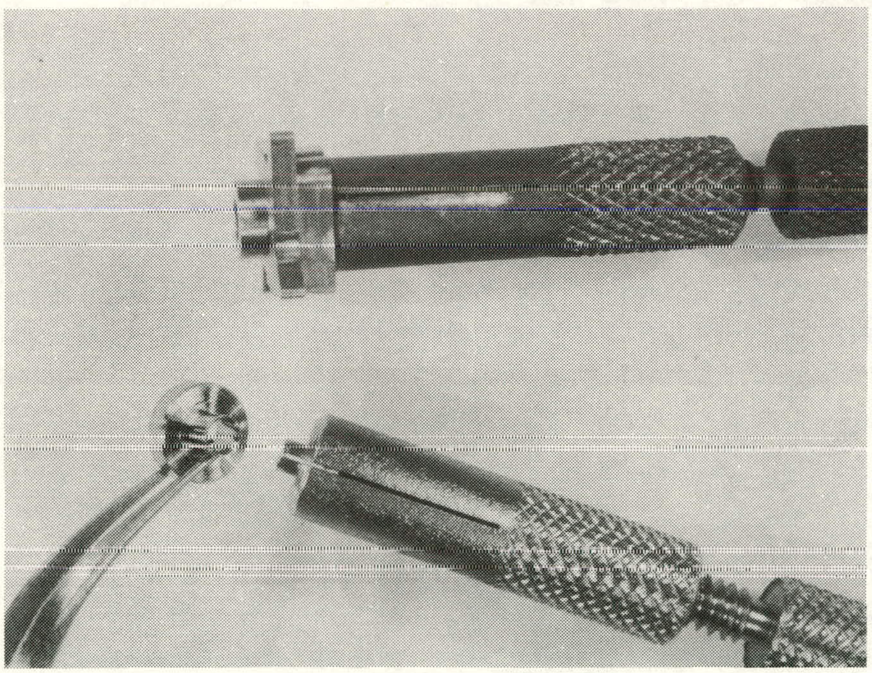

Figure 4. Expanding Mandrel In Use

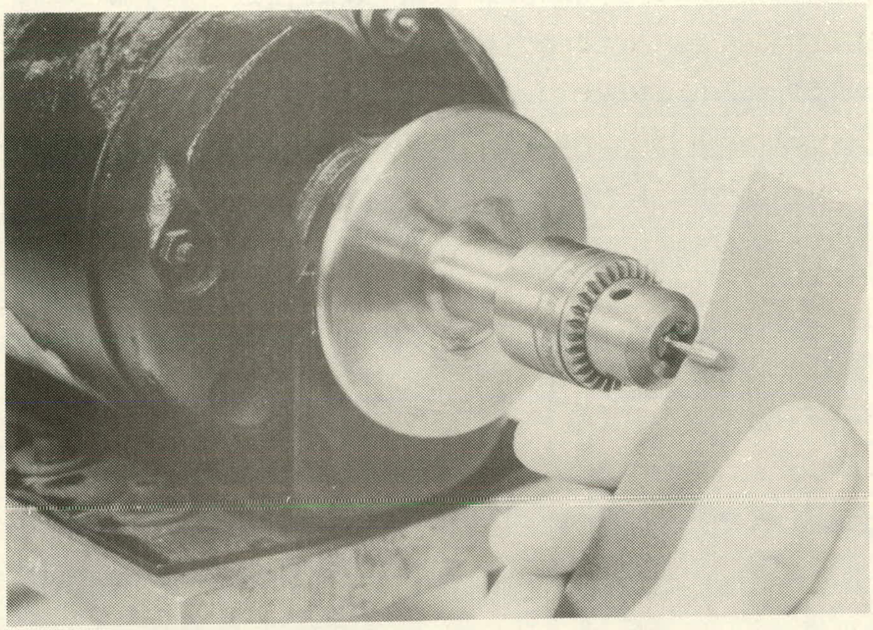

Figure 5. Part Held In Bench Motor

- Hand hold the part;
- Use a scraper if the burr is small enough;
- Use a large file if the burr is too big for the scraper;
- Use a burr knife, as necessary, for the hard to reach areas;
- Use sandpaper manually or a sanding disc;
- Use an abrasive filled rubber bullet mounted in a bench motor for all holes;
- Clean the part;
- Scrutinize; and
- Repeat steps as necessary.

Figure 6 illustrates the use of a scraper on a large aluminum part. On this size of part a scraper can readily traverse the edges. There are a number of such large parts, however, which have very small or intricate cutouts in which a scraper is not sucessfully usable. In this case, deburring knives and the abrasive paper products must be used.

Assume that a part is only 0.125 inch in diameter. Provided the part is a simple turned shape, the following operations would be performed:

- Place the part in the collet of the bench motor,
- Turn the motor on,
- Use abrasive paper or abrasive filled rubber tools on the edges,
- Clean the part,
- Scrutinize, and
- Repeat steps as required.

An alternate approach would be to perform the following operations:

- Put the part in the pin vise,
- Put the pin vise in the bench motor,
- Turn the motor on, and
- Repeat the steps in the previous listing.

The reason for putting the part in a pin vise is that some have brass jaws which will not indent the part. A common problem with small turned parts is that they can be easily indented or "marked." This scratching of the parts is not acceptable; Also, most bench motors have large steel jaws which hold the parts. It is very

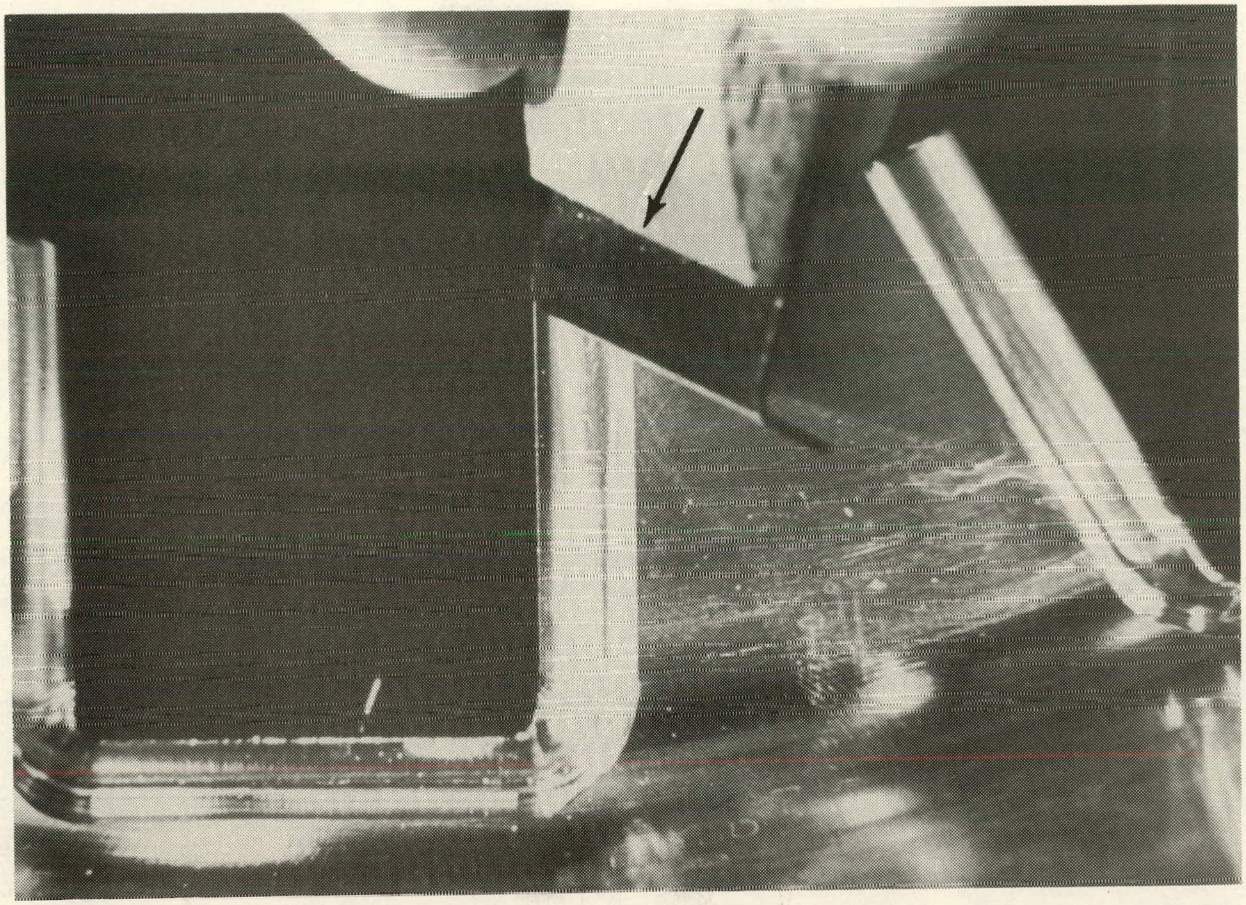

Figure 6. Scraper Used on Large Aluminum Part

easy to squeeze some parts until they become egg shaped. For the levels of precision we are talking about, however, ±0.0002 inch is the amount of egg shape in millionths of an inch. Thus, because of extreme levels of accuracy, distortion cannot be recognized without sophisticated measuring instruments.

The advantage of putting the part in the bench motor is that rotating the part or tool is much faster than hand holding or hand rotating the part. There will be many parts, however, which must be placed in a pin vise to provide the necessary part movement.

DEBURRING TO BE EXPECTED BY LATHE OPERATOR

Many large parts may be burr free when they arrive at the deburring operation. When machinists produce turned parts on lathes they are expected as part of their operation to remove the large burrs and, in some cases, to essentially do all the deburring on the part while it is on that lathe. As an example, many of the machining operations have a note at the bottom of the operation which states "deburr while on machine." This implies that the operator is expected to provide the necessary deburring not only for his inspection but to provide the deburring generally required to sell the part to inspection. In some cases, because of short machine cycles and hard to reach areas, or other reasons, the machinist may not fully deburr all edges or may not fully deburr any of the edges. For this reason, it is still necessary to scrutinize these parts to verify that they are adequately deburred.

For some parts, there is not enough time to deburr on the machine. As an example, automatic screw machines are one form of a lathe. These machines make screws by the hundreds of millions. These types of parts may come off the machine at a rate of 1 every 5 or 10 seconds. There are neither enough tools nor enough time to deburr parts being made at this rapid rate. As a result, parts produced on the screw machine will have no deburring performed on them at the machine. For smaller quantities of parts the parts will be produced on some form of a manually operated lathe. On many of these, total machining time is 5 to 10 minutes a part and in some cases even up to an hour for each part. Thus, there is time to do the deburring on the machine. The advantage of doing machine deburring rather than using a separate deburring operation is that the part is rotating.

CUTOFF BURRS

Figure 7 illustrates a typical burr found on most edges of small parts. In this particular example, the burr is on a screw machine part in which the small diameter is only 0.02 inches in diameter. The burr is relatively obvious on this particular part. Even though the burr is obvious, it is still a relatively small burr. For example, the particular burr shown in this illustration is probably only 0.003 inches thick. These are typical burrs, regardless of the size of the part.

There is one form of burr, a cutoff burr, which is much larger and more difficult to remove (Figure 8). This is not a burr in the true sense. The cutoff burr is material which has been left on the part because the tool did not completely cut the part from a bar of material. Cutoff burrs result from a part breaking off rather than being cutoff. In a few instances, cutoff burrs may remain on the part and not have to be removed. This is not generally the case, however, and unless specifically stated in a production traveler cutoff burrs are to be removed. In some instances, particularly in the case of brass or aluminum cutoff burrs, the burrs may be removed with a knife or a small file. In the case of stainless steel parts however, side cutting pliers may have to be used. These pliers have a scissors action that will cut off most of the burr. It may be necessary to smooth the edges of the remaining stub of material. In many cases, the deburring operation will occur after the cutoff burr has been removed. For example, the part may be turned around and another part dimension produced at the same time the cutoff burr is removed from the part. In this case, the machinist has cut the burr off. It is also possible to use a hand held stone such as the Arkansas stone to grind down the cutoff burr and smooth the end of the part.

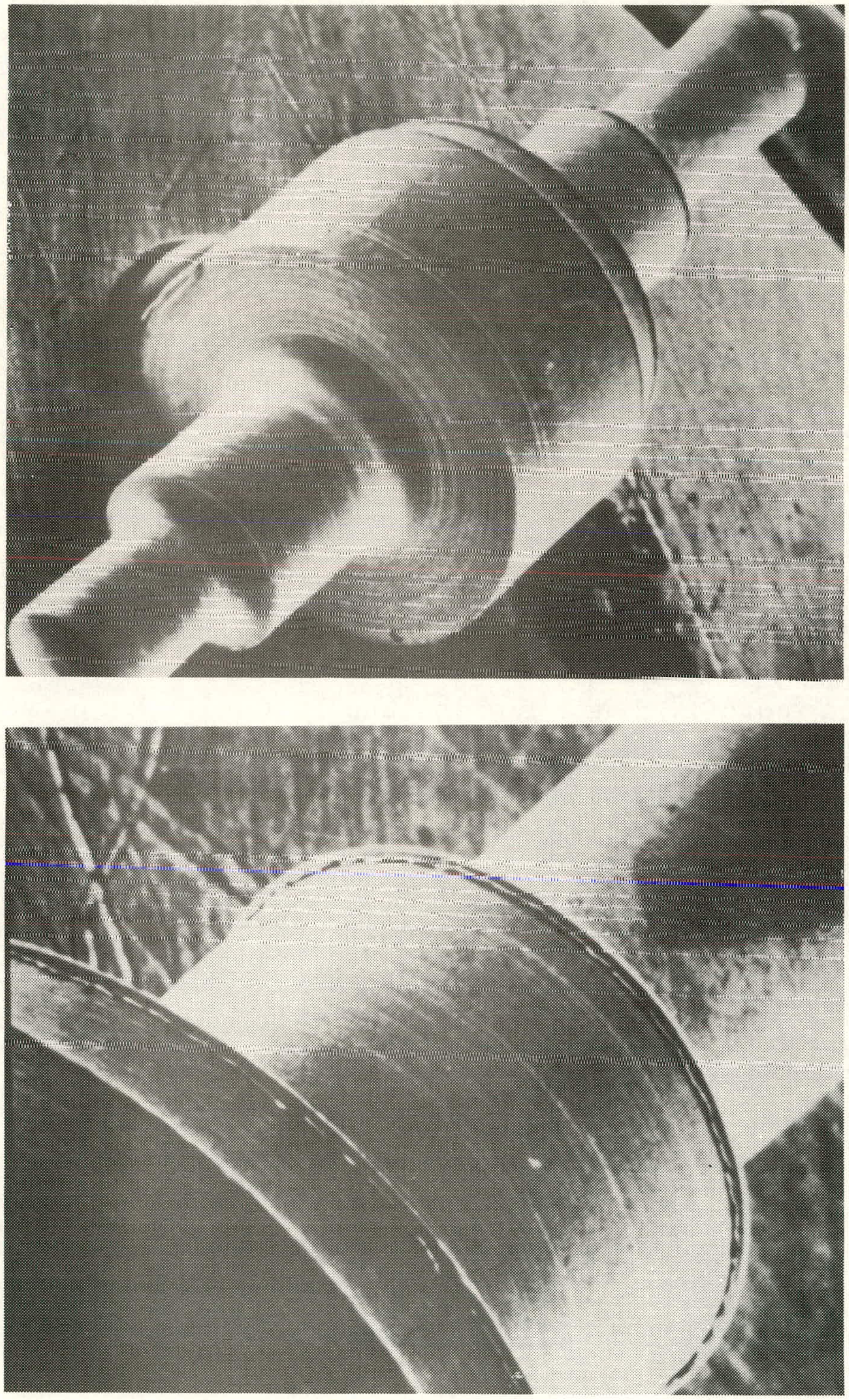

Figure 7. Typical Burr On Miniature Part

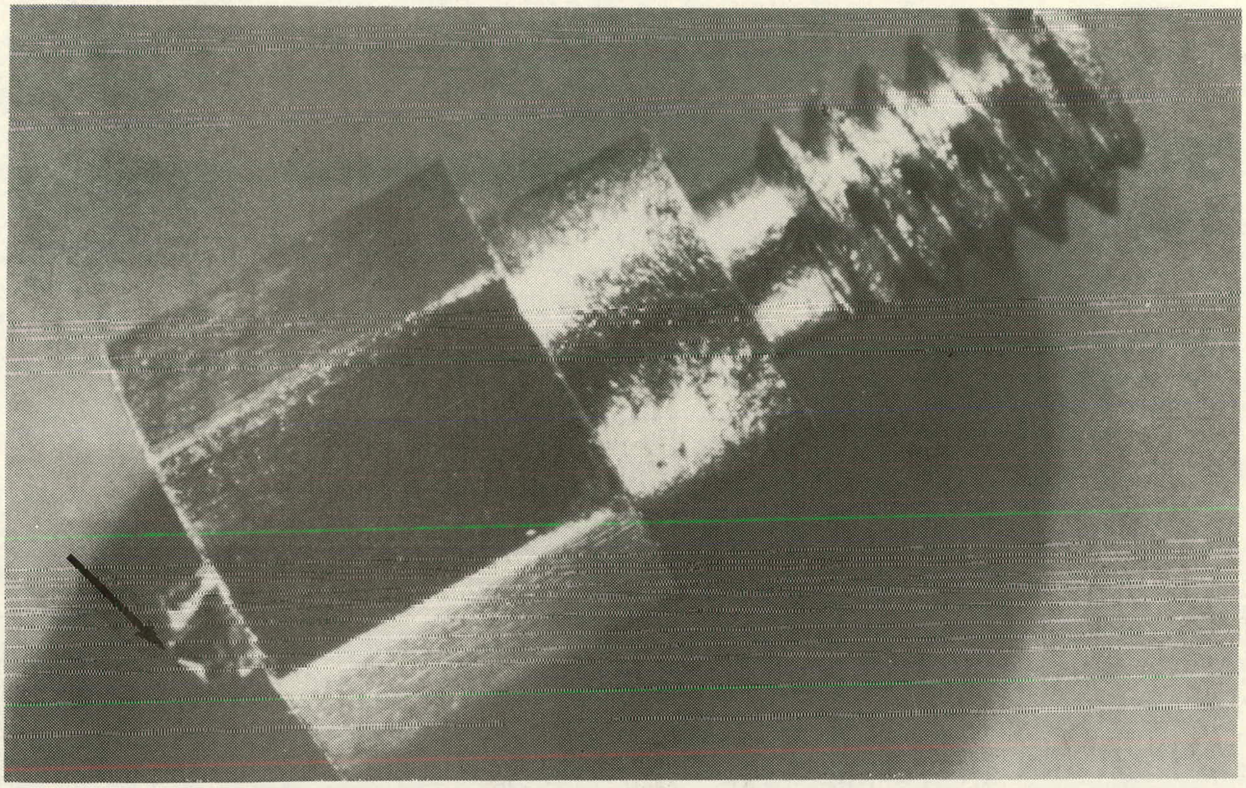

Figure 8. Cutoff Burr

POTENTIAL PROBLEM AREAS

There are at least four areas of concern with turned parts. During deburring operations, it is very easy to damage precision surface finishes. Figure 9 for example illustrates the surface finish required at the end of a gear shaft. A single slip of a knife or the use of the wrong sandpaper can damage the surface. When using sandpaper on a turned part, it is very easy to change the diameter of the part by 0.0001 inch or more. As a matter of course, holding the paper against the diameter of the part will change it by this amount in only 1 to 5 seconds if the part is rotating in a motorized spindle. Edge breaks are also important on many of the miniature

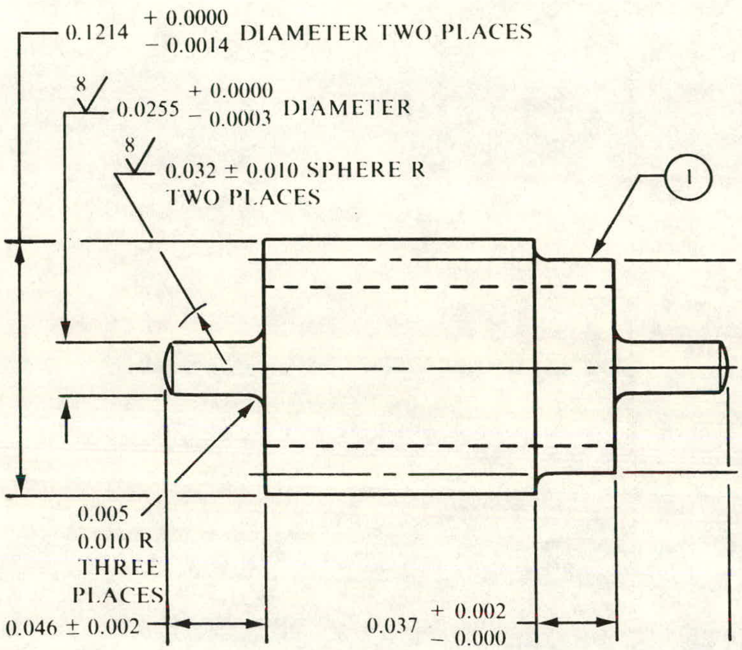

Figure 9. Surface Finish Required On Miniature Gear

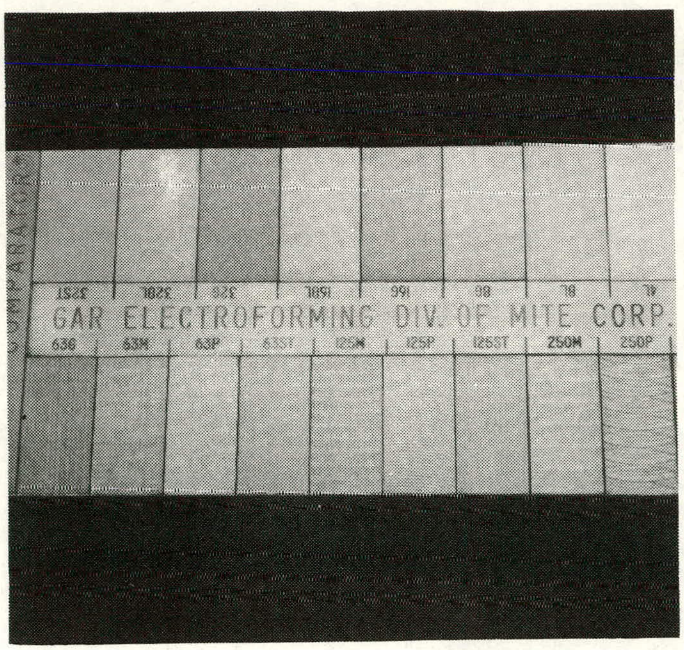

Figure 10. Comparison of 8 and 64 Microinch Surface Finishes

turned parts. Again, it is very easy to exceed radii or breaks such as 0.003 inch maximum. The last area of immediate concern is damage to the part by the chucking or colleting device. Again it must be pointed out that extreme care must be used when tightening the devices which are holding these miniature parts. It is necessary to verify that there are no burrs or chips on the colleting device which would indent the part.

One of the first requirements after obtaining a new pin vise or a new set of tweezers is to determine if they have burrs on them. Typically, these types of tools have a number of burrs on the holding edges which will indent even hard materials if they are tightened too tightly. Thus, the first requirement is to deburr the tool that is being used to hold the part.

Figure 10 illustrates what an 8 microinch surface finish really looks like when light shines on it. In comparison a 64 microinch surface finish is also shown.

Figure 11 illustrates one common problem found on many turned parts. As seen there the burr is thrown axially along the axis of the part and, in the case of many of the miniature parts, the burr is so short that it is not visible except under optium lighting. In such an example, it is important to use lighting which casts harsh shadows. While these burrs are small they will dig into the mating part and dramatically increase friction (Figure 12).

MECHANIZED PROCESSES FOR TURNED PARTS

Many of the turned parts will never be hand deburred because mechanized processes can provide adequate deburring much more economically. Table 1 illustrates the common mechanized processes used for deburring turned parts. It is general practice on the

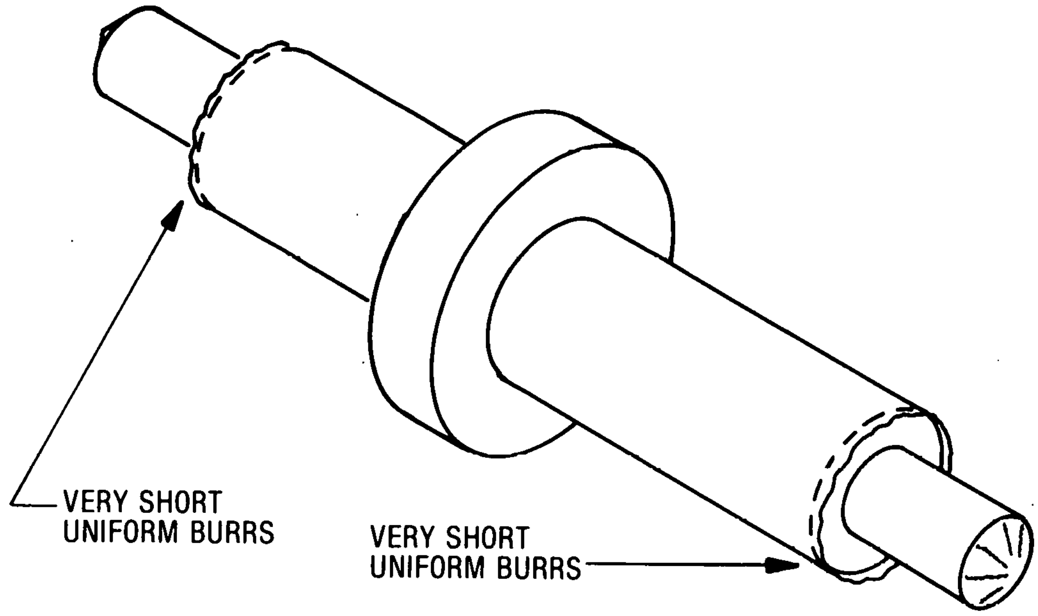

Figure 11. Small Burr Thrown Axially Along This Part

part of the engineers who prepare the production travelers to determine ahead of time whether the mechanized processes are adequate or not. In many cases, the mechanized processes have unusual limitations, which are not physically visible, that limit the use of the process. When a mechanized process might be applicable it is advisable to ask the supervisor to consider this process or contact the engineer for reevaluation of such a process.

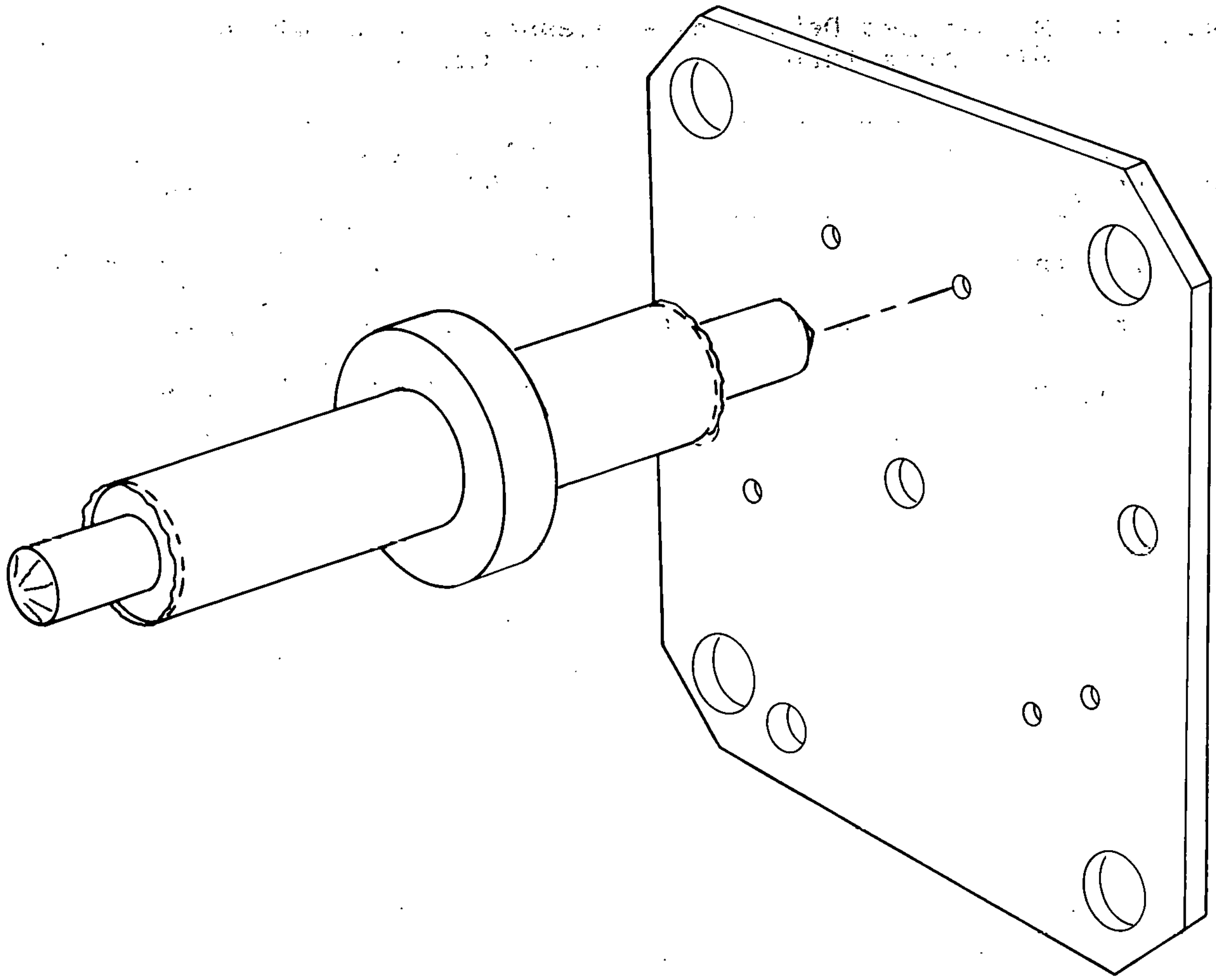

Figure 12. Axial Burrs Dig Into Mating Parts

Table 1. Mechanized Deburring Processes Commonly Used on Miniature Turned Parts at Bendix

Process	Applicable Part Size (inch)	Typical Cycle Time
Barrel Tumbling	0.020 to 6.000	24 Hours
Centrifugal Barrel Tumbling	0.020 to 0.500	20 Minutes
Vibratory Deburring	0.500 to 6.00	2 Hours

ASSIGNMENT

1. Deburr the turned parts which have been provided.

2. Define in your own words what is expected of machinists when they are producing turned parts.

3. Deburr the cutoff burrs on the samples provided.

4. Define the general problem areas one might expect to find when deburring turned parts.

5. Using sandpaper of 500 or 600 grit, place a turned part in a rotating motor and hold the sandpaper against the part for 1 minute. Record the diameter of the part before sanding and after the 1 minute deburring operation. List the amount of size change on the part as a result of the deburring operation.

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CHAPTER 12

DEBURRING FLAT PARTS

Another common configuration of parts which must be deburred are those which are typically flat (Figure 1). The fact that they are flat allows the use of many tools and makes the parts more amenable to deburring. Many flat parts are larger than turned parts. They are easier to hold, easier to deburr, and easier to inspect.

BASIC TYPES OF FLAT SURFACE PARTS

Typically, a flat part is very long and wide compared to its thickness. For example, it might be 20 times as long or wide as it is thick. A number of our parts, however, have chunky boxlike configurations which are also basically flat surfaces although thicker than the majority of the parts shown in Figure 1. Figure 2 for example illustrates a rather chunky, yet basically flat surface, type of part.

BASIC APPROACHES FOR FLAT PARTS

As an example of deburring of flat parts, assume a part which is 1 inch square and 0.05 inches thick. Further assume that it has no holes or other unusual features. It is basically a square part, 0.0500 inch thick. Three products can be used to deburr the part:

- Abrasive paper products such as sandpaper-like items,
- Abrasive paper products which have adhesive on the back side and attach to a rotating mandrel, or
- Abrasive filled rubber products.

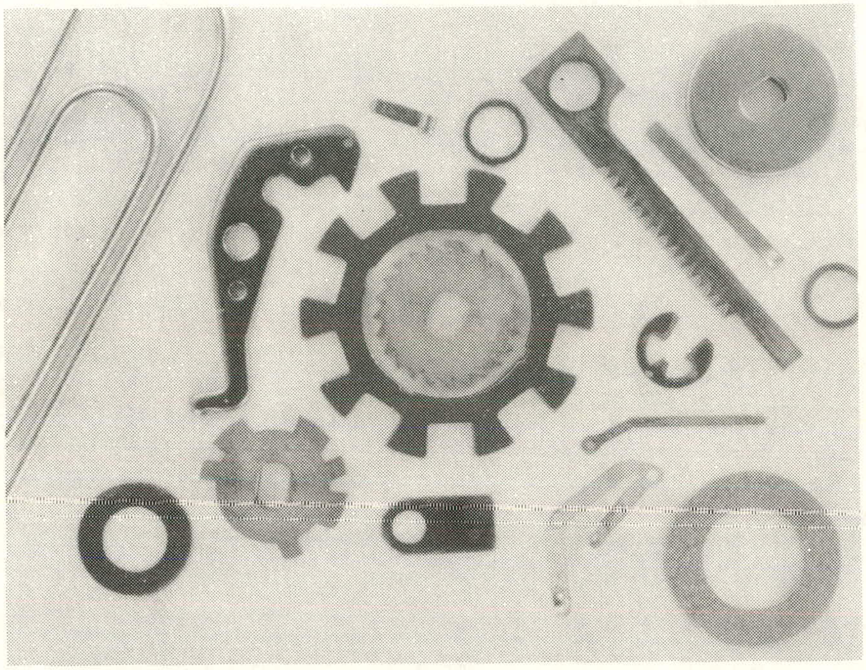

Figure 1. Typical Miniature Flat Parts

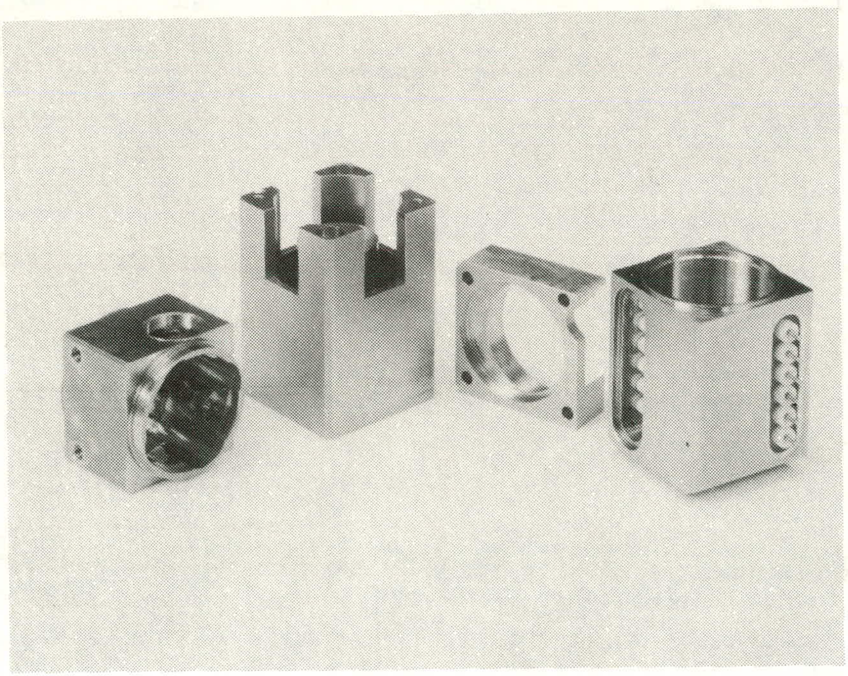

Figure 2. Box Like Parts

On very small square parts, a 1-inch-square piece of fine sandpaper is used to finish the edges. It is faster, however, to use an adhesive-backed disc (Figure 3), for once again the motorized tool provides the fastest method of deburring. It is also possible in some instances to tape a sheet of sandpaper to the workstation and rub the work piece on this hardback paper (Figure 4).

On hand size or larger parts, it is possible to use a jitterbug (orbital) or a belt sander (Figures 5 and 6). These sanders can be used not only on the edges but on the surfaces, if tolerances allow.

APPROACHES FOR SPECIFIC PARTS

Assume a part like the one shown in Figure 7. In this instance, the part has some square edges, some contoured edges, and a number of holes. It is basically a flat part 1 inch square and 0.0500 inch thick. In this particular illustration, the part is made of beryllium copper, which is somewhat softer than steel. A basic approach on this type of part, depending on the size of the burr, would be to use sandpaper on the edges and an abrasive filled rubber product or small nylon brush coated with an abrasive. The small holes would require the use of a bur ball or countersink tool and probably the use of an abrasive filled rubber dental point. The contour areas, that is those areas which are neither round or straight, may require some use of a knife followed again by the use of an abrasive filled rubber product.

With the very large parts, such as shown in Figure 8, it may be possible to use a file to remove the heavy burrs and then use a brush to blend out the sharp edges left by the file.

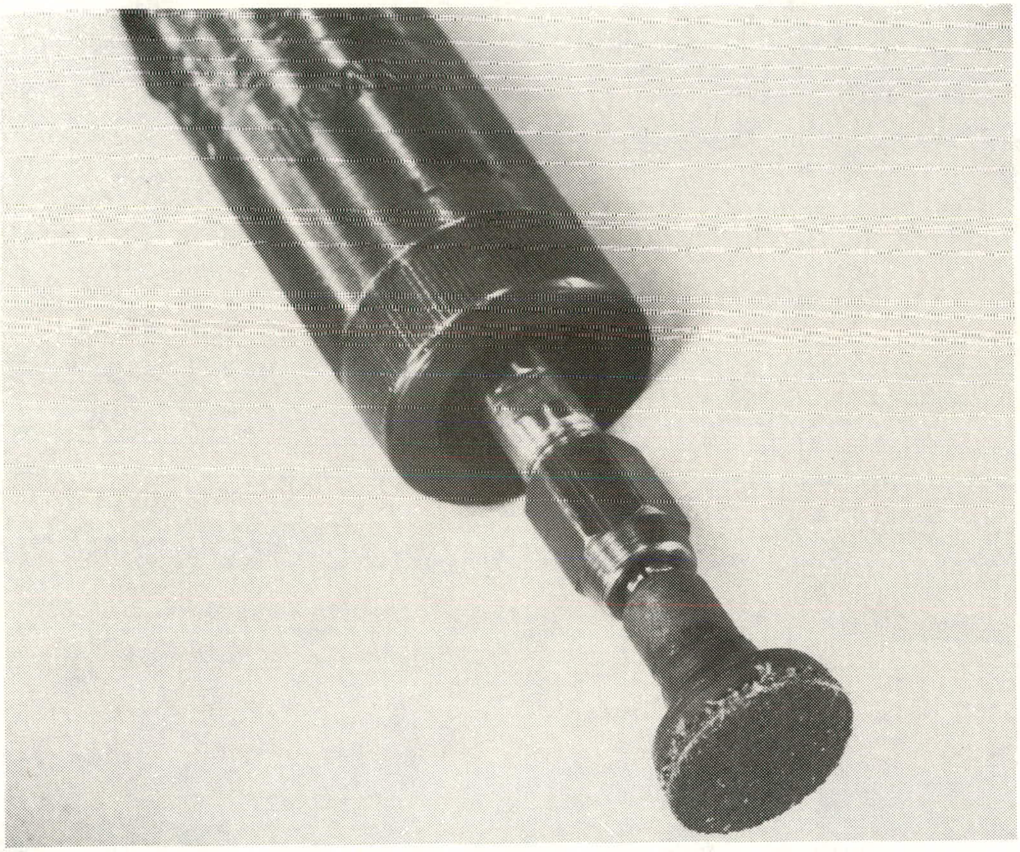

Figure 3. Adhesive Backed Disc Used for Flat Surfaces

MECHANIZED PROCESSES FOR FLAT PARTS

Some flat parts lend themselves readily to mechanized processes. For example, a small conveyorized sanding belt will sand the flat surfaces (as opposed to edges only) of flat parts (Figure 9). Also, such processes as barrel tumbling or vibratory deburring may also be used to deburr flat surfaces provided there are no intricate cutouts or very small holes in the surface. It is also possible to buy machines which automatically brush all surfaces of specific parts. In many instances, these automated machines (the automated brushes for example) are too expensive, require

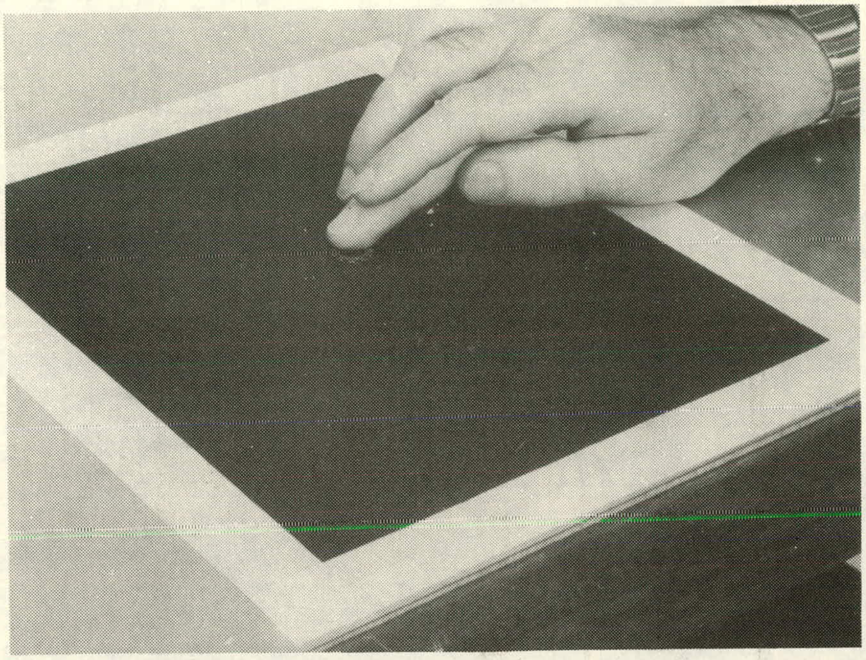

Figure 4. Sandpaper Taped to Work Bench

too much set-up, and do not concentrate all the action at the necessary points. For this reason, such tools are not commonly used on precision miniature parts which are only fabricated in small quantities.

Some of the jitterbug sanders will tend to concentrate all the action on the outside edges even though, to all apparent observations, the whole surface is being sanded (Figure 10). Because of this, such a tool may be highly desirable provided the part is big enough to be used with this approach.

POTENTIAL PROBLEM AREAS

As in the case for turned parts, there are three significant concerns when deburring flat parts:

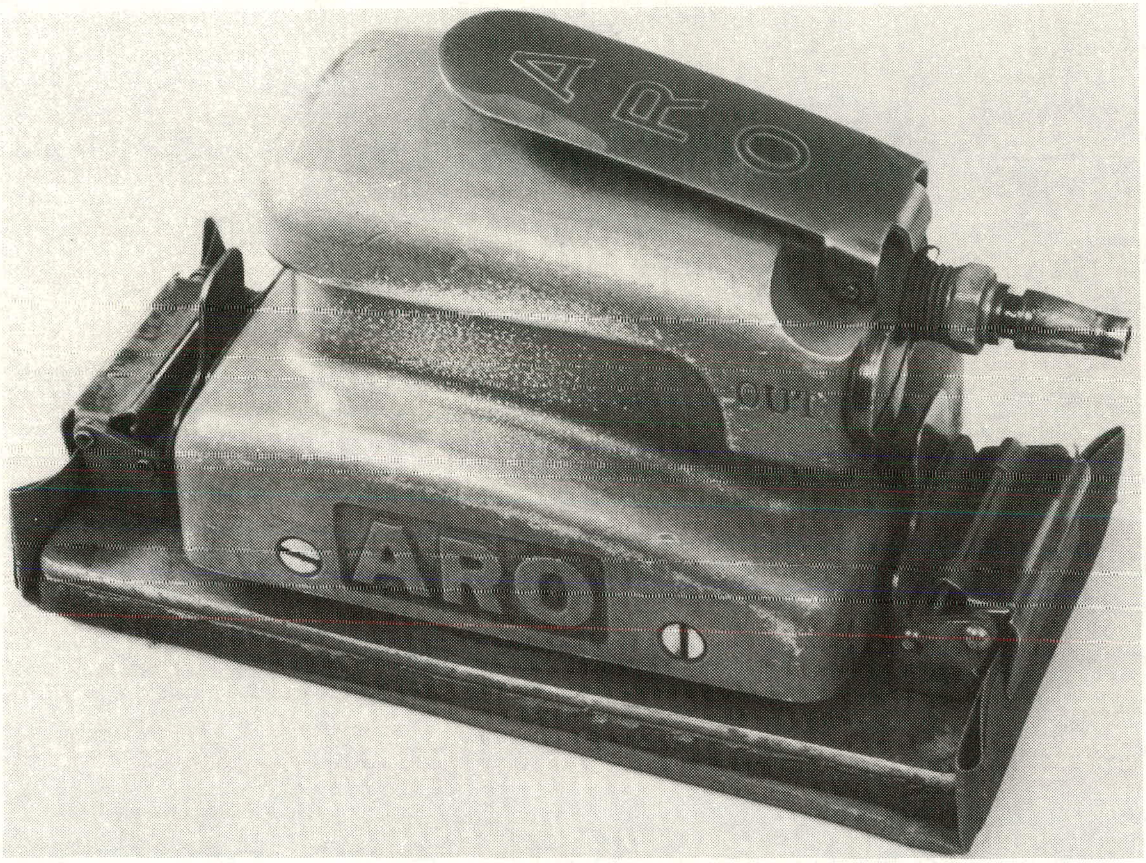

Figure 5. Jitterbug Sander Used for Flat Parts

- Part thickness must not be changed adversely;
- Surface finish on flat surfaces must not be affected adversely; and
- Edge breaks must not be exceeded.

While it is also possible to dent, scratch, mar, or otherwise damage flat surfaces, these are not normal circumstances. When using a 600 grit abrasive paper, for up to one minute of sanding, the thickness of the part may become smaller by 0.0001 to 0.0003 inches. In other words, the sandpaper will not only work on the edges but, if the surfaces are sanded, the thickness of the part will change

Figure 6. Belt Sander Used for Flat Parts

measurably. This is not allowable on many of the precision miniature parts. On larger hand sized parts small changes (0.0003 inch) may be acceptable.

The edge break is also critical on many of the small parts, particularly those which are very thin. The use of sandpaper, abrasive filled rubber products, and abrasive filled nylon brushes limit the aggressiveness of the deburring tools. As a result, most of these tools are acceptable and, when used with moderate pressure and reasonable experience, will not exceed a 0.003 inch edge break.

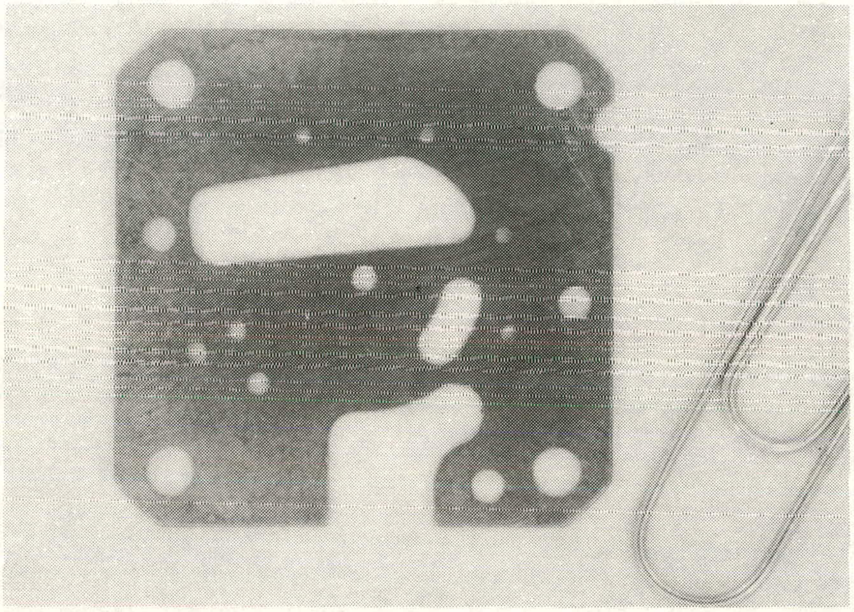

Figure 7. Beryllium Copper Escapement Plate

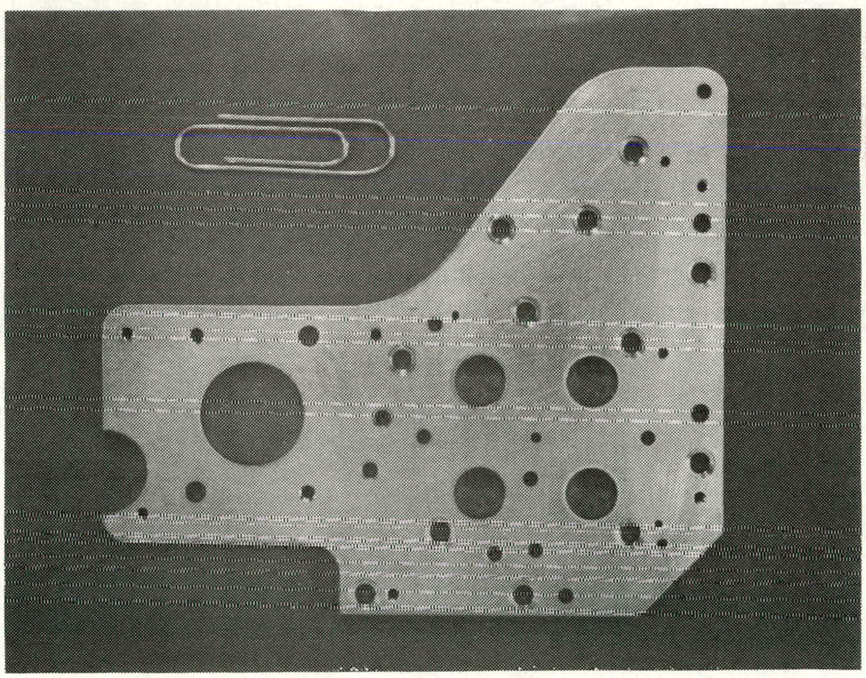

Figure 8. Large Flat Part

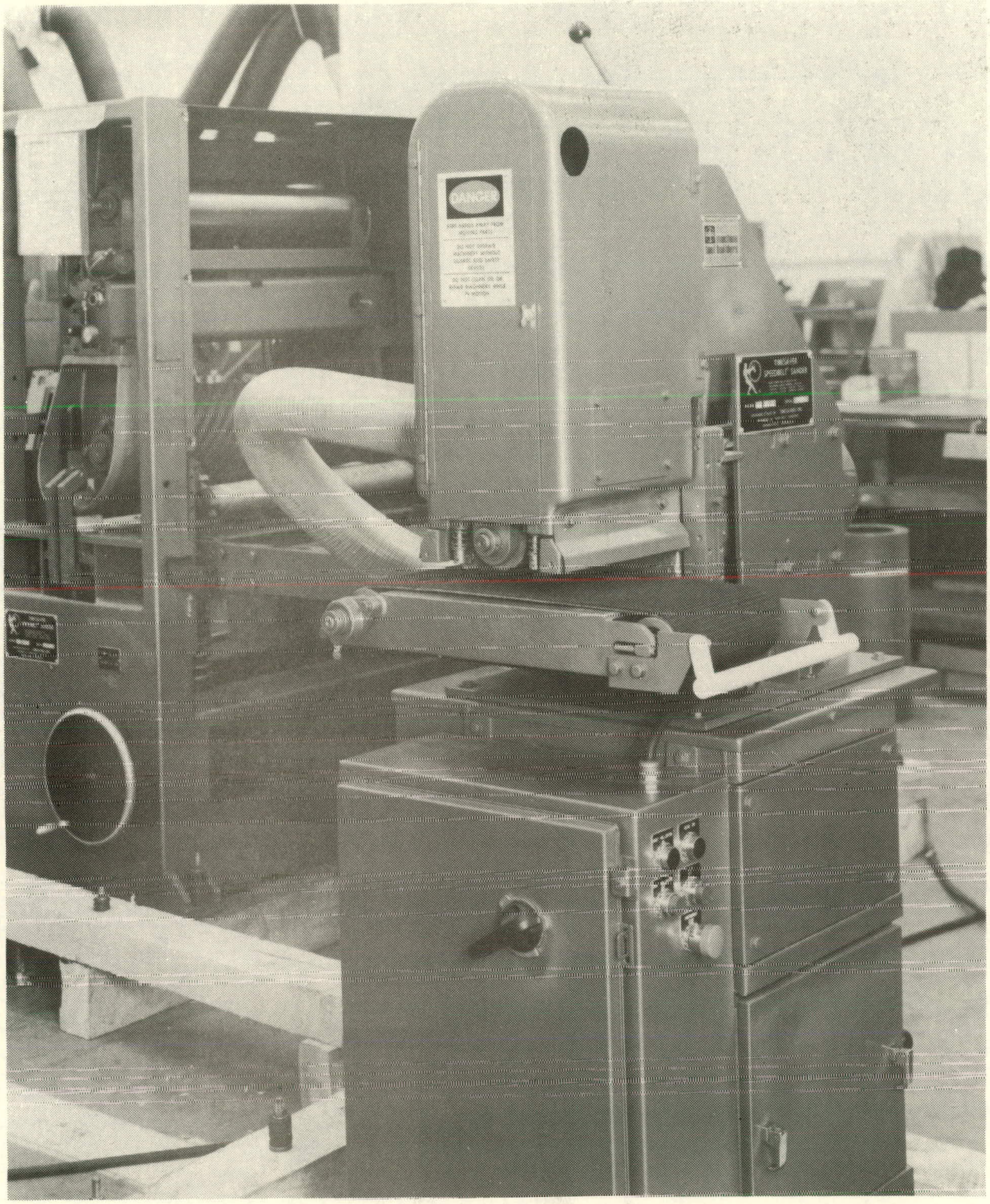

Figure 9. Small Parts Sanding Machine

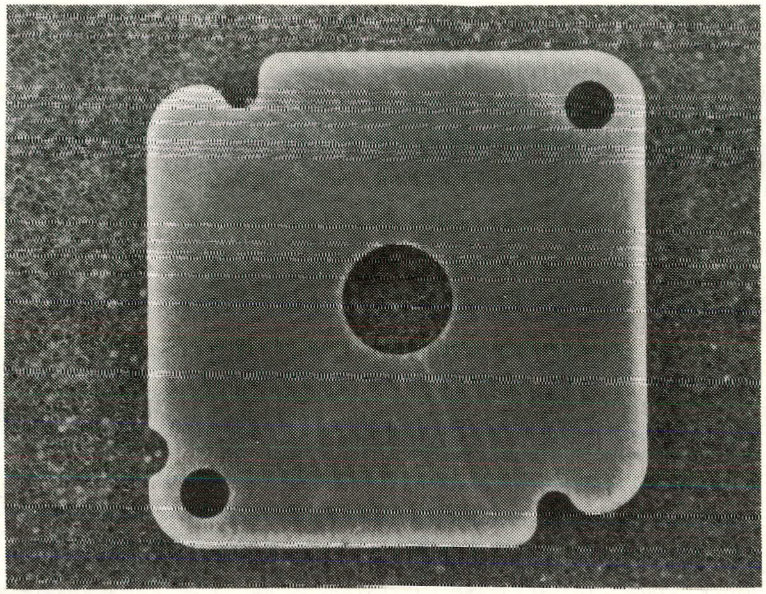

Figure 10. Jitterbug Sanders May Concentrate Action at Edges

ASSIGNMENT

1. Deburr the flat parts supplied, providing no more than 0.005 inch break on the edges.

2. Deburr the holes and exterior surfaces of the flat part provided. Generate no more than 0.003 inch edge break.

3. Using 600 grit abrasive paper, sand the surface of the sample provided for one minute with moderate pressure. Measure the thickness of the part before and after sanding and record the differences caused by sanding.

4. Measure the thickness of a flat part, sand it with 100 grit sandpaper moderately for one minute and record the change in thickness.

5. Using a jitterbug sander, flat sand the surface on the sample provided for one minute and look for bright spots indicating where actual sanding has occurred.

6. Sand the surfaces provided and measure the surface finish when completed. Use 100 grit abrasive for one part and 600 grit abrasive paper for the other part. Compare the surface finish readings from these two parts.

7. Tape a piece of 8 1/2 inch by 11 inch abrasive paper to the tabletop and sand the samples provided with this paper.

8. Using the samples provided, use only a brush to deburr the part.

9. Using the samples provided, use only a file to deburr the edges.

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CHAPTER 13

INSPECTION STANDARDS FOR BURRS

A large number of different types of parts are produced at Bendix and assembled into a variety of units:

- Non Critical Housings,
- Non Critical Electrical Parts,
- Non Critical Mechanical Parts,
- Critical Ceramic Parts,
- Critical Electromagnetic Coils,
- Critical Printed Circuit Boards,
- Critical Electrical Contacts,
- Critical Mechanism Parts,
- Critical Purchased Parts,
- Noncritical Screws, Washers, Snap Rings, and
- Semicritical Parts.

Each of the parts requires a slightly different level of burr-free conditions. As a result of this, it is often difficult to express exactly what is needed on each and every edge on each different part. Electronic parts require a certain edge condition. Large housings require perhaps a less precise edge condition, and precision miniature parts in general require yet another level of edge precision.

When considering the actual requirements of parts in assemblies, the following requirements apply:

- Edges must not cut wires.
- Edges must not cut mating parts.
- Raised metal must not interfere with mating parts.
- Metal from edges must not fall into assemblies.
- Edge breaks must not exceed welding limits.
- Raised metal or burrs must not interfere with precision gaging.
- Burrs and raised metal must not prevent press fit pins from entering holes.
- Burrs or edge roughness shall not increase part wear.

FORMAL INSPECTION STANDARDS

Many part drawings contain requirements regarding burrs and sharp edges. Most requirements for miniature parts, however, are described in the general workmanship standard for all parts in the plant as discussed in subsequent paragraphs.

Paragraph Number	Discussion
5.5.4	Hole Quality. The walls of holes shall be clean cut and shall present a good machined surface. Hole edges shall be free from burrs and shall not be ragged, chipped or torn. These requirements are subject to visual inspection only and are to be evaluated in terms consistent with the characteristics of the material and with the method used to produce the hole.

5.6 Removing Burrs and Sharp Edges. All burrs and sharp edges shall be removed to the extent that material fragments are not visible and sharpness cannot be felt. Either a 0.3 mm (0.010 inch) maximum x 0.3 mm (0.010 inch) maximum chamfer or 0.3 mm (0.010 inch) maximum radius is satisfactory treatment in breaking edges and deburring. Only those edges that appear to exceed these limits upon visual inspection need be measured for conformance to these dimensions. If it is necessary to break sharp edges or to deburr after application of chemical surface treatment, the bared metal shall be touched up as required. Flash on molded plastic parts that does not cause the part to exceed maximum dimensional limits need not be removed. These requirements do not apply to rough and semi-finished metal castings and forgings.

5.12 Flaws. Flaws include scratches, cuts, dents, cracks, checks, pits, blow holes, bumps, ridges, and similar mars and imperfections. Acceptance of parts having surface flaws shall be at the discretion of the Buyer and shall be based upon the function of the part.

6.1.2 Appearance. All threads shall be free from burrs, nicks, and rough or chattered surface, that are visible without magnification.

6.3.5 Chamfer. The leading ends of internal threads shall be chamfered as shown in Figure 1. If accessible, both ends of through-tapped holes shall be chamfered. Chamfering shall not result in elimination of more than one pitch of thread depth. For the purpose

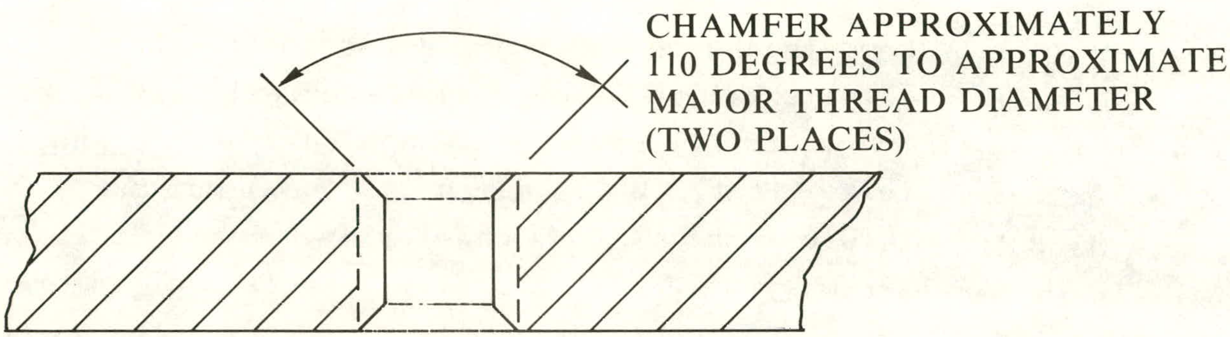

Figure 1. All Internal Threads Shall be Chamfered

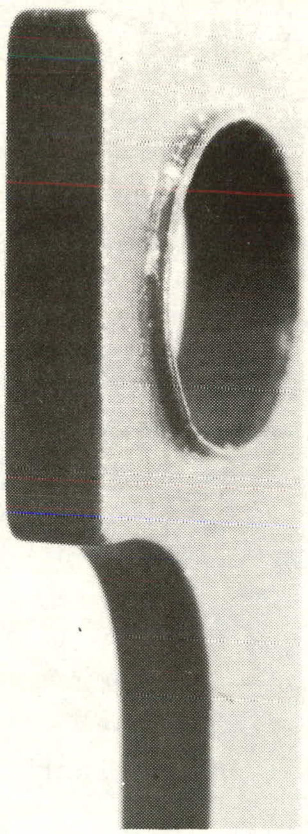

Figure 2. Raised Metal Is Not Allowable

of determining the number of complete threads from the surface adjacent to the hole, the chamfered thread may be counted.

The intent of the plant standard is relatively obvious, but some aspects require some additional interpretation.

Paragraph 5.6 indicates that burrs must be removed to the extent that fragments are not present. On most miniature parts even a smooth bump or smooth area of raised metal is not allowed, even though this material is not a fragment (Figure 2). In essence, <u>any material extending past the theoretical intersection of the two surfaces creating the edge will be rejected as unacceptable</u>.

If, however, notes on the part drawing allow burrs at specific locations, then the previous comments do not apply at those locations.

Three specific assemblies at Bendix require more stringent edge requirements than those listed in the plant standard. These units specify that edges must meet the following requirements.

5.1 <u>Intersections of Surfaces</u>. Surfaces intersecting to form internal corners shall not have an undercut. All burrs, raised metal, and sharp edges must be removed from external corners. The maximum size of chamfers or radii, generated by machining or deburring, is limited by the adjacent surfaces as follows:

A. No surface shall be more than 1/2 used in chamfers or radii.

B. Any surface 0.050 inch or less in length may lose up to 0.005 inch at both ends of chamfers or radii.

C. Longer surfaces may lose up to 0.010 inch at both ends of chamfers or radii.

5.3 Surface Flaws. Flaws are surface irregularities and imperfections that occur at one place, or at relatively infrequent intervals in contrast to the normal irregularities produced by the surface finishing operations. Flaws include surface conditions such as scratches, cuts, dents, steps, cracks, checks, pits, blow holes, bumps, ridges, and similar mars and imperfections. Stains, discolorations and foreign material shall be considered surface flaws. Surface flaws are acceptable if the product function is not impaired.

6.1.2 Appearance. All threaded parts must be free from burrs.

7.2 Visual Inspection. Normal inspection for Section 5, "Manufacturing Requirements," and 6.1.2, "Appearance," shall be visual using seven to ten magnification. The use of other powers or techniques is acceptable.

> When variations which might impair the product function are found the production agency product engineer shall determine if the part is still functional.

These paragraphs require some interpretation. First if the drawing dimension of the short side (Table 1) was 0.049/0.051 inch, then the nominal size would be 0.050 inch, and the consequent allowed edge break would be 0.005 inch. Even if the part measured 0.049, the requirement would be 0.005 inch because the nominal drawing requirement was 0.050 inch.

Second, since deburring operations do not typically show part dimensions, it is the Engineering Division's responsibility to provide instructions on the required edge radius whenever this specification or drawing is required.

INSPECTION PRACTICE

The inspection departments are responsible for assuring that all parts made meet the requirements of these standards. Although some minor differences exist among inspection departments (as a result of the particular types of products being inspected), the following inspection guidelines are used universally.

The inspection traveler states, "Standard sampling plan, visual inspect at 5-8X magnification." The Standard sampling plan essentially says to pull a group of 15 parts from the parts submitted for inspection, inspect them for burrs and if any part has burrs the entire lot is rejected and returned to production for completion of deburring. A 15 piece sample may not seem to represent the entire lot, but experience has shown that it does in fact very well indicate when significant numbers of parts fail to meet the burr-free requirement.

Table 1. Edge Break Requirements as a Function of Part Dimensions (See Figure 3 for Examples of Usage)

English Units	
Short Side Dimension of Part (inch)	Maximum Permissible Edge Break/Radius (inch)
<0.020	¼ length of edge*
≦0.050	0.005
>0.050	0.010

<0.020 indicates that the part dimension is less than 0.020.

>0.050 indicates that the part dimension is greater than 0.050.

*Drawing SS331834 says that no more than half of a surface can be used in edge break. The values shown here assume that this quantity is equally split between the two edges. In actual practice, this may not be the case.

Inspection does not measure edge breaks unless they appear to exceed allowable limits.

Inspection supervision does not use high magnification unless some doubt exists as to part quality. For example, parts are not automatically checked at 30X just to reject them. Some part drawings do specify, however, that 20 to 30X magnification be used.

Bendix procedures say ". . . Inspection supervision judgment may be exercised to. . .use a power higher than specified to resolve uncertainties or to assure compliance with applicable requirements. . . . In all cases the selection and use of magnification equipment is to be based on sound, informed judgement with the object of making a realistic determination of product condition in relation to applicable requirements and quality standards." This procedure allows inspection to use 30X magnification if necessary. However, inspection seldom exceeds 10X magnification.

One of the requirements of any inspection department is that it not be forced to accept discrepant parts in such a manner that others are led to believe that they do in fact meet drawing requirements. As a result, in most companies throughout the world, inspection departments are entirely independent of production pressures. Inspectors can take as long as required to verify edge quality. They do not have to meet a standard hour rate. Their purpose is to ascertain if the parts meet the specification.

When assembly inspection departments indicate the burrs still exist on certain locations of certain parts submitted to stores, inspection supervision informally asks inspectors to pay special attention to these areas. The same is true of parts and features which recently have been rejected by any department. The inspection departments can recall any parts in stores or next assembly to verify burr free status.

The assembly inspection department can reject assembled units if burrs that would be or could be detrimental to the unit are found.

The product engineer can ask inspection to be particularly critical of specific areas or to ignore "small" burrs on noncritical areas. Whenever possible, however, Engineering is required to define explicitly on the drawings and the travelers exactly what edge requirements are needed.

Inspection monitors some edges closely because past experience with assembly departments rejecting parts for burrs makes it desirable to look closely at the edges.

When miniature threaded holes are gaged, the thread gage can raise a burr. Inspection can reject the parts for this burr, but in most cases manufacturing supervision has agreed to remove any such burrs generated by inspection. In such situations inspection does not initiate a "reject" citation since the parts were acceptable as received.

Inspection looks particularly closely at threaded features, because they are easily overlooked and are a frequent source of concern in next assembly.

As previously indicated, inspection will reject parts for burrs even though fragments are not visible. For example, if a smooth mound of material is present, that is sufficient reason to reject a part for burrs.

For parts which require strict edge conditions, the inspection traveler states, "100 percent inspect, visual inspect at 7-10X magnification." Thus every part is checked for burrs on all edges.

Because of the large number of edges involved and the time and difficulty required to measure edge radii, the inspection department only measures those edge breaks which appear to exceed the allowable limits.

The inspection department's general philosophy is that if an edge is critical it is indicated specifically on the drawing and the inspection traveler. For example, a 0.003 inch maximum break would be called out on the drawing.

EXAMPLES OF UNACCEPTABLE EDGE QUALITY

Figure 3 illustrates a retaining ring. These retaining rings are produced by the millions commercially and used in many precision miniature components. One will note in Figure 3 that this particular part has raised metal and burrs around much of the edge on one side. This is not allowable in most precision assemblies. Figure 4 illustrates the quality which can be produced by mechanized processes very simply and easily. As seen in Figure 4 although not all of the raised metal has been eliminated, for the specific application this is used in, that is not necessary. One should note, however, that for the majority of parts at Bendix raised metal is not allowable on the edges or surfaces.

Figure 5 illustrates a ball bearing race used in a bearing on one miniature assembly. When taking a careful look at some of the holes in these bearings, it can be seen that burrs exist, at least on the example shown (Figure 6). Further investigation (Figures 7 and 8) illustrates a number of burrs on these holes. This bearing is a small bearing and the burrs themselves are also very small. They cannot be seen without the use of microscopes and, as indicated by the magnification level on these photographs, a very high magnification may be required to bring all of them plainly into view. Despite the fact that these burrs are very small, they are not allowed in these assemblies. This particular example was observed after a unit failed to operate properly. Those little burrs can slow a bearing sufficiently to prevent a whole mechanism from working properly.

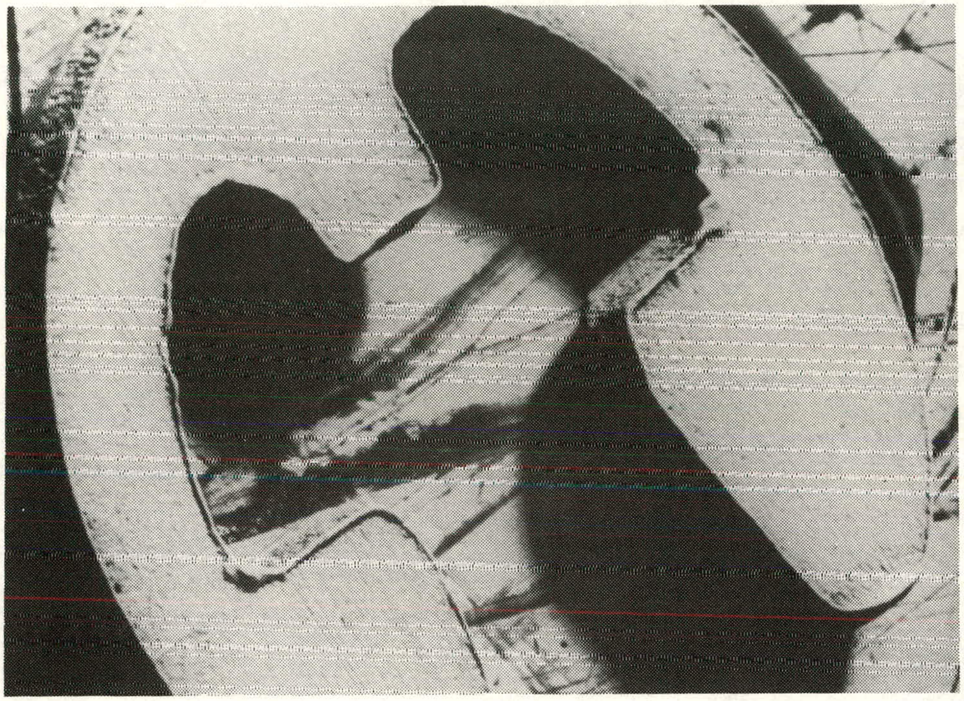

Figure 3. Burrs on Retaining Ring

At this point, the reader should return to Volume 1, Chapter 9 and review the thread qualities illustrated there. As previously indicated, threads are one of the most difficult deburring problems and one of the situations most subject to visual differences of acceptability. Threads must be burr-free, free of raised metal, and free of chips and loose particles.

Figure 9 illustrates a burr at one end of a very miniature pin. The diameter of this pin is 0.020 inch, which again is roughly the size of a paper clip wire. This part had been deburred by a mechanized process which did not totally remove the burr. As seen in the illustration, the burr was long enough and thin enough that the process beat the burr back over against the diameter and caused

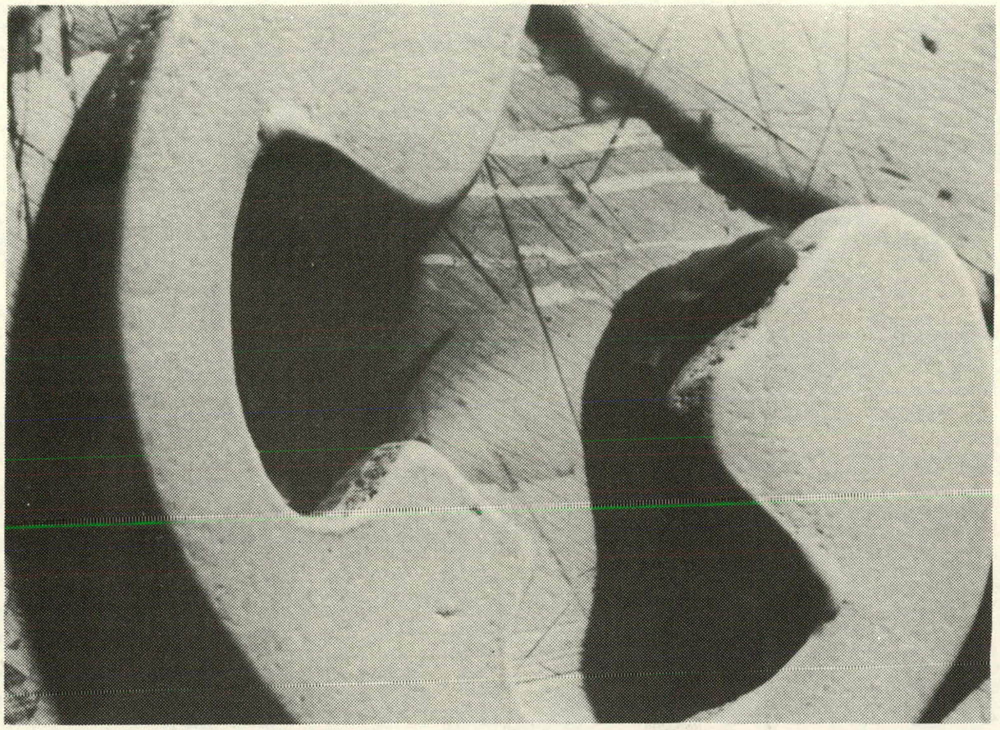

Figure 4. Retaining Ring After Mechanized Deburring

a slight raised metal condition at the end of the pin as well as a very thin component of burr on the diameter. This is not an acceptable condition, because as the pin is pushed into a hole, the hole will shear this metal and allow it to fall within the assembly.

At this point, we have not provided a definition of a burr. Bendix does not have a formal definition of a burr. However, a reasonable definition for use at Bendix can be projected:

- A burr is defined as being plastically deformed material produced by a chip producing process. It can be a sharp ragged projection, it can be firmly adhered or loose hanging projections, or it can be a small swell of raised material.

Figure 5. Ball Retainer in Precision Miniature Ball Bearing

- None of the these conditions are allowable. If the workmanship specification is a drawing requirement, these conditions must be visible under 4X magnification. If these conditions must not be visible under 10X magnification. Individual parts may have specific drawing notes indicating magnifications other than indicated here. The drawing notes take precedence.

- Sharp edges are not permitted. For reference purposes, a radius of 0.0005 inch or less shall be considered sharp.

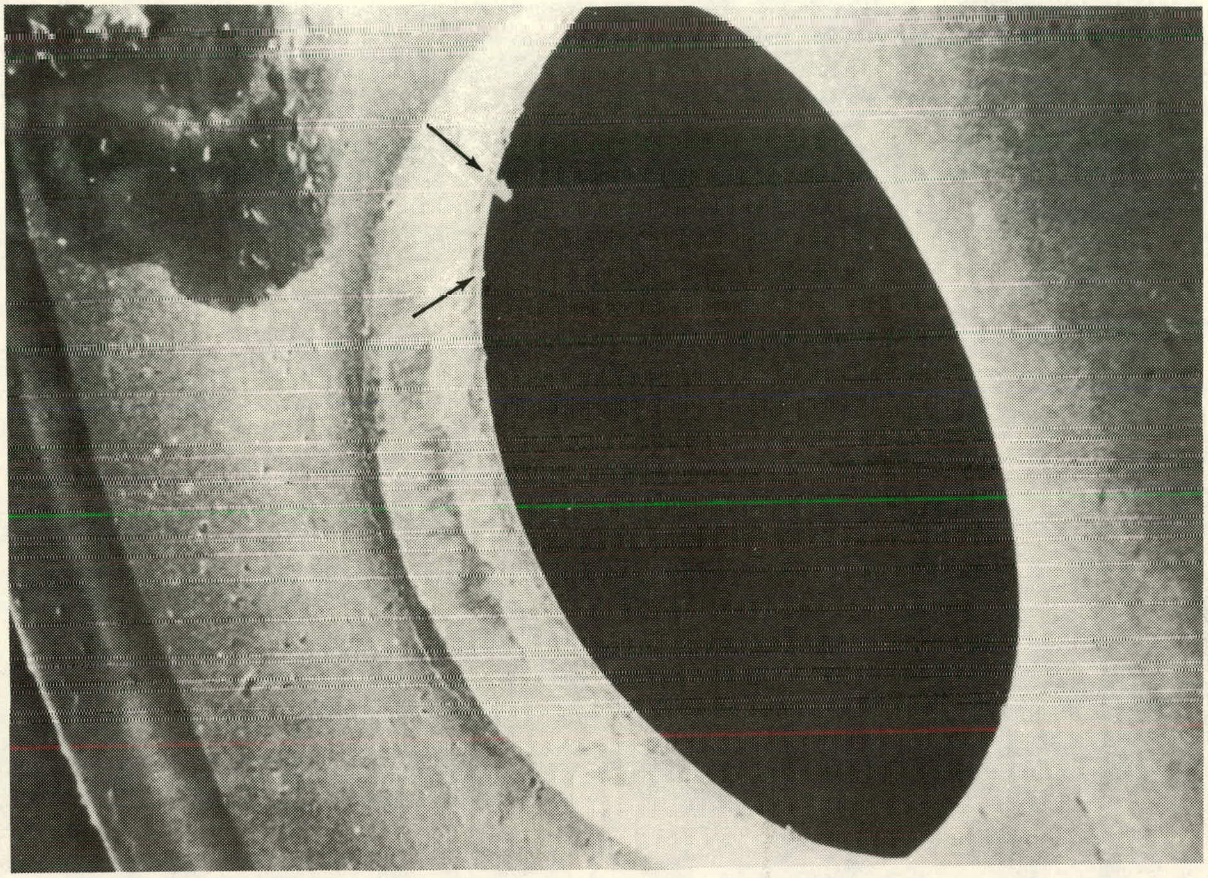

Figure 6. Burrs in Ball Retainer Holes

Sooner or later the question arises, "How big a burr is allowable?" On miniature parts, a burr only 0.0002 inch is too large in many situations. Even a burr half that size is too large for many situations. The Bendix expectation on small parts is that all burrs or particles visible at 10X magnification must be removed. In some cases, the production traveler will indicate that 20X magnification or even 30X magnification should be used to look for burrs. In actuality, no burr is allowable on many small parts. In practice, because a number of other indiviuals handle parts, because parts get cleaned many times, because many other operations

Figure 7. Burrs in Ball Retainer Holes

are performed after deburring, it is possible that a small burr might not hurt the next assembly. Bendix cannot afford, however, to deal in such subjective situations. It is important that all burrs be removed and that we not depend upon subsequent individuals or processes to remove even the very minute particles.

Figure 8. Burrs in Ball Retainer Holes

INSPECTION AIDS FOR THOSE DOING DEBURRING

A few inspection aids are available for providing nearly sharp edge breaks. The easiest inspection aid to use is the set of edge break standards shown in Figure 10. These standard samples have

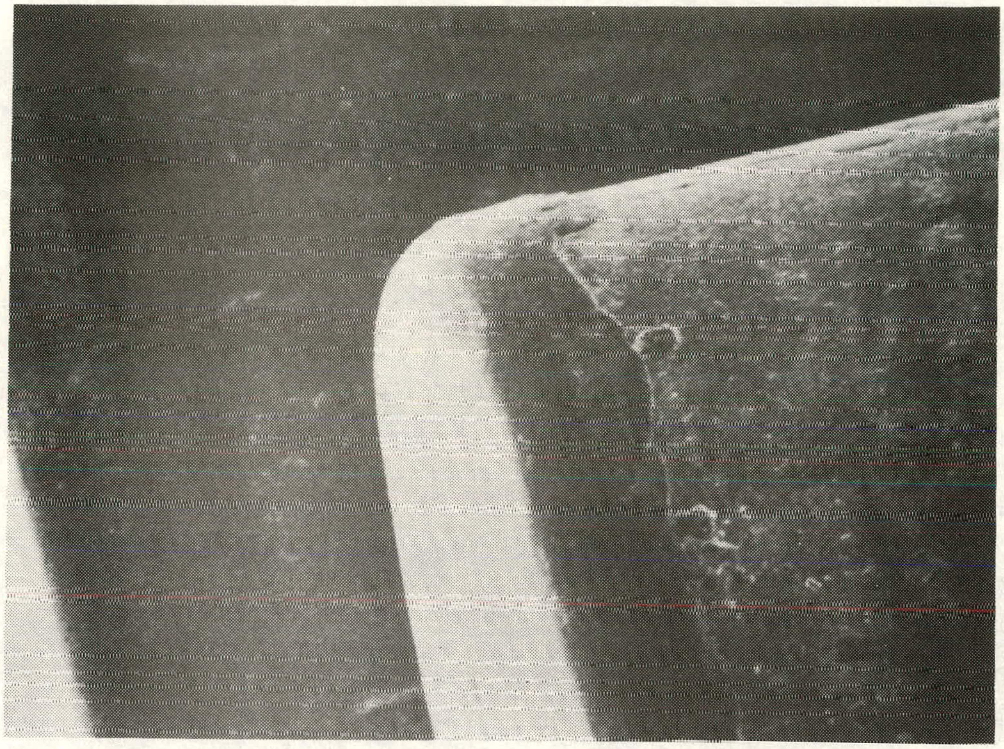

Figure 9. Burr Beat Over at Pin End

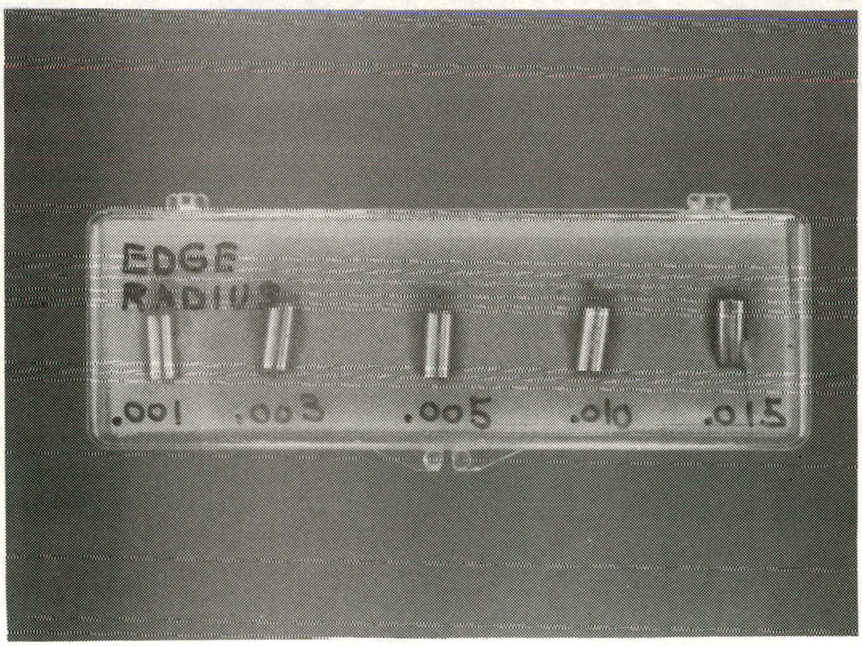

Figure 10. Inspection Aids for Comparing Edge Breaks

small chamfers or small radii on one end and a number marked on the sample. As an example, one of these samples will have a 0.003 inch radius. To use this sample, it is placed underneath the microscope adjacent to the part radius to be evaluated. Then determination can be made as to whether the part has more or less radius than that of the sample. While this visual inspection of edges is not a precise measurement, it is generally adequate for the majority of parts to indicate whether or not edge breaks are close to the desired requirements. These standard samples are available from the supervisor.

Lenses are available for use in the eyepiece of microscopes to measure edge radii. These lenses have a series of arcs which at 30X magnification will indicate 0.003, 0.005, 0.007, and 0.009 inch radii. These are used like edge break samples except that they must be held at the edge to be viewed so that it is concentric with one of the edge radii markings (Figure 11).

Two other inspection aids are available for general assistance. The first of these aids is a hair from the head of any individual. As previously indicated, the diameter of a hair is generally close to 0.003 inches. As a result, if one could hold one of these underneath the microscope he or she would have an aid which is 0.003 inches in diameter or which has a radius of 0.0015 inch. This can be held against the edge to be reviewed to determine if the edge break is close to either the radius indicated or the diameter of the hair (Figure 12). Similarly, a normal sheet of paper can be held at the edge and compared to the edge radius in the part. Most papers are roughly 0.003 inches thick. This can be verified with the use of a micrometer.

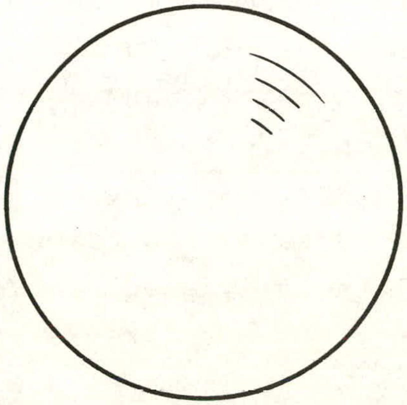

Figure 11. Microscope Eyepiece With Area for Measuring Edge Radii

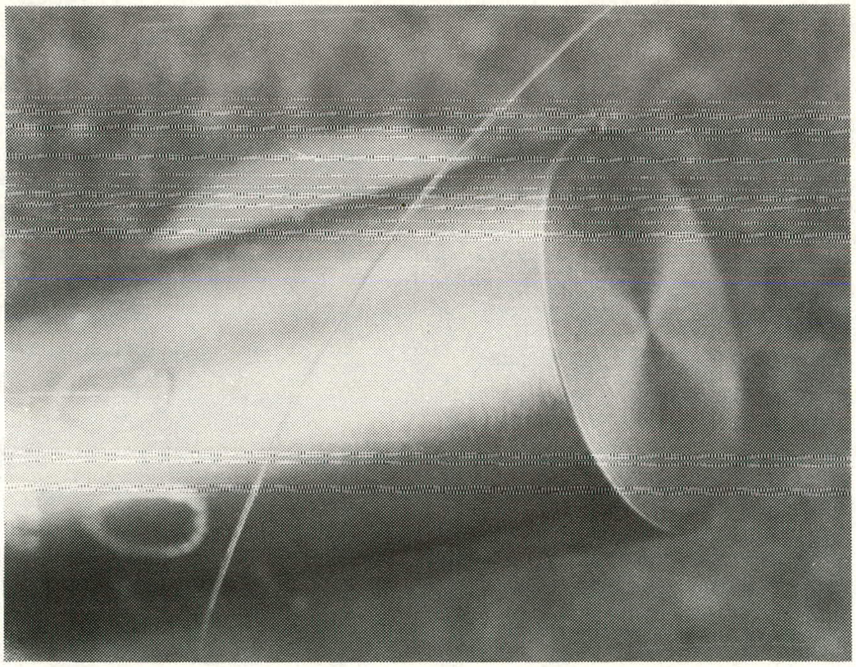

Figure 12. Use of a Human Hair to Compare Edge Breaks

ASSIGNMENT

1. Measure the diameter of a human hair. Record the results and report them at the next class session.

2. Measure the thickness of a common piece of paper. Record the results and report them at the next class session.

3. What is the standard edge break requirement unless otherwise indicated on parts?

4. What is the major difference between the general workmanship standard and the critical condition standard?

5. On a part only 0.01 inch thick, how much edge break is allowable on each edge?

6. List the concerns on threaded features.

7. What can you use conveniently to determine if edge breaks are adequate?

8. Describe in your own words the Bendix definition of a burr.

9. How large a burr is allowable?

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CHAPTER 14

STANDARDS FOR SURFACE FINISH

Previous chapters have covered the problems of scratching on surface finishes and the need on many miniature parts to have precision surface finishes. This chapter will define exactly what surface finish means. Completing this chapter should provide a basic understanding of what the surface finish numbers mean and the intent of the Bendix standards on surface finish.

BENDIX REQUIREMENTS FOR SURFACE FINISH

The Bendix general workmanship requirement indicates that, unless otherwise specified, all parts must have a surface finish of 125 microinches. Many of the smaller parts have additional requirements for a smoother surface. As an example, some precision miniature parts must have a surface finish of at least 63 microinches. Many Bendix drawings also call out even more precision surface finishes for certain areas of a part. For example, in Figure 1 the two shafts on the gear have a surface finish call out for 8 microinches.

An individual performing deburring will not know what surface finish is required on a part unless a production traveler indicates something different than the standard practice. As previously mentioned, the standard practice on the majority of miniature parts is a finish which has a roughness of 63 microinches.

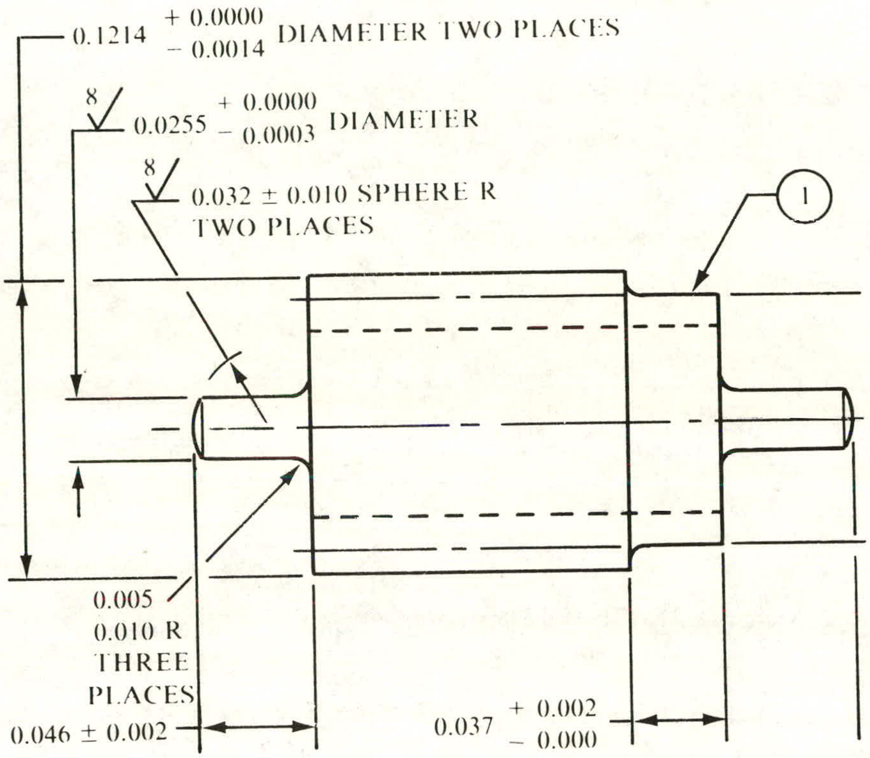


Figure 1. Precision Surface Finish Required on Gear Spindle

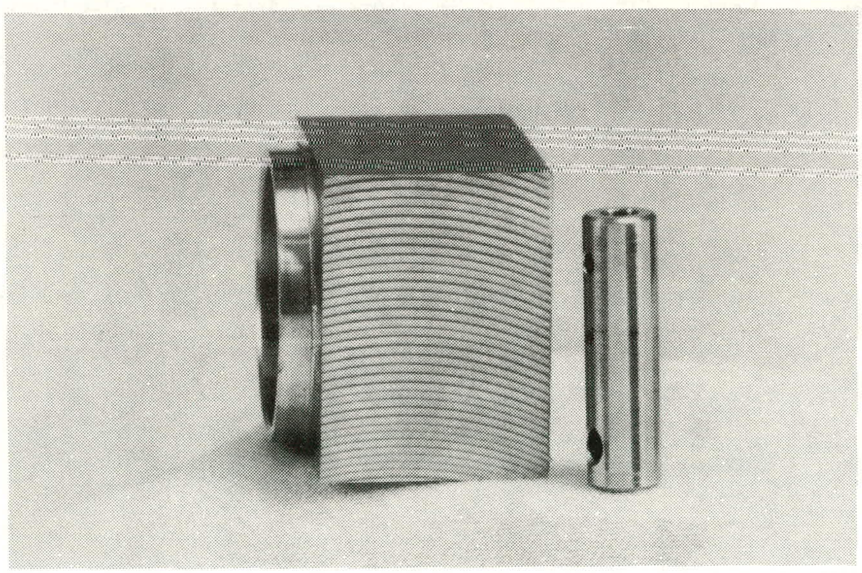


Figure 2. Finishes on Production Parts

APPEARANCE

Surface finish numbers do not mean anything without a visual comparison. Figures 2 and 3 provide some relative appearances of various surface finishes. In Figure 2, two parts, one having a fine finish and one a very coarse finish, are shown. An 8 microinch finish is very fine. In actual practice, a typical finish on miniature parts is 32 microinches.

VISUAL COMPARISON

While photographs such as Figures 2 and 3 provide some basis for making judgements about surface finishes, in practice it is essential to have something that is more three-dimensional than a photograph. For this reason, visual comparators are available to indicate various degrees of roughness and the types of finish produced by various processes. Figure 4 illustrates one of these surface finish comparators. It is the type of comparator which is used by running a fingernail over the surface to get a feel as well as a visual understanding of how rough each of the numbered surface finishes are.

IMPLICATIONS OF SURFACE FINISH NUMBERS

Numbers like 8, 63, and 125 microinches have already been mentioned. Those numbers mean that the average surface is smooth within 8 millionths of an inch, 63 millionths of an inch, or 125 millionths of an inch. Figure 5 illustrates the cross-section of a part cut in half. As seen there, under very high magnification any surface has a considerable amount of roughness to it. For this illustration, the roughness is highly magnified to illustrate the point. Dragging a phonograph needle across the surface causes the needle

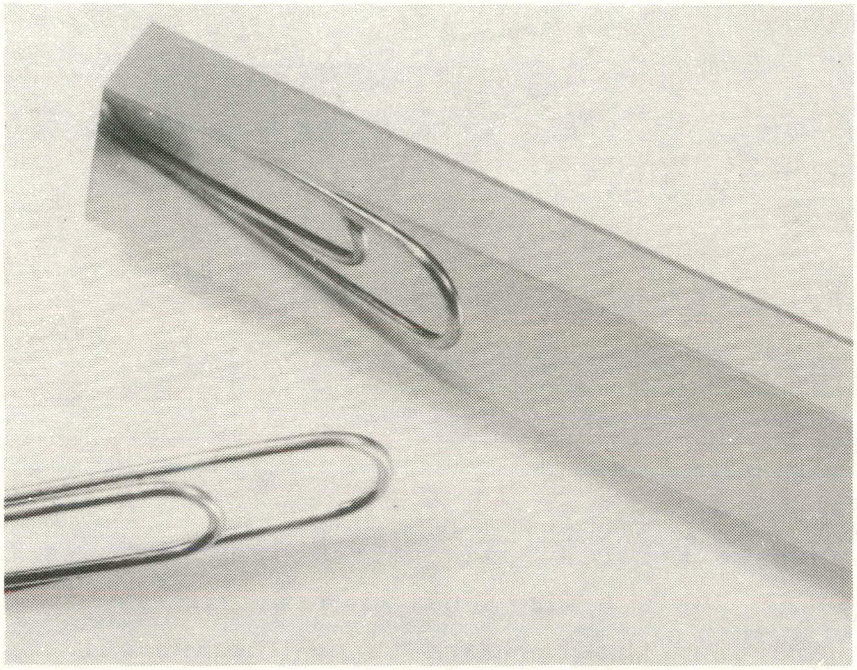


Figure 3. Part Having Very Smooth Surface Finish

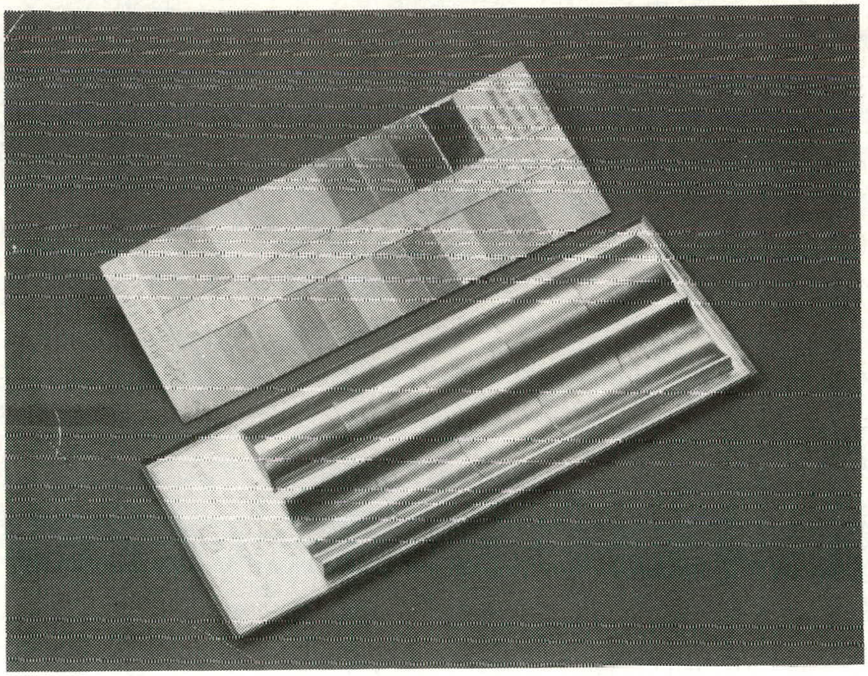


Figure 4. Two Forms of Surface Finish Comparators

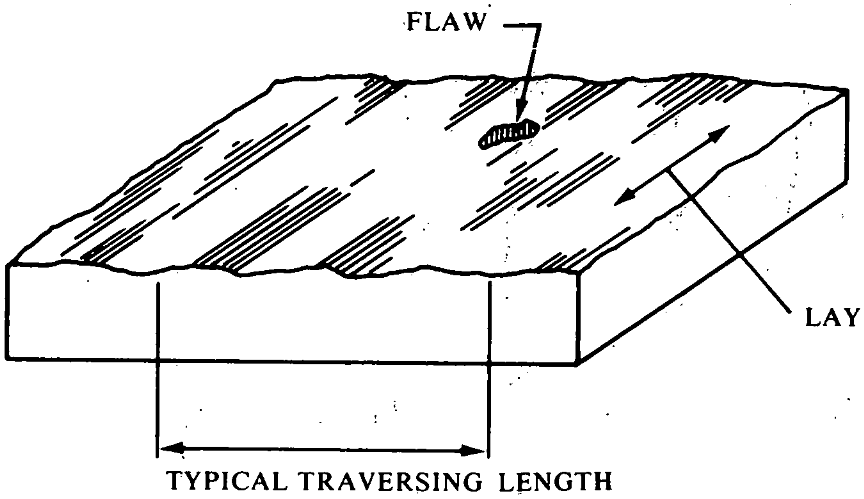


Figure 5. Roughness on a Surface When Viewed Under High Magnification

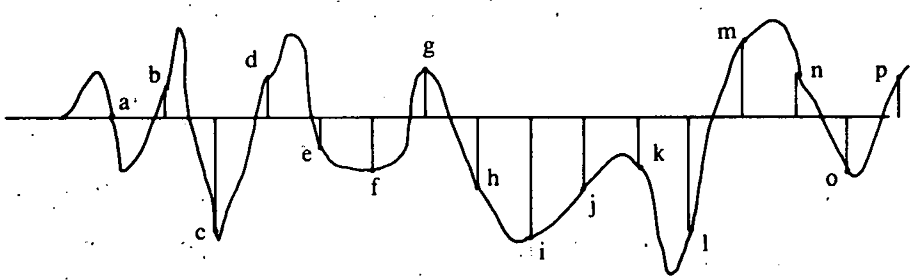


Figure 6. Roughness Calculation Having a Large Scratch

to fall into the grooves and rise up to the tops of the peaks. Keeping track of the number of times the needle fell, how far it fell, the number of times it rose, and how high it rose then averaging all these across the entire surface of the part provides an average roughness reading for the part. That average is what is meant when using numbers to describe surface finish.

Machines actually add up the total number of times the needle rises and falls and the distance it rises and falls each time. Adding up as shown in the following equation makes it possible mathematically determine the roughness of a finish.

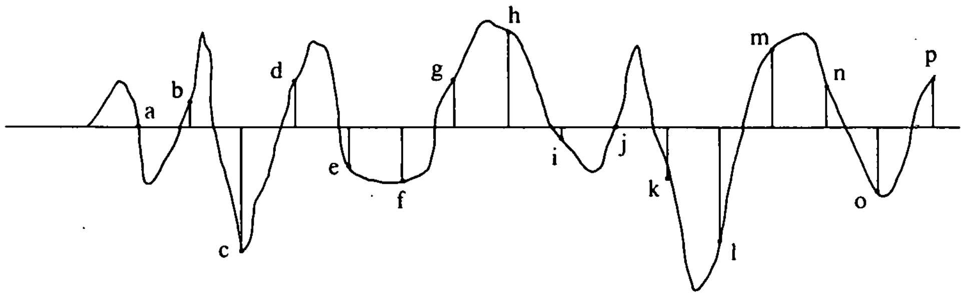


Figure 7. Cross Section of Scratched Surface

$$\text{Average roughness} = \frac{\text{Sum of heights from center line of all points}}{\text{Total number of points measured}}$$

As an example, assume that the surface looks as rough as shown in Figure 6. Further, use the numbers shown in Table 1 to illustrate how high or how low each line segment in Figure 6 is. As seen in Figure 6, line b is only two microinches high, line c is three microinches high, line e is, similarly, only two microinches low. If we add up the lengths of these lines, and ignore the fact that some are below and some are above the line, then the total quantity of roughness that we measure is 20; but as is indicated we have taken 16 measurements. If we divide 16 into 20 then the average surface finish measurement is just slightly more than 1. For this example, the surface finish of 1.25 indicates that the average roughness is 1.25 millionths of an inch.

This illustration indicates there are very high levels of precision on many of these parts. It is important for the operation of many of these parts to have such high levels of precision. Consider what would happen if we scratched the surface just shown such that at position j and k we scratched out considerable metal. In this case, the cross section would look as shown in Figure 7. For this illustration, we look at Table 1, example number 2 and find that

Table 1. Data for Calculating Surface Finish

Line Identification	Example Number 1 Line Height	Example Number 2 Line Height
a	0	0
b	1	1
c	3	3
d	1	1
e	1	1
f	1	1
g	1	1
h	2	1
i	0	3
j	0	2
k	1	1
l	3	3
m	2	2
n	1	1
o	2	2
p	1	1
Total 16 lines	20	24

the total sumation of heights is now 24 units or 24 microinches. When we divide by 16 measurements there is very little change in surface finish even though we erased a large quantity of metal in this scratch.

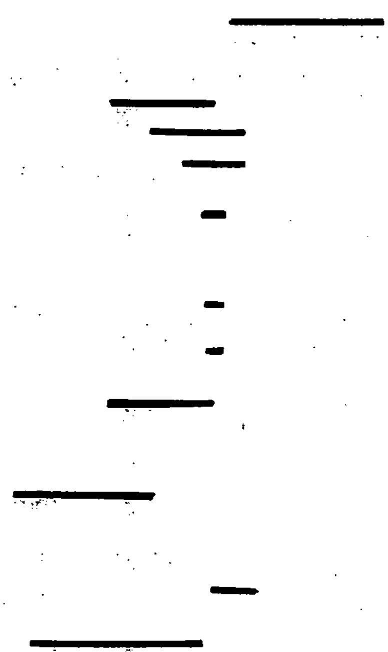
The point is that a single scratch on the surface does not change the average surface finish reading. From a technical standpoint, that is an important observation. In real life, however, a single scratch still may not be acceptable. Parts have to function not only from the average surface finish but from the friction on the surface. Scratches can cause excess friction which will cause units to fail. They also provide a cavity in which dirt and debris can collect. Despite the fact that a single scratch does not cause measurements to exceed the average surface finish allowed on a part, it can be reason to scrap many parts.

MECHANIZED PROCESSES

When parts come off lathes and milling machines in Bendix's precision miniature machining area, the majority of these parts will have surface finishes of 30 or 40 microinches. Precision parts will, of course, have a precision surface finish already on them when they come to deburring. Mechanized deburring process can be used on many of these without affecting the surface finish. For example, Table 2 illustrates that a barrel tumbling or electrochemical deburring operation will not worsen a surface finish of 16 microinches. When an 8 microinch finish is required, however, most mechanized deburring processes cannot be used. For this reason, most parts with such fine finishes must be deburred by hand and great care must be taken to see these surfaces are not scratched.

Table 2. Basic Capabilities of Deburring Processes--Surface Finish*

Deburring Process	Typical Working Range, Surface Finish (μin.) (1)	(10)	(100)	(1000)
ABRASIVE				
Abrasive Jet				
Loose Abrasive				
Barrel				
Centrifugal Barrel				
Vibratory				
Sanding (Edges Only)				
MECHANICAL				
Mechanized				
Hand				
Brushing				
CHEMICAL				
Chemical				
ELECTROCHEMICAL				
Electrochemical				
Electropolish				



*Based on the removal of 0.003 in. thick burrs from the edges of 303Se stainless steel directly exposed to the deburring process. These capability estimates assume that surface finishes of 32 μin. exist on the workpiece prior to deburring. Surface finish effects are defined as changes which occur on exposed surfaces adjacent to the burr laden areas. Small squares indicate that the indicated process does not affect surface finish.

ASSIGNMENT

1. Using the samples provided, sand the surface of one sample with a 600 grit abrasive paper for one minute. For the other sample sand the surface with a 240 grit abrasive paper for one minute. Have your supervisor have the surface finishes measured and observe the results.

2. Run your fingernail across the surface finish comparators provided (both flat and turned surface comparators).

3. Answer the question, "Do precision surface finishes have large numbers or small numbers?"

4. What is a typical surface finish required on Bendix parts?

5. What is a typical surface finish required on many miniature parts?

6. What is the finest surface finish one can expect to be required to maintain on a precision miniature part?

CHAPTER 15

WRITTEN DEBURRING INSTRUCTIONS

THE PRODUCTION TRAVELER INTENT

The purpose of the production traveler is to provide all the necessary information about product requirements and specifically needed tools to produce a part. In the case of machining operations, almost all cutting tools are specified. For deburring, this is not necessarily true. There is such a wide variety of individual preferences and tools to select from that they are not normally specified in deburring processes (except as noted later).

Three items are specified on production travelers for deburring operations:

- The edges which must be deburred,
- The amount of edge break required, and
- Specific information about critical areas on the part.

As indicated before, some deburring processes involve only the deburring of one or two specific edges. Other deburring operations involve the deburring of the entire part or at least the verification that the entire part is burr free. Because some parts may have three or four separate deburring operations, it is imperative that the engineer who prepares a production traveler designates the area and amount of deburring expected in each of these operations.

As indicated in the previous chapter, there are three basic edge break requirements specifically required by Bendix standards. These are 0.010, 0.005, and 0.003 inch maximum edge breaks. In addition, there are a number of drawings which have specific edge break requirements different than this. Despite the presence of the 0.005 or 0.003 maximum edge break requirements, the majority of parts actually require 0.010 inch breaks maximum for the majority of edges. It is, of course, the smaller edge breaks which create the largest problem and require the most skill in deburring.

Because many parts have 50 or 60 separate edges, it is impossible to use written instructions only to indicate which edge, how much edge break, and what type of special care is required. For this reason, whenever doubt may exist as to which edge or detail is to be deburred, an illustration should be provided by the engineer. These illustrations are part of the production traveler deburring operation. For some who are intimately familiar with individual parts, such illustrations may not be necessary. When three different shifts of production workers each having different levels of skill and experience must work on parts, such illustrations are mandatory.

When a part has critical surfaces (close tolerances, fine finishes, callouts for no tool marks or scratches, or thin sections) these aspects of the part must be noted on the production traveler. Failure by the engineer to specify these considerations can easily result in damage to the parts with just normal care by those performing the deburring.

As an example, 600 grit abrasive paper will taper a small shaft 0.002 inches in 10 seconds very easily even when an attempt is made to hit only the edge of the part (Figure 1).

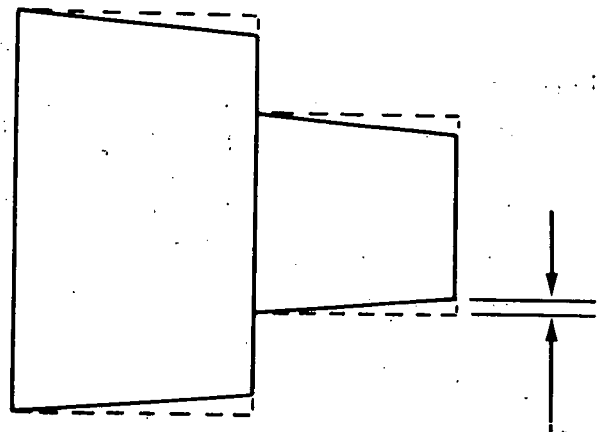


Figure 1. Sanding Can Easily Taper Part Diameters

For in-process deburring, each of the three aspects just listed must be specified. For final deburring in which some edges have already supposedly been adequately deburred, but others have not, the engineer must indicate on the traveler those edges which should be deburred at this operation. In addition, the engineers are obligated to add such words as "...and verify that remainder of edges are burr free." For the final deburr operation in which edges other than 0.010 inch maximum edge break are specified, it is important for the engineer to indicate what these edge breaks were supposed to be even though those edge breaks were supposedly produced at a prior operation. As an example, Figure 2 is an illustration for an in-process deburring operation, and Figure 3 is the same basic illustration for the final deburring operation.

As a general policy, the deburring tools which might be used to deburr the parts are not listed. One of the major reasons for not doing so, as previously indicated, is that each deburring operator has some differences in his/her capabilities which limit the usefullness of some tools that others might find better. As an example, a few tools are designed for right handed users. This is an obvious disadvantage for a left-handed individual. There are three exceptions to this general policy.

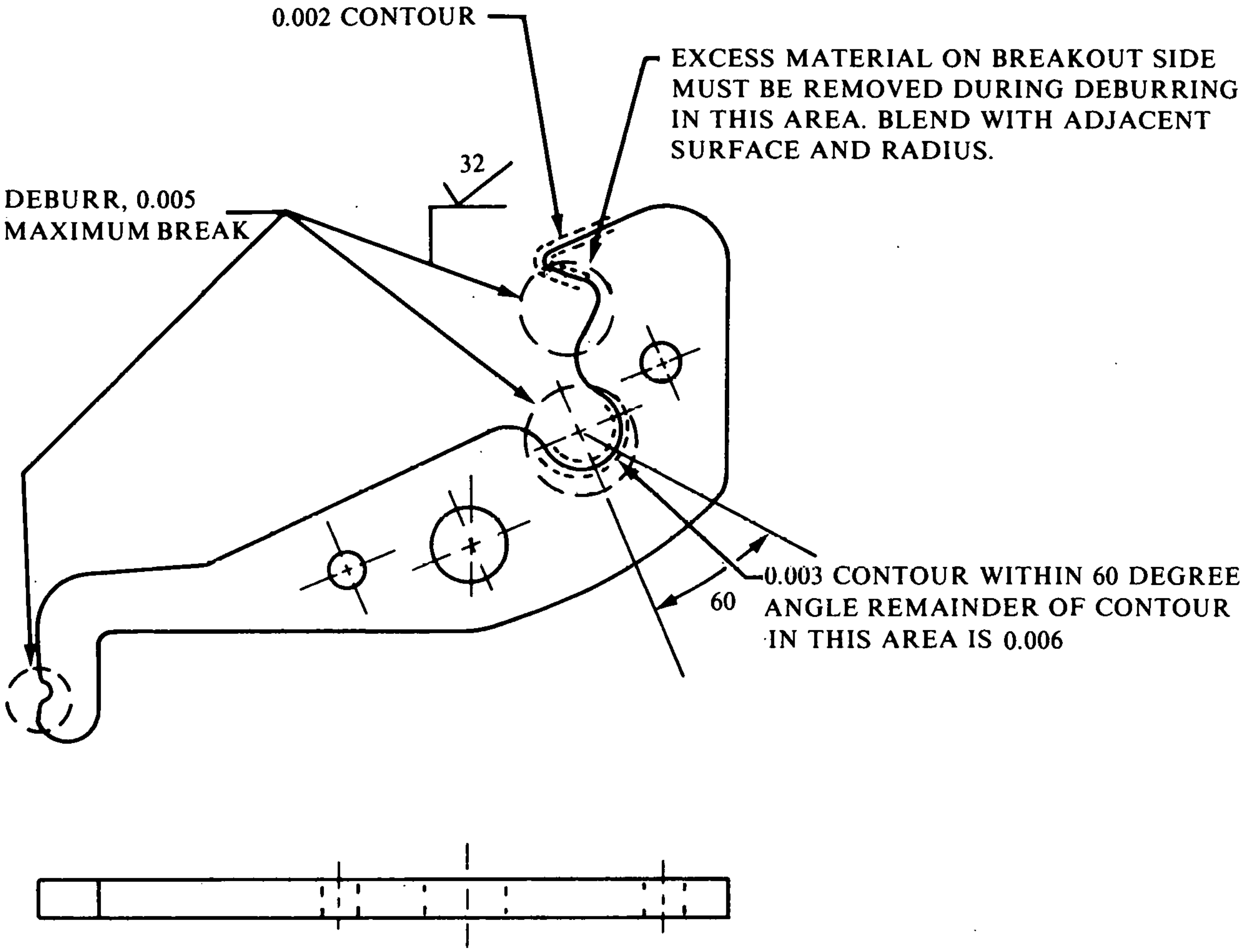


Figure 2. Typical Illustration for In-Process Deburring Operation

- The first exception concerns threaded holes. All threaded holes should have a brush called out in the Requirements List for the deburring operation. This particular requirement is the only way to assure that threads are reasonably free of burrs and chips.

- The second exception to the general rule concerns the use of microscopes. When the drawing or the required workmanship standards dictate inspection under magnification, then this

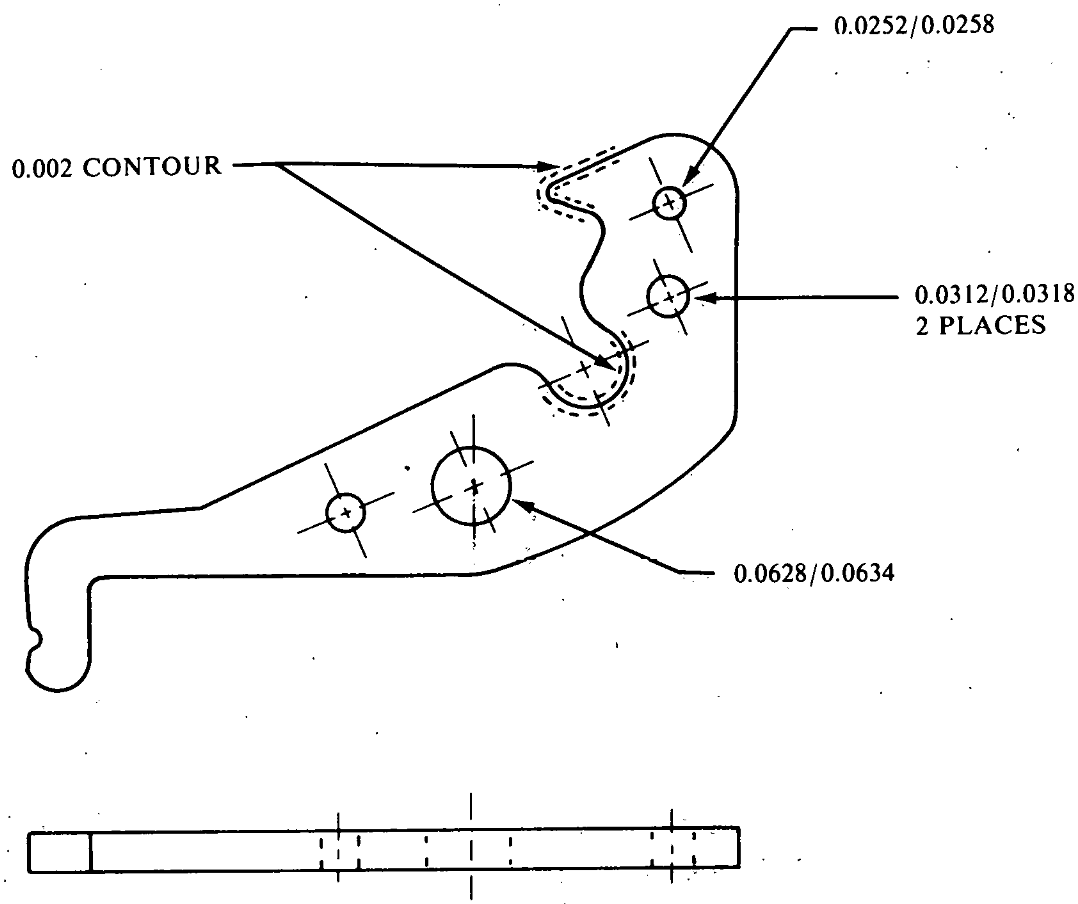


Figure 3. Illustration for Final Deburring Operation

must be indicated to those performing deburring. This is accomplished by adding the words "microscope--up to 20X" in the Requirements List in the deburring operation. A few parts which have specific callouts on the drawing requiring other conditions also will indicate in the text of the deburring operation to "deburr at 7-10X" or related magnifications.

- The third exception to the general rule concerns specific parts in which there is an obvious deburring problem, i.e., something often overlooked, quality often not obtained, or special tools required. These conditions are handled as necessary so that everyone is aware of the special tools or requirements.

- On some parts, to assure quality or productivity, special deburring instructions will be added in the text of the operation (above the burst of asterisks). At the present time, the industrial engineering department is adding this information with the concurrence of the individual process engineer when a time study has been completed.

  In these situations, the tools required to meet the indicated production rate and/or quality will be specified in the text as well as in the Requirements list. Also, the sequence of tools used will be specified in the text for these situations.

  The purpose of this information in the text is to add emphasis that this is the required way to finish the parts. If a faster way is conceived, it should be evaluated by the industrial engineering department, the supervisor, or the process engineer responsible for the production traveler.

All deburring operations (Z901 and Z902) should be on a page by themselves. The practice of having more than one operation for each page makes it difficult for those performing the work to find the appropriate instructions. The current practice is to provide deburring instructions on separate pages.

SAMPLE PRODUCTION TRAVELERS

Figure 4 illustrates a sample deburring operation as specified on production travelers. Note that Z902 is the type of deburring operation (final deburr). This page defines the basic area which

PRODUCTION TRAVELER

SNAP ACTION SHAFT

PROC CHG NO. 035/IJ, SHT NO. CHG 27

05/09/79

260 Z902 .14517 M 6.9 PCS/HR

VERIFY THAT HOLES, CAM SURFACE EDGES, AND MILLED FLATS ARE BURR FREE.

DEBURR REMAINDER OF PART COMPLETE.

REQUIREMENTS LIST:
MICROSCOPE -- UP TO 20X MAGNIFICATION

- SEE ILLUSTRATION -

Figure 4. Typical Written Instructions for Final Deburring

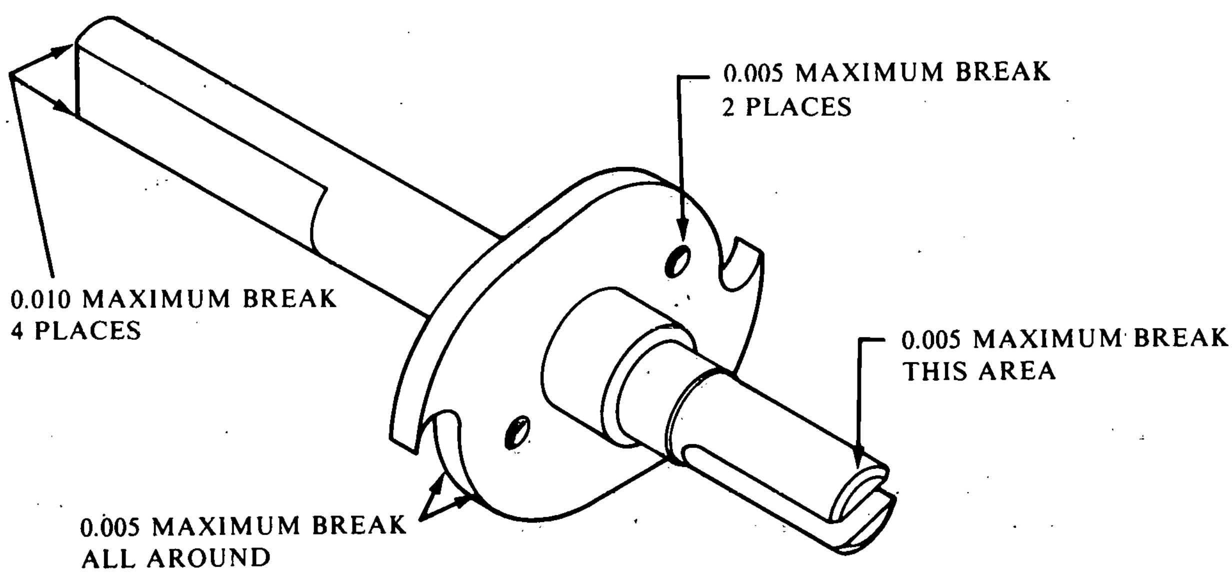


Figure 5. Illustration Corresponding to Figure 4

must be deburred. It indicates that an illustration is available defining the requirements. Also, it indicates that a microscope is required and that the deburring will be inspected at up to 20 power magnification.

It is important to note at this point that 20X magnification is an inspection requirement. Those performing deburring may use any power magnification that they desire, but they are expected to have a microscope with up to 20 power magnification at their disposal. If these parts can be accurately deburred at 7X magnification, then that is all the magnification the operator need use. If, however, an individual performing deburring can only adequately deburr them at 30X magnification, then he is expected to use that magnification. The note "--up to 20X" implies only that inspection is obligated to use up to this amount of magnification in verifying a burr free condition. Figure 5 is the illustration referred to on this deburring operation.

Figure 6 provides instructions for deburring a part. As seen there, an illustration is also provided (Figure 7). Specific instructions on how to deburr the part are also indicated although the instructions are basically general in nature. The fact that two tools are specified in the requirements list implies that those performing the deburring are expected to use these tools and that they must be available at the work station when this operation is performed. If better tools are obtained or faster techniques are known, the individual is then expected to use the fastest technique available. When significant differences exist, those performing the deburring should notify their supervisor that the production traveler does not represent the fastest method for deburring these parts.

The following deburring check list indicates the types of questions each engineer must determine in his own mind as he prepares the production traveler operation for deburring.

PRODUCTION TRAVELER

CODE WHEELS M ACKMANN

PROC CHG NO. 035/DF, REV. REQ. LIST, OPER. 130 15-
09/06/78

130 Z901 .01484 M 67.4 PCS/HR

DEBURR PER ILLUSTRATION, USING FINE GRIT SAND PAPER FOR BACK FLAT AND NYLON BRUSH FOR CONTOURED AREAS. BURR KNIFE SHOULD BE USED ON HEAVY BURRS ONLY.

REQUIREMENTS LIST:
NYLON BRUSH NO. 10207257 OR EQUILVALENT
MOTOR ARBOR NO. 50800196 OR EQUILVALENT
MICROSCOPE - UP TO 20X MAGNIFICATION

- SEE ILLUSTRATION -

Figure 6. Written Deburring Instructions

- Is deburring specified?
- Are specific areas to be deburred specified?
- Are edge breaks specified?
- Is an illustration required?
- Is a brush specified for threaded holes?
- Is a microscope required and called out?
- Are critical surfaces or close tolerance areas indicated on deburring operations?

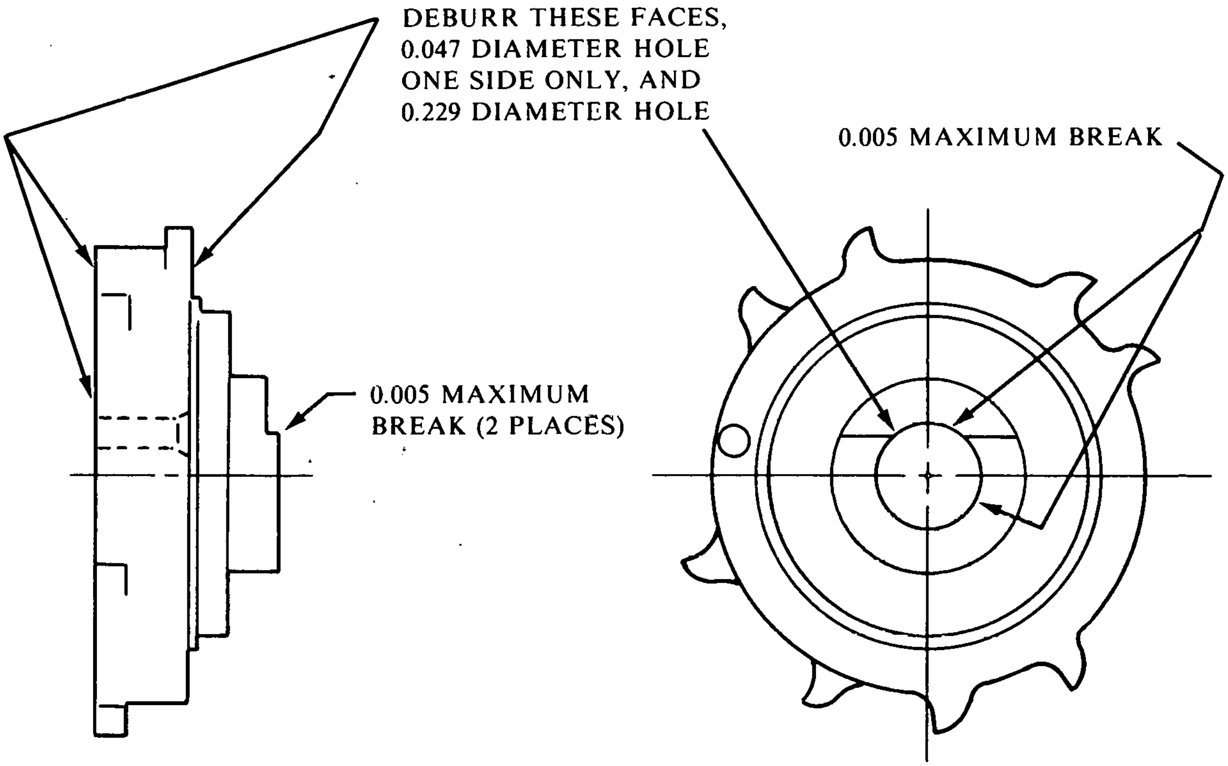


Figure 7. Illustration Corresponding to Figure 6.

- For final deburring, are all edge requirements specified?
- For final deburring, are those edges supposedly previously deburred designated as reference edge breaks?
- Are any special required tools specified?
- Has the necessary paperwork been submitted to provide adequate deburring tools in the nearest tool crib?

KNOWING WHAT TO USE IN THE ABSENCE OF INSTRUCTIONS

On the previous illustrations, not all edges had an edge break callout specified for them. In the previous chapter on standards, if edge breaks were not specifically called out, they were 0.010 inch maximum edge break. To simplify illustrations, it is common practice to not specify edge breaks which are 0.010 inch maximum. Since this is the standard for all parts unless otherwise specified, it is not necessary to again indicate these requirements specifically. Thus, when viewing production traveler operations for deburring, if edge breaks are not specified on any edge, then a 0.010 inch maximum edge break must be assumed. If this is in error (for example, edge break requirements are actually 0.005 inch maximum), then the fault is that of the engineer preparing the traveler and not the production worker.

The fact that deburring tools are not specified for most deburring operations should not concern most workers. By the time readers finish this training course, they will be knowledgeable about the majority of deburring tools, how to use them, and their various capabilities and limitations. Also, by the time readers finish this training course, they will have had considerable experience using these tools on a variety of parts. For this reason, you will have a good knowledge of how to approach individual parts and individual situations. There will be many times, however, when there will still be questions about the best tool for specific situations. When this occurs, supervisors or other workers will help suggest alternative ways. While others suggest ways successful for them, the final responsibility is actually yours. The part is yours to deburr as best you can to meet the Bendix quality and production requirements. While at times, that responsibility may be frustrating, with experience it will also be a challenge to see if you can find a better or quicker way.

Because production travelers change frequently to meet the constantly changing demands of production, it is important for operators to know the exact words and numbers specified on a production traveler. While many individuals have deburred parts for several years and know the techniques they have used in the past from memory, if the production traveler requirements change, those techniques may result in scrap parts. For this reason, each production worker is expected to have the written production traveler instructions at his or her work station at the beginning of working on those parts. In some instances, two or three individuals may be working on the same part at the same time. In this situation, it is the responsibility of each worker to read and understand the instructions on the production traveler prior to working on parts. If an individual has any questions, his supervisor will assist him.

ASSIGNMENT

1. Deburr the parts provided using the production traveler description for quality requirements and techniques to use.

2. As you are completing the part in Assignment #1, write down for your instructor the types of information you feel should have been on the production traveler to make your job easier.

3. Write down specific questions you had about deburring this part.

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CHAPTER 16

RESEARCH ON HAND DEBURRING

Bendix has made a number of studies which provide quantitive data about hand deburring miniature parts. This chapter presents the results of some of those studies. These studies include both the repeatability of edge radiussing and size of edge break which can be produced by a variety of deburring tools. In reading this chapter it is important to recognize the main points, and also important to recognize that, on real parts, research only provides a trend. Research results do not necessarily mean that the exact results can be reproduced on parts run in production. The reason for this is that parts made in production may have larger burrs, may be made of different material, or may have different configurations than are used in a test. In addition, these studies were made by experienced individuals, but, as in the case of any test performed by humans, every individual will produce results different from his compatriots.

REPEATABILITY OF HAND DEBURRING

In one study, experienced deburring personnel were asked to deburr cube-like samples (Figure 1a). A 0.005 inch maximum break was the goal on these parts. Extensive measurements indicated that 95 percent of the edges met the 0.005 inch maximum break. Fifty percent of the edges had radii of 0.002 inch or less. These samples were made of 303 Se stainless steel and had normal burrs on them.

In the second study, the sample (Figure 1b) was deburred, again in an attempt to maintain 0.005 inch maximum break. In this case, the actual edge break that was produced varied depending on which

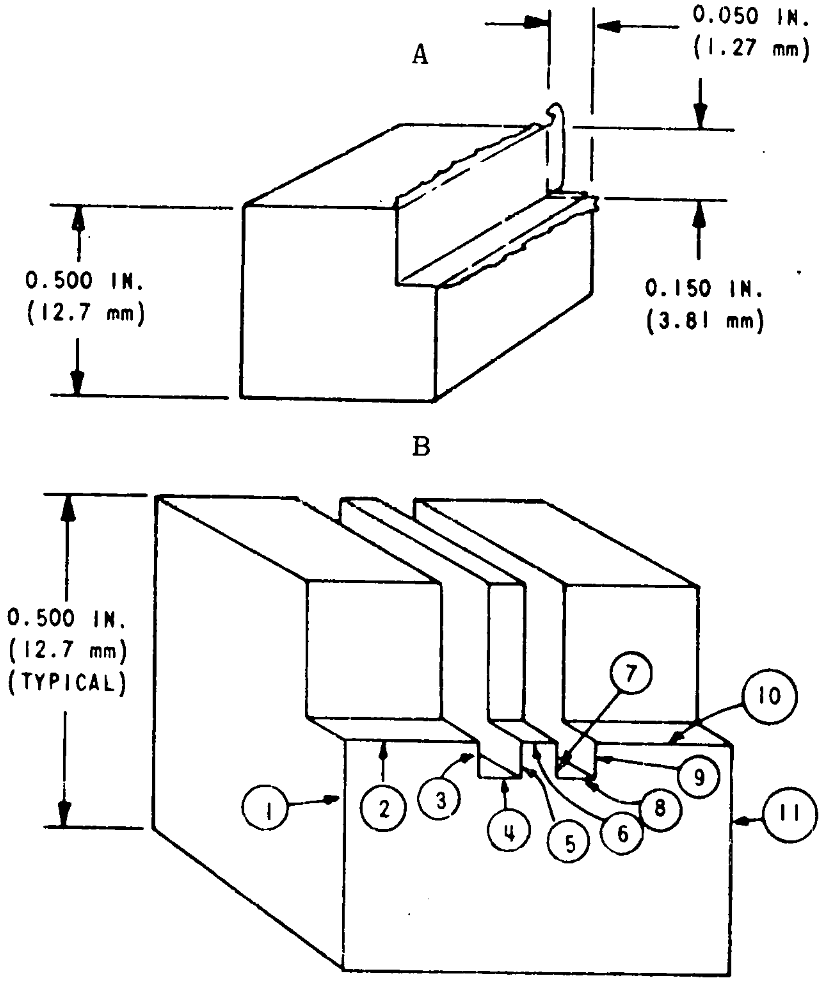


Figure 1. Specimen Geometry Used to Assess Edge Break Repeatability

edge was involved. Edge Number 2, for example, consistently had breaks which exceeded 0.005 inch. In reality, the average radius on most edges was between 0.002 and 0.004 inch. Part requirements at Bendix, however, are that every point on an edge must be less than the indicated maximum break. Typically, if the average break was 0.004 inch, then half the breaks varied from 0.004 to 0.0066 inch. This is not a large variation, but it is large enough so that every part in this study would have been rejected for excessive break.

At this point, the question arises "are requirements like 0.003 or 0.005 inch maximum really needed on miniature parts?" In some cases, they are not, but in the majority of cases, there is a real need for small breaks. Sometimes, a small break is required to provide an adequate bearing surface for small diameter journals (Figure 2). If a larger radius existed on the example shown, the hole diameter would quickly enlarge and allow the shaft to change its precision location. Sometimes, the available space for press fitting pins into holes is so limited that a large chamfer on the hole or pin would not provide enough area to hold the pin in the hole (Figure 3).

Close edge breaks are generally required at Bendix to assure a complete and sound weld. Large breaks require higher laser weld power which heats surrounding metal, burns thin sections, and blows more weld beads onto surrounding surfaces (Figure 4).

One other reason for close edge breaks which is not widely appreciated is that on miniature magnetic solenoid or rotors the edge radius affects the magnetic flux lines and either slows or increases the rate or location at which a rotor develops its maximum torqure (Figure 5). Miniature solenoids are very sensitive to these changes in available torque or power.

In regard to breaks produced on the slotted sample, close and exact edge breaks are significant. Figure 6 is a graph of edge breaks on Edge Number 2 of Figure 1b. The graph shows that 3 percent of the edge had a break of 0.002 inch or less; 44 percent of the edge had a radius of 0.004 inch or less; and 75 percent had a radius of 0.005 inch or less. Thus, of the samples measured, 25 percent of the edge had an edge break greater than the specification. This fairly large range of results also indicates some of the difficulty of maintaining edge breaks of 0.003 inch or less or toleranced edges, such as 0.002/0.005 inch.

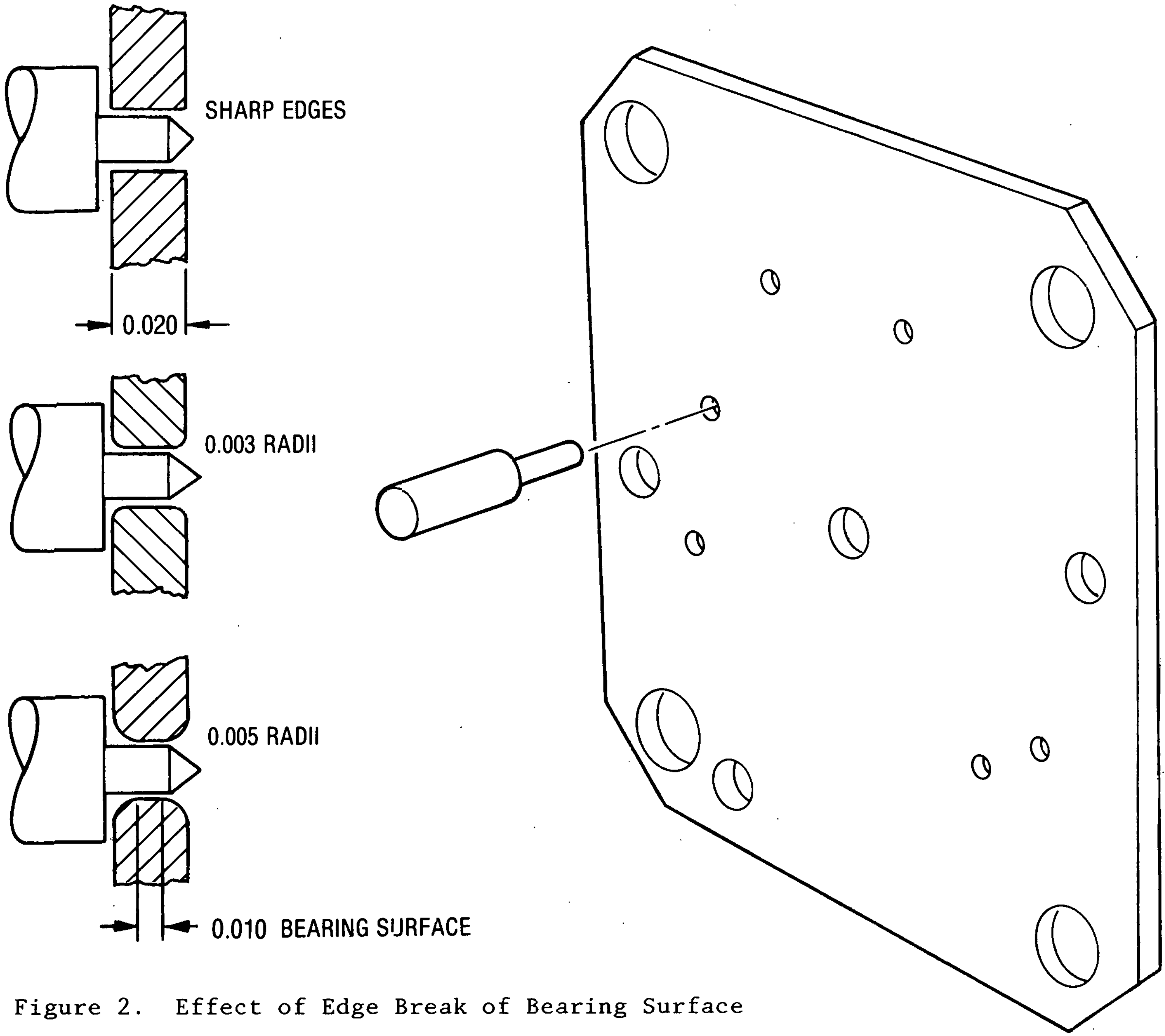


Figure 2. Effect of Edge Break of Bearing Surface

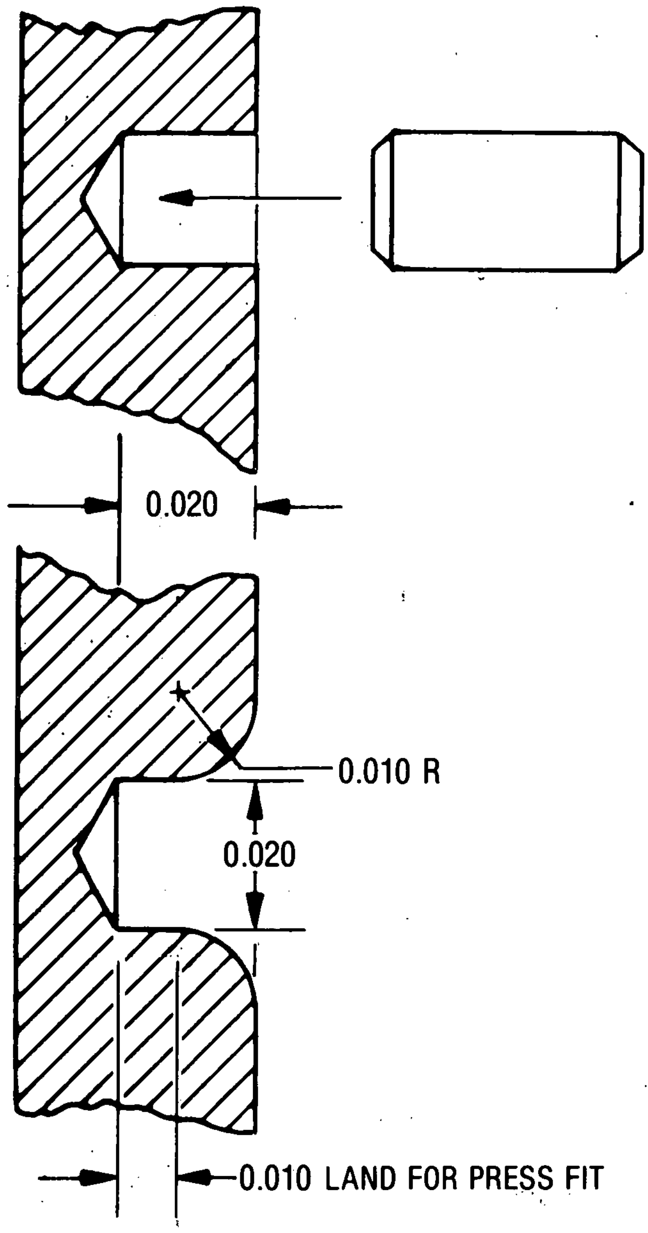
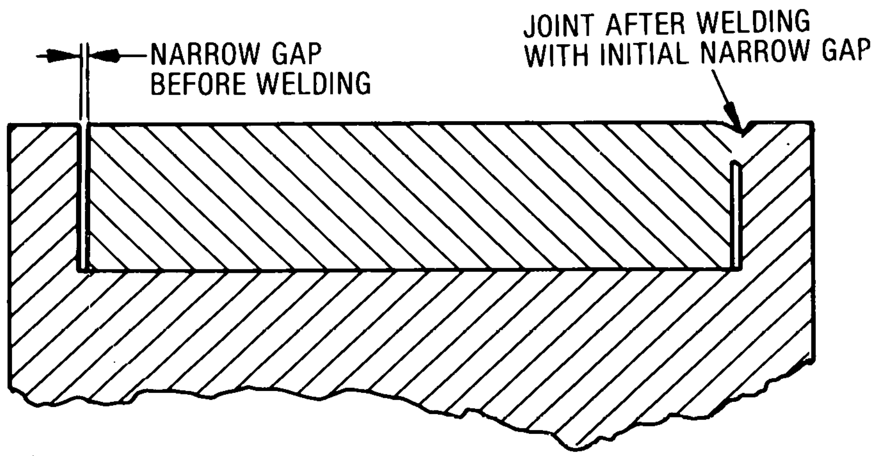
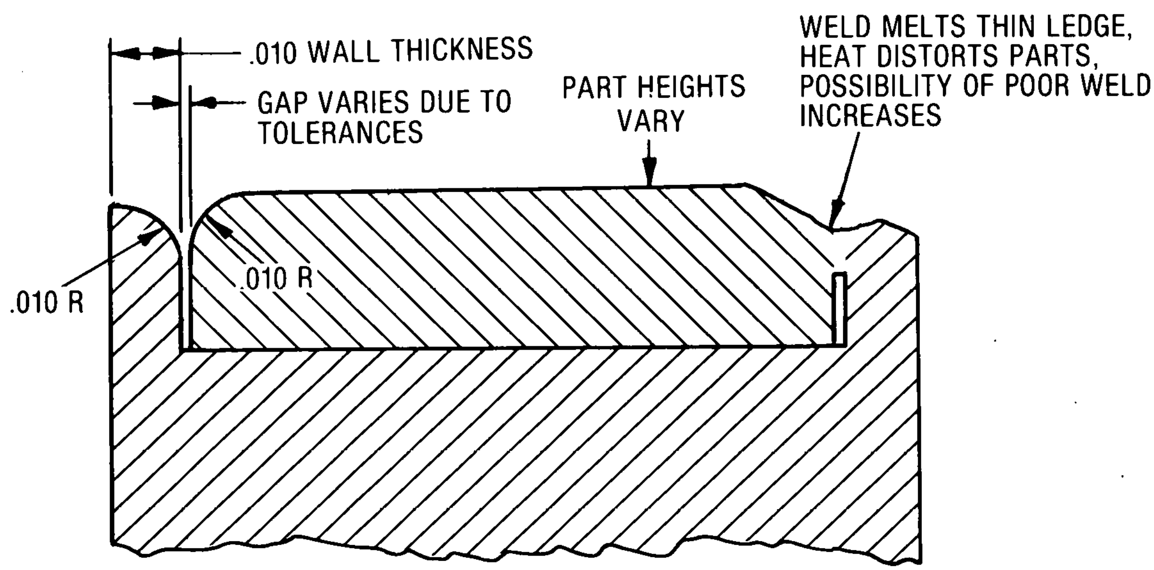


Figure 3. Effect of Edge Break on Press Fit Engagement



IDEAL CASE FOR WELDING



EFFECT OF LARGE EDGE BREAKS

Figure 4. Effect of Edge Break on Laser Welds

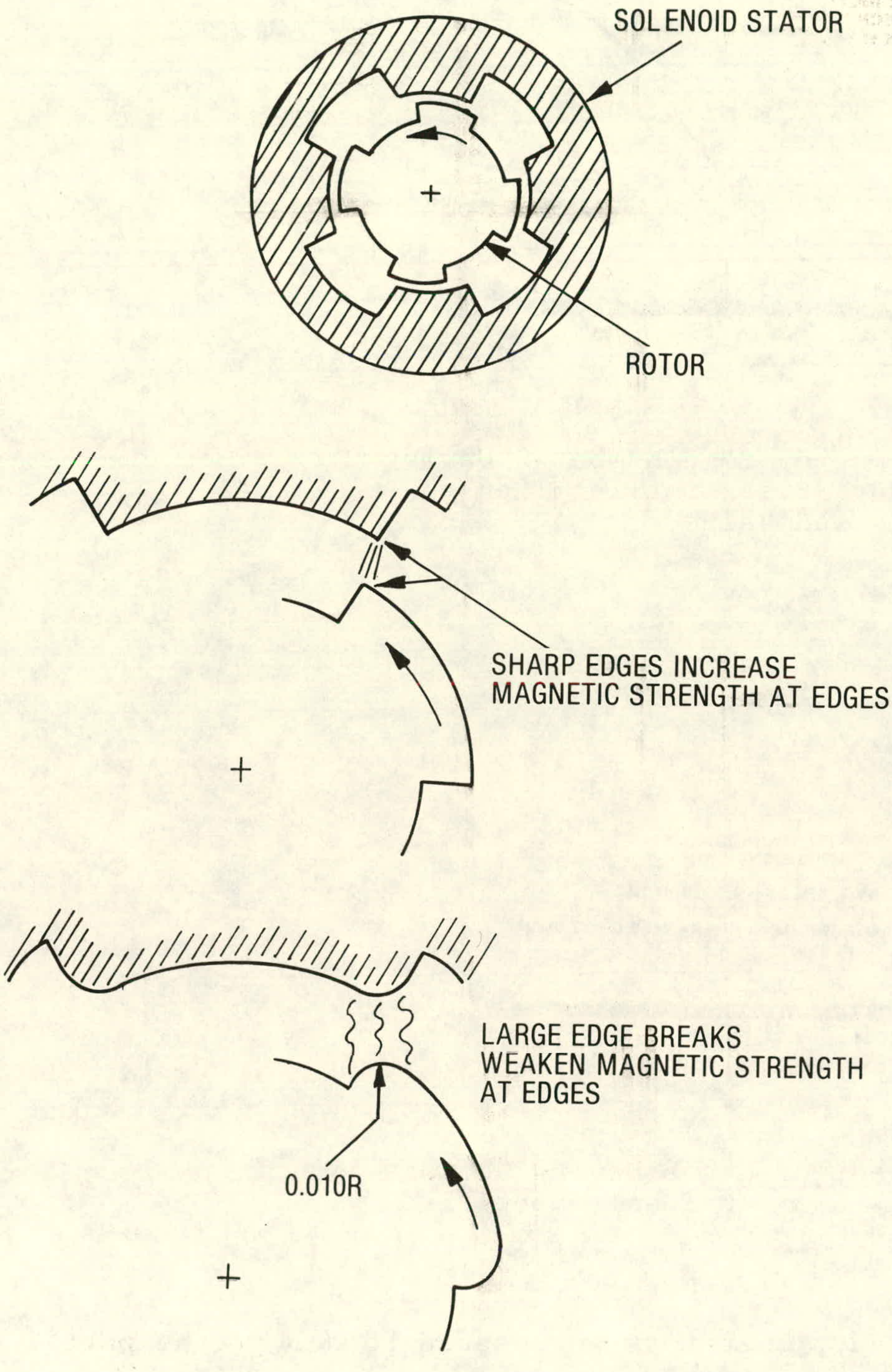


Figure 5. Effects of Edge Break on Solenoid Performance

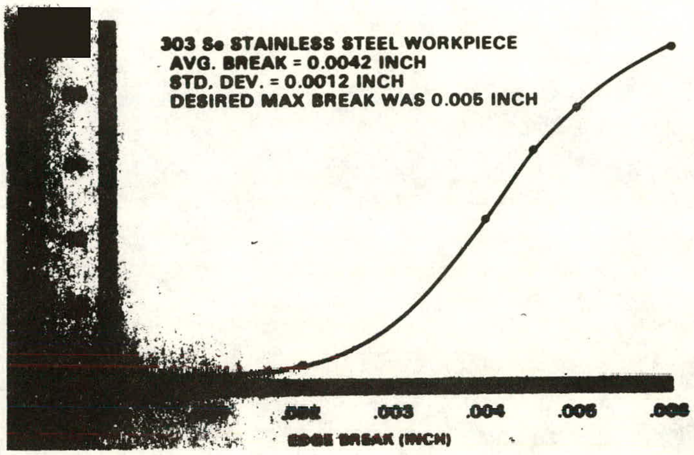


Figure 6. Percent of Edge Number 2 Having an Edge Break Smaller Than a Specified Value

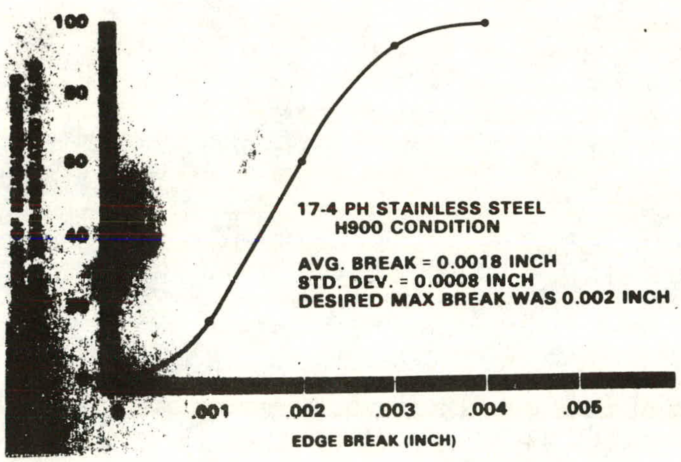


Figure 7. Percent of Edges Having an Edge Break Smaller Than a Specified Value

In the third study, operators were asked to deburr the part illustrated in Figure 1b and at the same time to maintain a 0.002 inch maximum edge break. Three hundred thirty edges were measured. On stainless steel samples, only 18 percent of the edges actually had a 0.002 inch or smaller break across the entire edge. Figure 7 illustrates the typical results obtained in this study. Although a large percentage of edges had some portion with 0.002 inch break or less, it is significant that, because of so many edges on a part, not a single part had all edges within the required 0.002 inch. Essentially, 0.004 inch would have to be allowed to accept 95 percent of the parts.

Although it may be true that some individuals can do better than indicated in Figures 6 and 7, this work was performed by several well-qualified people. The results point out that, with normal practices using knives, abrasive paper, and brushes, it is almost impossible to produce 0.002 or 0.003 inch maximum breaks on all portions of every edge of an intricate part.

In subsequent tests, individuals with only two months' training on deburring were told they were not capable of maintaining 0.003 inch maximum breaks but that they were to try to do it anyway using any technique they desired. They were given the parts shown in Figure 8. These parts had normal to small burrs (0.003 inch thick or less) and were made from 303 Se stainless steel. In this study, 24 of 25 people maintained edge breaks of less than 0.0025 inch on all edges and at least 25 percent of the individuals maintained edge breaks less than 0.001 inch.

In analyzing the results, several items stand out. These "rookies" were told it was almost impossible to meet the requirement. As a result, they took great care in deburring the parts. In a normal situation, they would be trying to meet a production rate of close to 2 minutes a part. In this study, they had as much time as they wanted--and most took 20 minutes a part to meet the requirement.

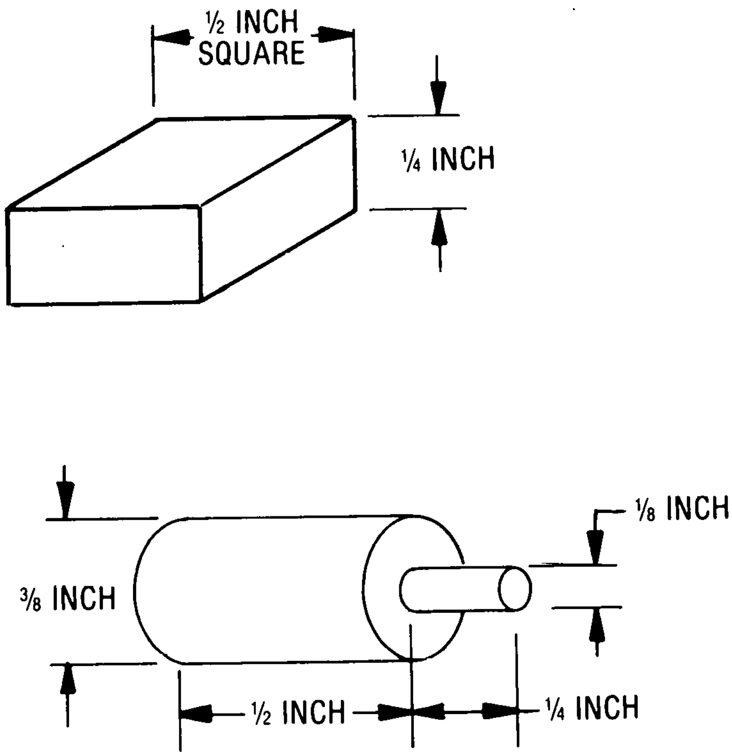


Figure 8. Test Specimen Used to Determine Smallest Edge Break Individuals Could Maintain

Second, they knew that their work was going to be measured and that everyone else would know how "good" or "bad" their performance was.

Third, to meet the requirement, they realized that for most of them it would be impossible to use knives or brushes. Most resorted to 600 grit abrasive paper, sanded parallel to edges, and used comparators to check their own work. Some used the backside of abrasive paper to limit the abrasive action.

Finally, the parts used had easily accessible edges and only one-fourth to one-half the total length of edge on a part as used in the initial studies. As a result, the level of burr removal difficulty was much lower than the specimen shown in Figure 1b.

They did far better than would have been expected, but used nonstandard methods and took up to 10 times longer than individuals using conventional approaches.

Figure 9 illustrates the ability of experienced hand deburring workers, each using his or her own approach, to produce a burr-free edge with the minimum possible edge break. The group of 25 maintained 0.003 inch breaks or less on 92 percent of the edges of the simple parts shown in Figure 8. Unfortunately, of the 50 samples measured 12 still had a small burr on them. Thus, roughly 25 percent of the samples from the most experienced workers would not have been acceptable to inspection. Although the burrs left were minute and were found only on one small portion of an edge, they were present and could have caused problems in the mechanism of an assembled part.

Of the parts produced by the nine individuals generating the smallest edge breaks and leaving no burrs, essentially 100 percent of the edges had 0.003 inch breaks or less. The most skillful individual observed in this study had 97.7 percent of all his edges 0.001 inch or smaller.

A possible reason for the presence of burrs on the samples was that some workers prejudged the time normally expected for their work and, therefore, allowed expected production rates to override the goal of optimum quality. Although this explanation is conjecture, each individual knew his or her time and capability were going to be listed by his or her name. These individuals utilized an average of 10 minutes for each part, which was half the time of inexperienced workers.

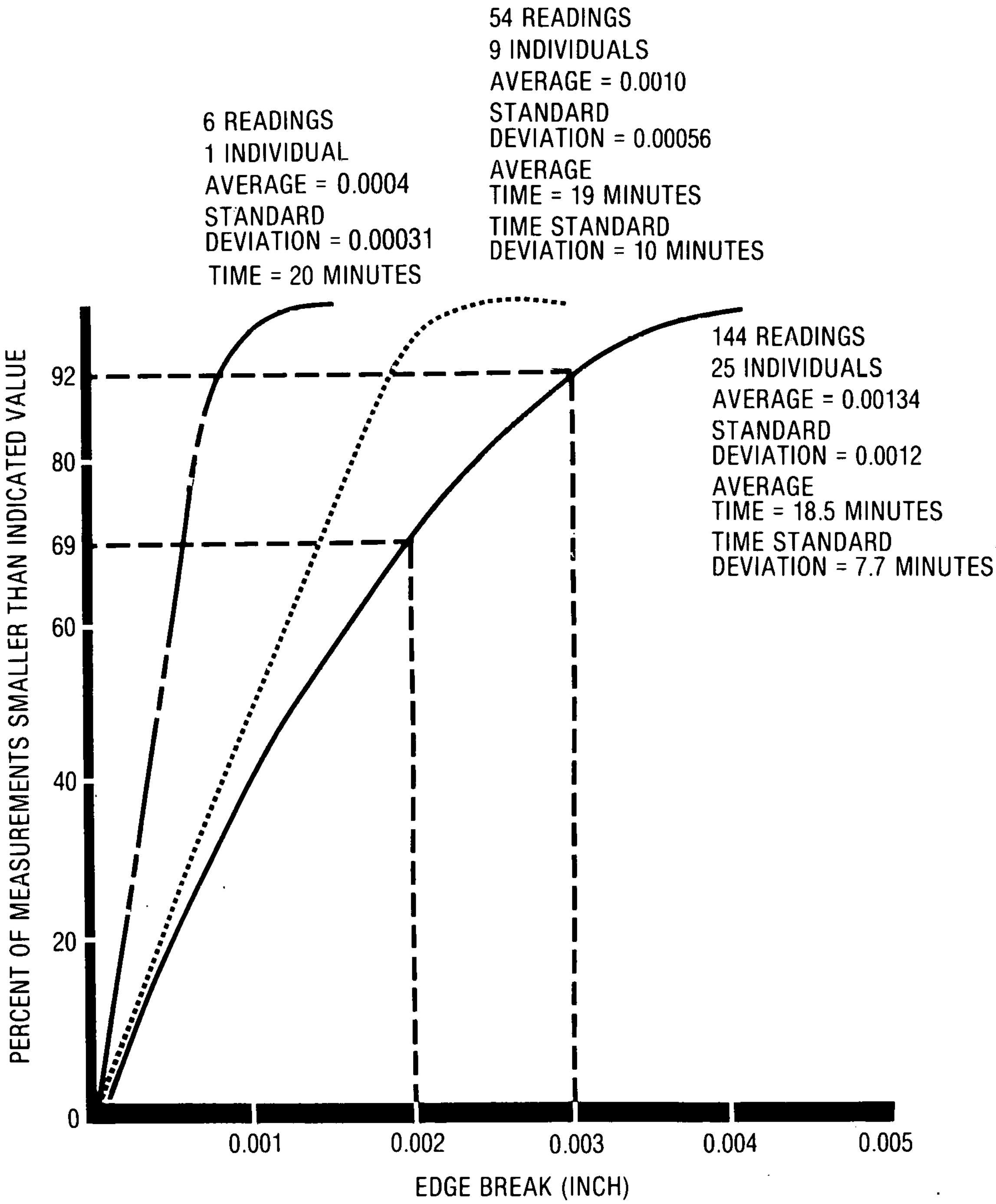


Figure 9. Percent of Edges Having an Edge Break Smaller Than a Specified Value (Produced by Experienced Deburring Workers)

BASIC CAPABILITIES OF SOME DEBURRING TOOLS

The limits that each hand deburring tool and technique are capable of have not been defined. For example, the questions might be asked, "Can an abrasive filled bullet remove a burr and produce no more than a 0.001 inch edge break." If it can, how long does it require and what technique must be used to achieve it?" Although extensive detailed information is not available some recent results provide some background information.

Figure 10 shows results obtained by using a variety of tools. For example, one individual using only a miniature file was able to remove burrs and leave an edge break of only 0.001 inch. Another person could not produce a break smaller than 0.002 inch. By aggressive action, a 0.010 inch break can be produced with miniature files.

A deburring knife or a one-inch-diameter, abrasive-impregnated nylon brush also can maintain 0.001 inch break provided the user is very skillful and careful (Figure 10). Typically, knives produced a 0.003 to 0.005 inch break.

Some useful guidance on the aggressiveness of various tools is available from this study. However, every individual will generate somewhat different results even under identical conditions. Part geometry and burr size also will influence the results.

Figure 11 illustrates the effect that grit size has on surface finish when various abrasive papers are used. The finish is subject to considerable variation. Worn abrasive paper and wet sanding typically produce the best finishes. Table 1 describes the finishes produced by a variety of deburring products on a sample having an initial finish of 4 to 10 microinches AA. Figure 12 illustrates the impact that some of these items have on part dimensions.

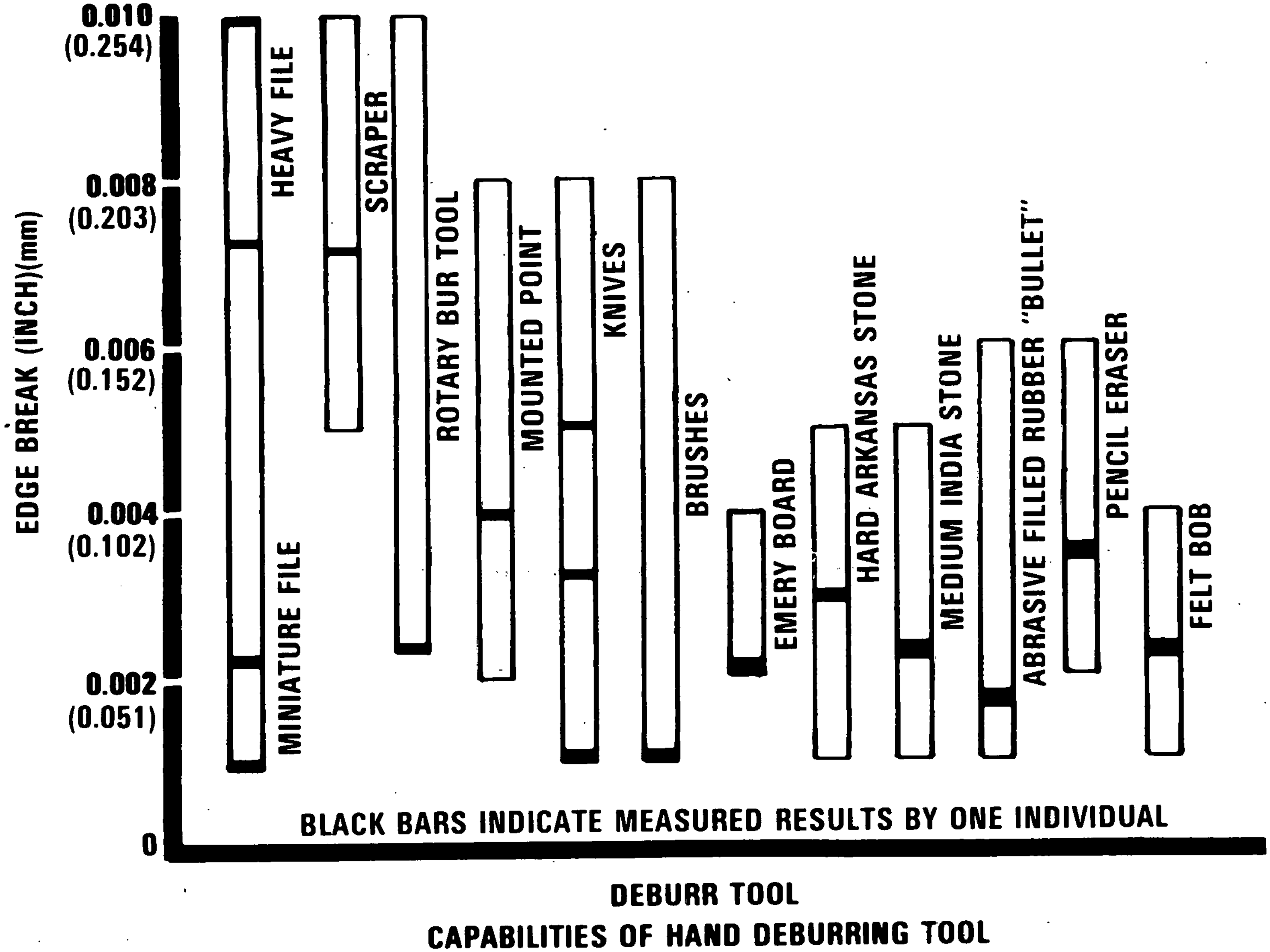


Figure 10. Basic Edge Break Capabilities Using Specific Tools to Remove 0.003 Inch Thick by 0.003 Inch High (76.2 by 76.2 μm) Burrs from 303 Se Stainless Steel

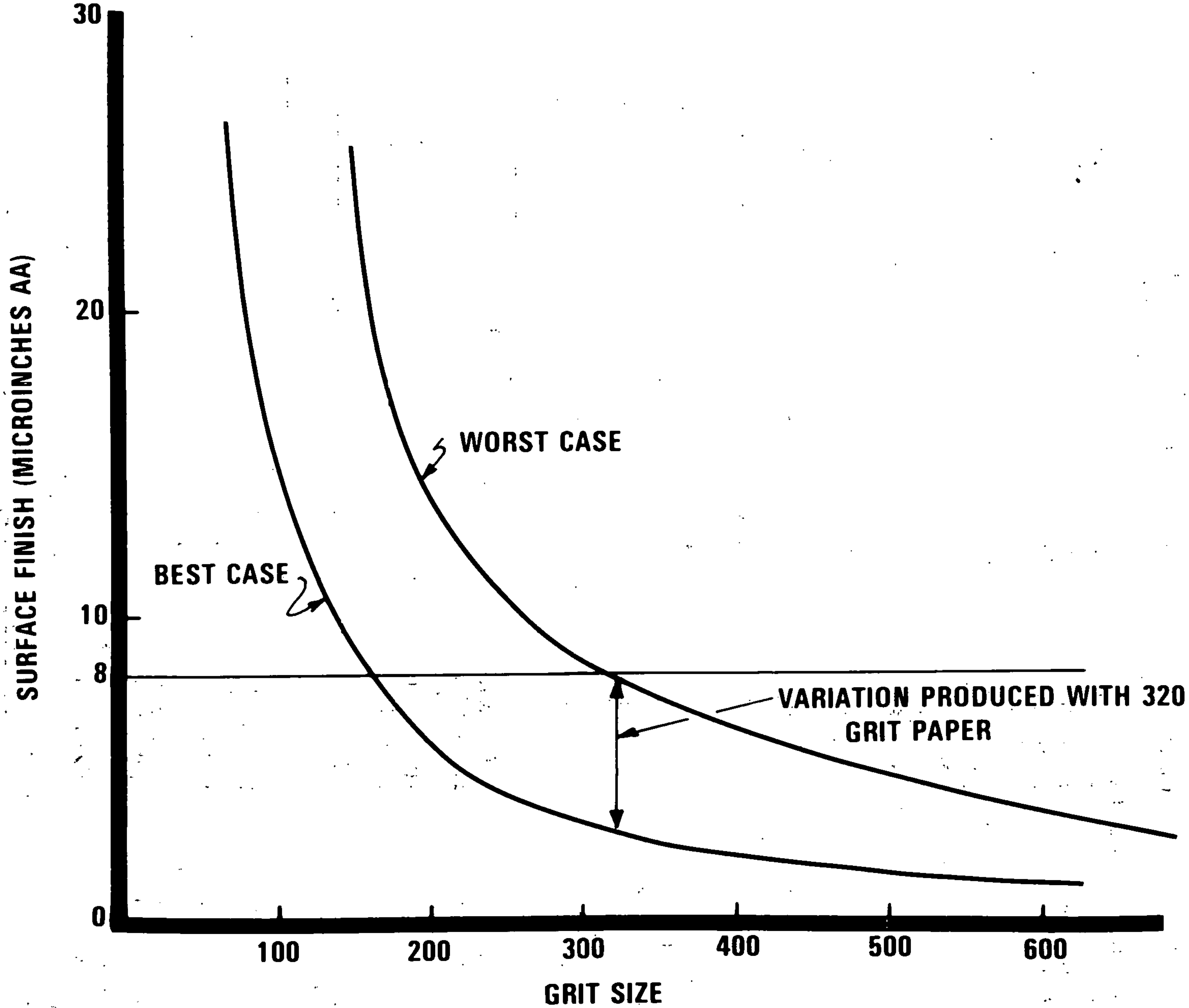


Figure 11. Surface Finish Produced as a Function of Grit Size Used

Table 1. Effect of Various Deburring Products on Surface Finish

Product	Bendix Code	Surface Finish Produced
Abrasive Filled Rubber Products		
Extra fine (gray) bullet	10604813	
Fine (brown) bullet	10604822	9
Fine disc	10207176	11
Extra fine disc	10207182	7
Coarse stick	10604806	13
Medium stick	10604807	8
Green dental bullet	10604818	12
Green dental bullet + 10650612	10604818	20
Brown dental bullet	10604819	8
Abrasive Paper		
150 grit		20
400 grit		6
600 grit dry		2
4/0 polishing paper		6
Crocus cloth		4
Stones		
Bright boy	10604688	9
Diamond hone	10604689	11
320 grit stone	10602030	7
Hard Arkansas	10604000	12
Fine India	10604105	
Brushes		
Steel bristle	10207230	8
Steel bristle	10207244	5
Steel bristle	10207246	10
Steel bristle	10207232	21
Brass bristle	10207240	5
Abrasive filled nylon (white)	10207251	11
Abrasive filled nylon (black)	10207251	4
Beartex wheel	---	13

The initial finish on the 302 stainless steel test coupons was 4 to 10 microinches AA.

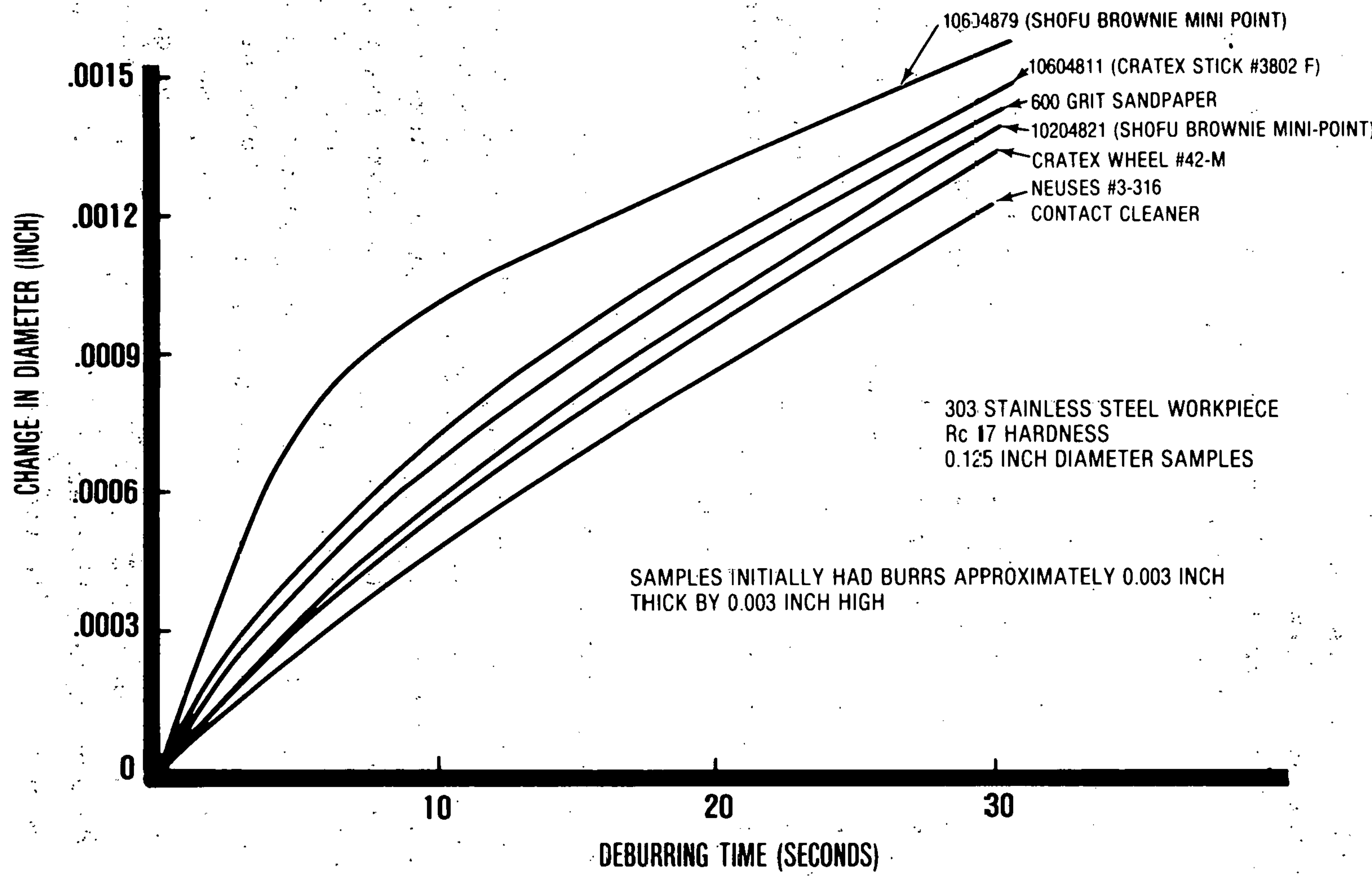


Figure 12. Effect of Deburring Product and Time on Part Dimensions

EFFECT OF BURR SIZE ON DEBURRING TIME

Figure 13 illustrates how burr thickness influences removal time. Washer-like parts with 0.005 inch thick burrs took four times longer to remove than burrs 0.0015 inch thick. Obviously, thinner burrs require considerably less deburring time.

EFFECT OF HOLE SIZE ON DEBURRING TIME

Smaller holes frequently require more time to deburr than larger holes (Figure 14). More time is spent scrutinizing, under a microscope, the result of deburring small holes than larger holes. In addition, most deburring tools are designed for 0.125 inch diameter holes rather than smaller sizes. Ten percent of the allowed time is spent looking for burrs on simple parts rather than deburring. On small gears, 50 percent of the rated time may be spent just looking for minute burr fragments.

EFFECT OF BURR LOCATION ON DEBURRING TIME

Figure 15 illustrates a part having four small holes breaking into a larger one. The time required to deburr the intersections depends on the diameter of the large cross hole. When the large hole was 0.5 inch in diameter, a 6061-T6 aluminum part (Figure 16) required less than 3 minutes to deburr. When the horizontal hole was 0.062 inch, deburring took 11 minutes. Unfortunately, with a very small cross hole, providing a nice smooth blend at hole intersections by hand deburring is not possible. As a result, more time on such difficult features is required and also deburring quality worsens. Processes such as abrasive flow deburring and electrochemical deburring can, however, provide smooth blending on any of these hard to reach intersections.

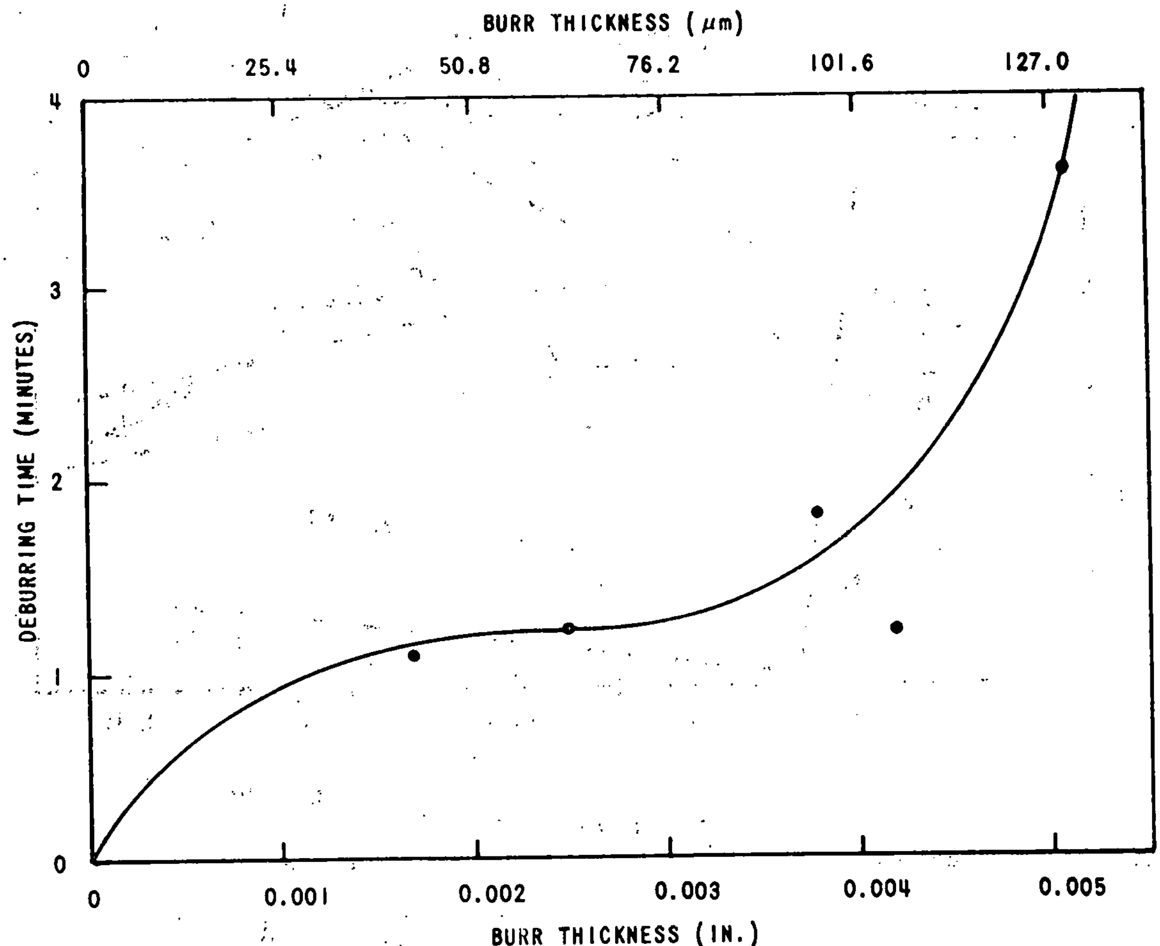


Figure 13. Effect of Burr Thickness on Deburring Time.

Figure 17 illustrates the time required for deburring slotted parts. As slot width decreases, deburring times rise exponentially when hand deburring is required.

PROVEN AIDS TO SPEED HAND DEBURRING

Figure 18 illustrates one approach to improving hand deburring time. As mentioned in a previous chapter, by taping sandpaper to the table the deburring of large parts can be speeded up. Abrasive

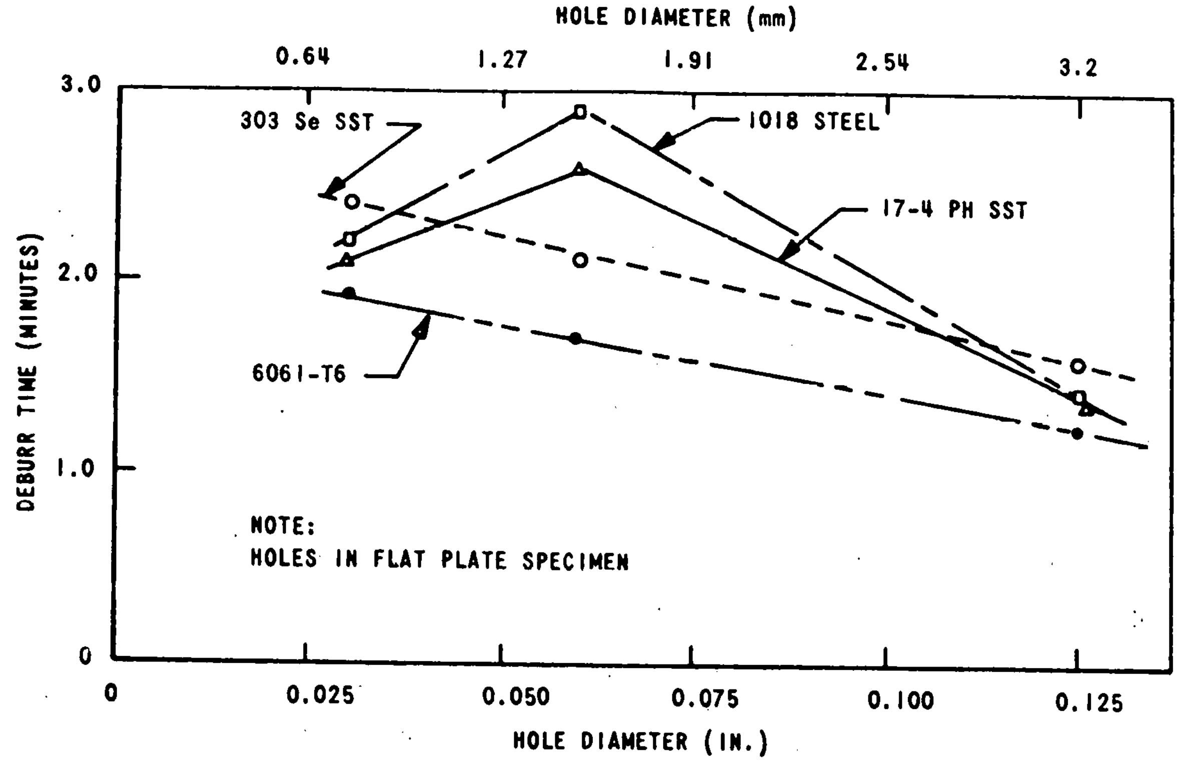


Figure 14. Effect of Hole Size on Deburring Time

paper is also available with adhesive on the back surface which would eliminate the need for taping. This may not be an advantage for handling very miniature parts however.

Figure 19 illustrates the convenient storage of deburring knives. In this case double back tape is used to affix a piece of plastic foam to the worktable.

The knives are inserted in the plastic foam. This allows them to stand vertically and be spaced apart to minimize the time spent grasping for parts which are horizontal and laying together. Figure 20 illustrates one convenient approach for picking up parts.

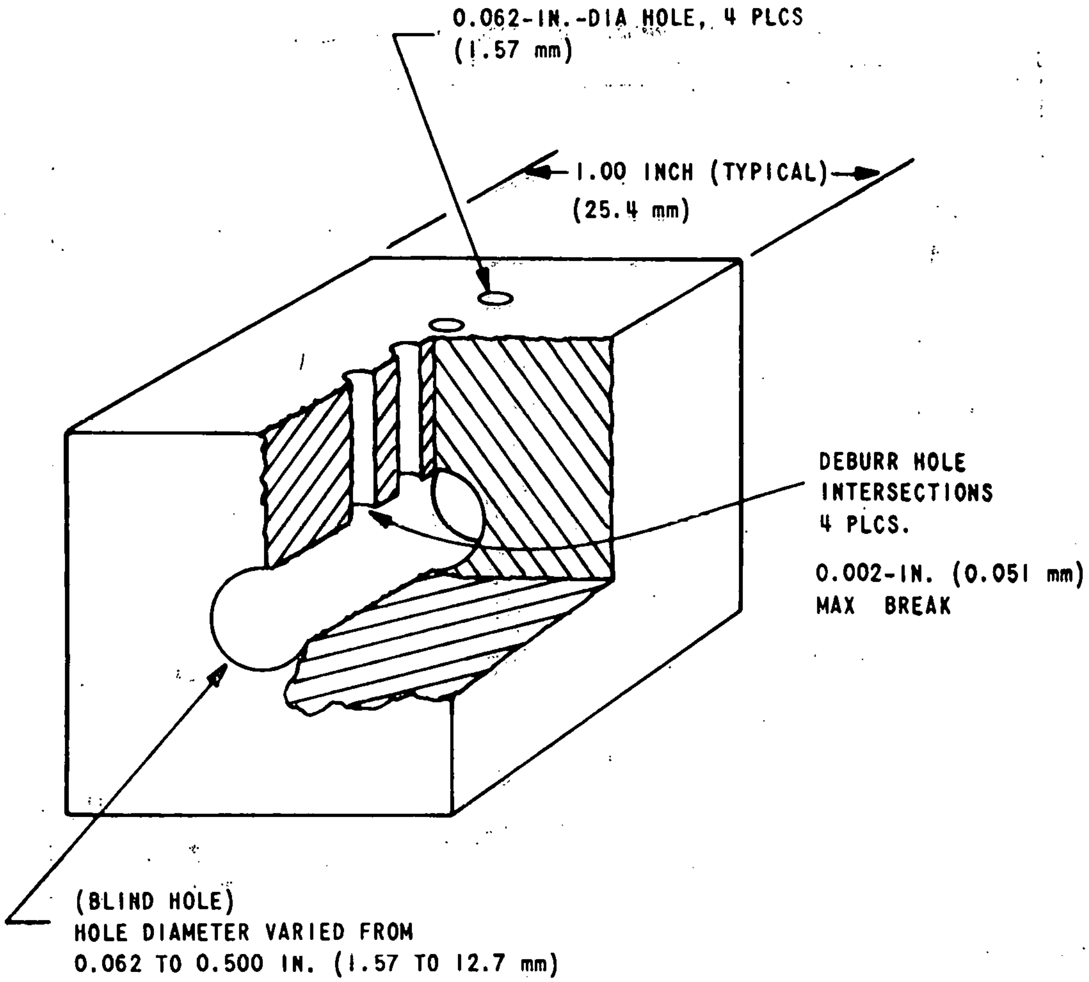


Figure 15. Geometry of Intersecting Hole Specimen

In this case, the parts are lain on a relatively thick (1/2 inch or thicker) piece of soft foam rubber pad. When reaching to pick up a part, the foam depresses and allows fingers or fingernails underneath the part. This is particularly convenient for nonmagnetic parts.

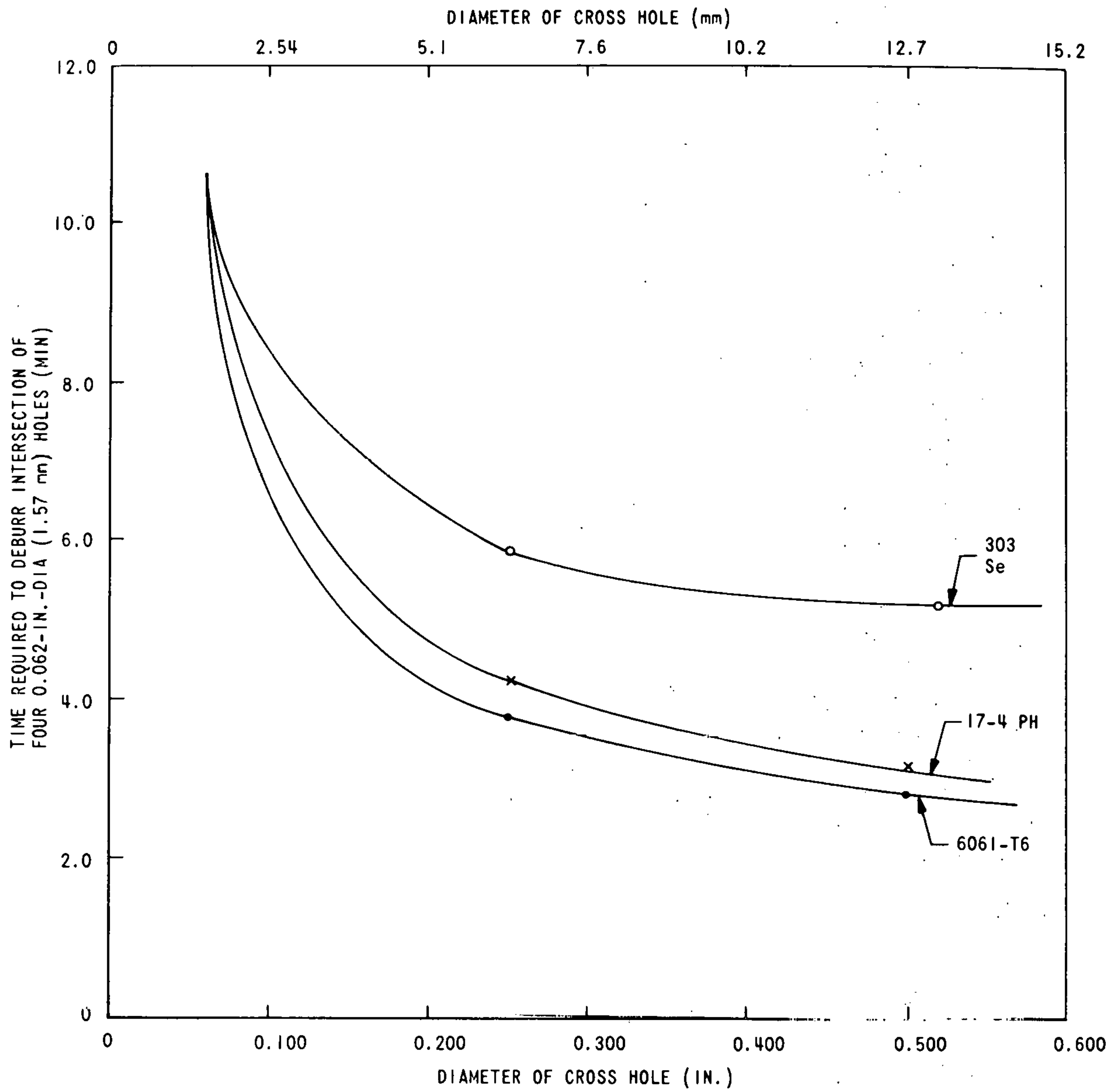


Figure 16. Effect of Cross-Hole Diameter on Deburring Time

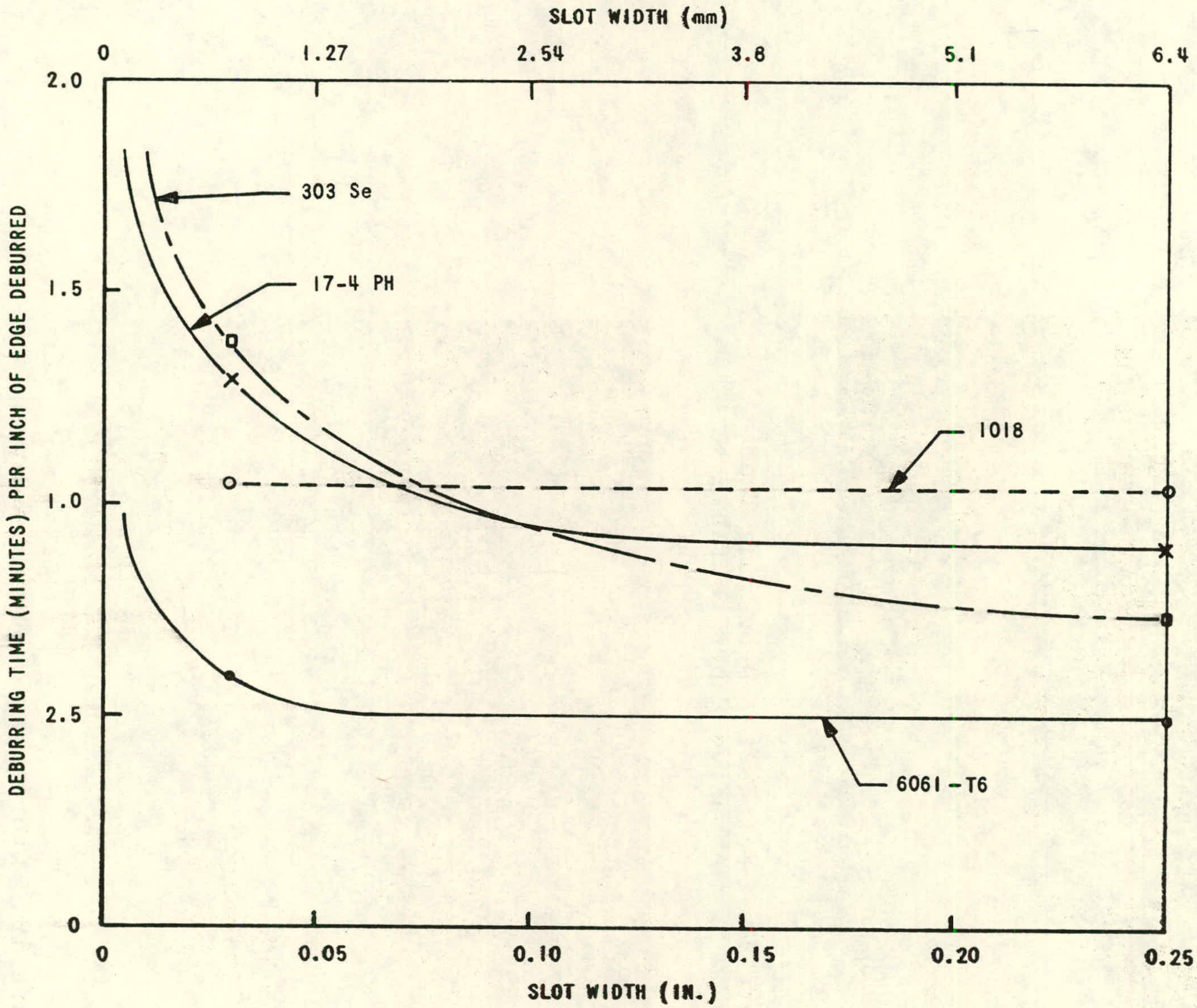


Figure 17. Effect of Slot Width on Hand-Deburring Time

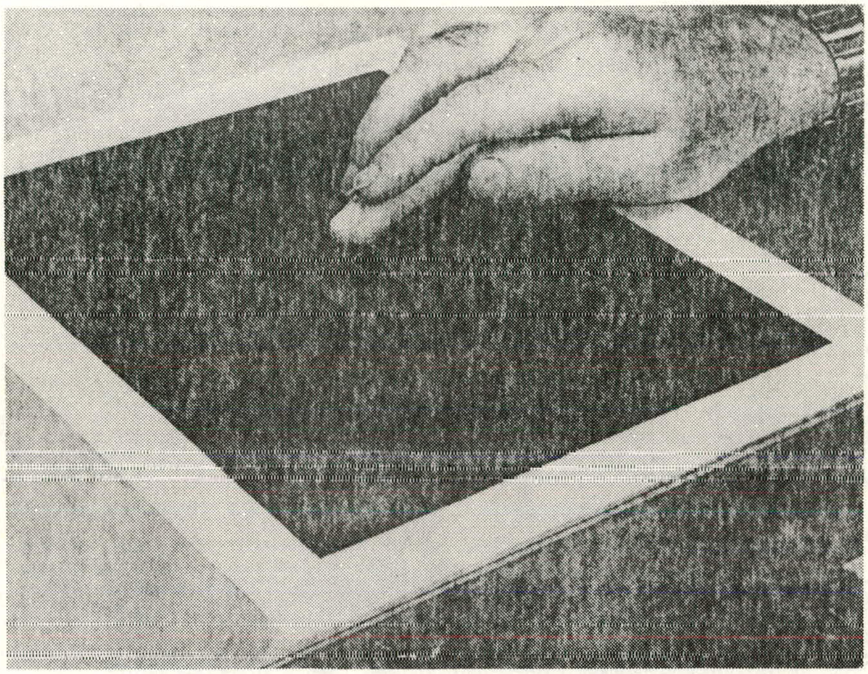


Figure 18. For Faster Deburring Tape Abrasive Paper to Table

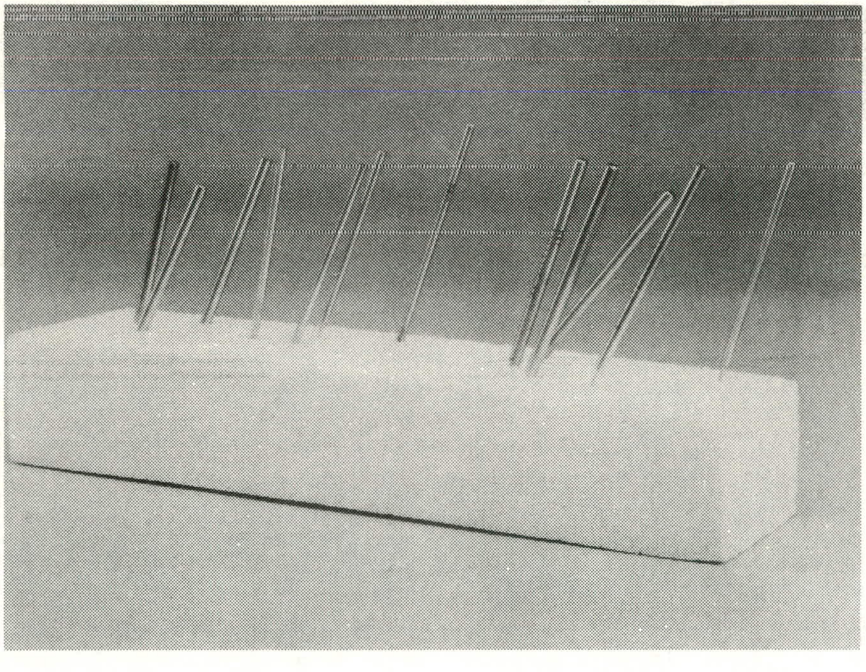


Figure 19. Storage of Deburring Knives

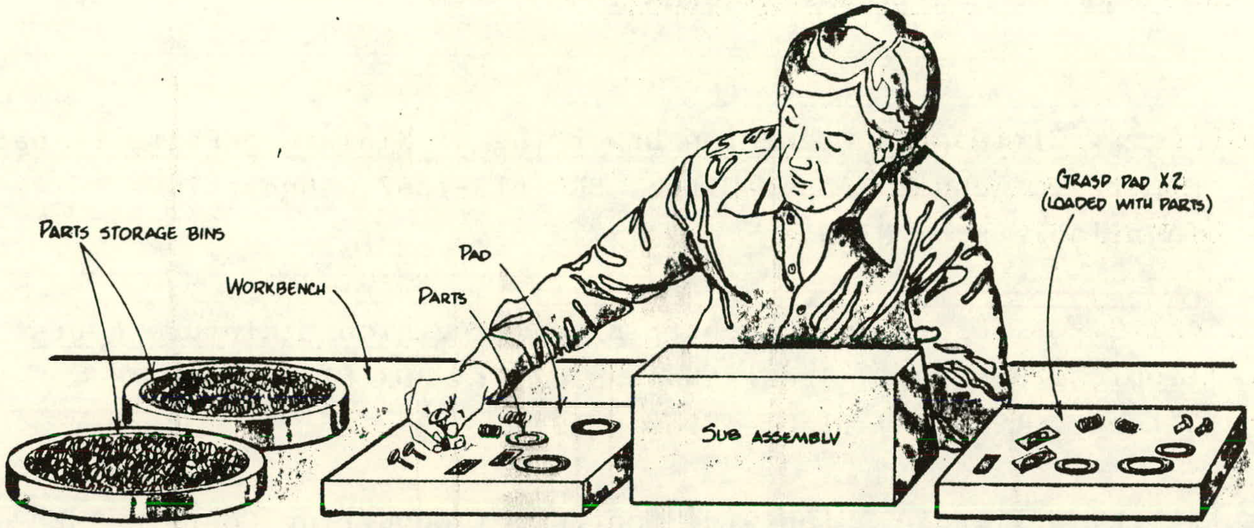


Figure 20. Using Foam Rubber to Speed Part Pick Up

SOURCES OF ADDITIONAL INFORMATION

[1]L. K. Gillespie, Precision Deburring of Miniature Parts (Final Report). Bendix Kansas City: BDX-613-1697, August 1977 (Available From NTIS).

[2]L. K. Gillespie, Hand Deburring of Precision Miniature Parts (Topical Report). Bendix Kansas City: BDX-613-1443, October, 1975 (Available From NTIS).

[3]L. K. Gillespie, Plantwide Control of Deburring Costs. SME Paper MR77-05, March, 1977.

[4]L. K. Gillespie and others, Hand Deburring, A Necessity That Can Be Improved. SME Paper MRR78-03, 1978.

[5]L. K. Gillespie, editor. Advances in Deburring. SME, 1978.

[6]L. K. Gillespie, "Hand Deburring: A Plague or the Most Economical Way?," Machine and Tool Blue Book, November 1978, pp. 102-113.

ASSIGNMENT

1. For the samples provided deburr the part completely and produce the smallest edge break you are capable of maintaining.

2. Deburr the turned part provided and again maintain the smallest edge break which you are capable.

3. Deburr the production part provided and again maintain the smallest edge break you are capable of on all edges. Record the time required for deburring this part.

4. Deburr the two samples provided and record the time required. Note that one sample has a very small burr, the other one has a very large burr.

5. Deburr the sample provided and maintain a 0.005 inch maximum break. The area to be deburred is that of the intersecting hole.

6. Deburr the parts provided using <u>only</u> the tools indicated by the instructor.

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CHAPTER 17

ASSEMBLY REQUIREMENTS

The size of the Bendix plant makes it easy for individuals to work months in one department and not have the opportunity to see how the parts they work on fit into other assemblies in the total scheme of manufacture. This chapter discusses the assembly requirements for parts made in one department. The assembly requirements, in many cases, dictate the high levels of precision and burr free part requirements.

GENERAL CLEAN ROOM REQUIREMENTS

Consider for a moment the clean rooms used to develop spacecraft for spaceflights to the moon. In showing the extremely high levels of cleanliness required, most TV commentators noted that those levels were required to assure not only that the parts function repeatably and successfully, but that the moon not be contaminated.

There is something very reassuring about seeing workers in white coats and white hats working in a clean room environment. It is another indication that high levels of quality are demanded by the products assembled in such atmospheres. Many of the parts produced by the Bendix Miniature Machining Department are assembled under such conditions. While the actual quality level of cleanliness may not be as high under some conditions as others, the same concepts and many of the same needs and problems exist in the clean room environment.

Consider the implications of the name clean room. By its very name it implies that something or everything is clean. In actuality, it is necessary that the following things be cleaned in order to maintain a clean assembly

- Floor,
- Air,
- Workstation,
- Parts,
- Assemblies, and
- Clothes.

While this list is not complete, it at least illustrates the real needs. Anything in the clean room which is not clean contaminates everything else. When people enter a clean room, they must not only smock-up, (Figure 1), but they must wash their hands, button smocks tightly around neck, and hands, and brush shoes to remove particles. These are basic entrance requirements.

While everybody has seen muddy cars, oil and dirt caked automobile engines, and a variety of other particulate soils, many of the particles on industrial parts are extremely small. MIL-Handbook 406 is an example:

> "Sitting or standing, wearing clean room garments with no movement, an individual will shed approximately 100,000 particles per minute of 0.000013 inch or larger. The same person with only simple arm movements will generate 500,000 particles. Average arm and body movement with some slight leg movement, will produce over 1,000,000 particles per minute."
>
> "Walking slowly - 5,000,000; average - 7,500,000; fast - 10,000,000 particles per minute. Boisterous

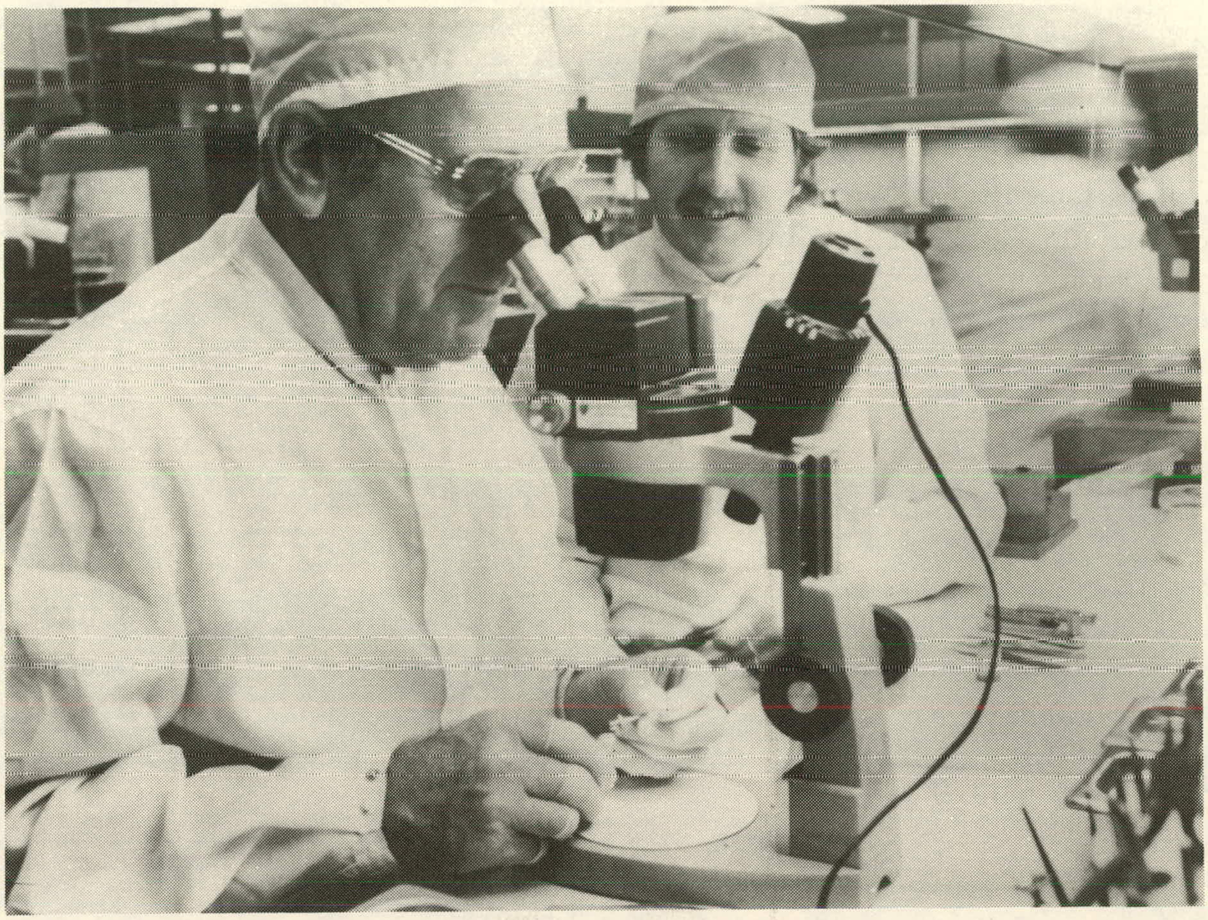

Figure 1. Examining Parts in Clean Room Assembly Area

> activity in the clean room can result in a release of as much as 15 to 30,000,000 particles per minute into the environment."

Table 1 illustrates particle sizes produced by a variety of common activity in industry. As seen there, flaking skin will produce particles 0.00016 inch in diameter. Despite this minute size, these particles are big enough to cause precision miniature mechanisms to fail. The types of particles which can cause failures

Table 1. Particles Produced by Various Actions*

Activity	Particle Size (In Microns)	In Inches
1. Rubbing ordinary painted surface	90	0.004
2. Sliding metal surfaces (non-lubricated)	75	0.003
3. Crumbling or folding paper	65	0.0026
4. Rubbing an epoxy painted surface	40	0.002
5. Seating screws	30	0.001
6. Belt drive	30	0.001
7. Writing with ball point pen on ordinary paper	20	0.001
8. Handling passivated metals such as fastening materials	10	0.0005
9. Vinyl fitting abraded by a wrench	8	0.00032
10. Rubbing the skin	4	0.00016

*From MIL-HDBK-407

include such items as dirt, chips, hair, lint, and other materials which will be discussed in a later chapter. Look once again at the types of failures possible in an assembly. First, there must be no burrs on the assembled parts because they can cause

- Electrical short circuits,
- Jammed mechanisms,
- Interference fit,
- Scratched parts, and
- High friction.

In addition, there must be no sharp edges on many parts because they will cause

- Cut electrical wires and
- Electrical arcing.

As indicated previously, these units must have small edge breaks to

- Provide adequate surface,
- Provide press-fit friction,
- Provide necessary welding requirements, and
- Provide sufficient rotor torque.

The previous chapter discussed the reasons for the needs shown in this latter list. Again, it must be emphasized that these high levels of precision are necessary for these parts to work successfully.

BASIC FUNCTIONS OF ASSEMBLED UNITS

Miniature parts are assembled into precision miniature timers, electromechanical switches, and various types of actuators. As implied by their names these assemblies must move, in many cases, like the mechanisms in mechanical watches. If a person looks closely at the components of a disassembled watch, it is easy to see that a burr or any particle in such an assembly can cause a failure. There just is not room enough for anything except the required part dimensions.

These units typically have some form of electrical energy applied to them to make them work. These mechanisms go back and forth, in and out, up and down, but they have to perform some form of motion. These units must work. They are tested many times and they must function correctly each time. They must actually move as required and they must have the desired electrical properties each time they are tested.

ENVIRONMENTAL TESTING OF UNITS

A wall clock is expected to work day after day with perhaps the addition of only a battery or an adjustment once a year. We would, of course, like to have the same expectation and simplicity and reliability as a wall clock on our units. But the majority of units which are assembled must undergo a much more rigorous life than merely setting on a shelf or being placed on a wall. As an example, it is not uncommon for many of these units which have 400 to 500 parts in them to undergo the following types of environmental tests:

- Operation under high temperatures,
- Operation under low temperatures,
- Operation while vibrating,
- Operation after vibration,
- Operation after transportation shocks,
- Operation while being swung in a centrifuge,
- Operation after extended life wearout tests, and
- Operation after high levels of shock.

The list, while impressive, does not totally and adequately indicate the rigorous nature of the tests which are involved. The actual magnitude of the testing can only be appreciated by actually following the unit and watching the testing sequence.

There are many commercials on television which illustrate starting a car after the car has been frozen in a solid block of ice or left on a northern lake all winter. The point made in those commercials is that the unit did start after that rigorous frozen weather exposure. Many mechanisms must operature under even harsher conditions.

The nature of many components makes it necessary that they work every time. If the car in the commercial had not started in real life it would have meant that the driver would have been late to work or to his appointment. While frustrating, that is not a life or death situation. The nature of our parts again dictates that they must work every time, not sometimes and not with a probability of 50, 60, or 70 percent. The unit simply must operate every time to remain functional.

While the cold temperatures such as -65°F represent one level of extreme in which the unit must work, the opposite level of high temperatures (165° to 1000°F) is just as demanding if not more so than the lower temperatures.

At one time, many television commercials also showed cars and trucks driving down rough roads and across railroad ties. The vibration inside the truck was supposedly greatly minimized by the design of the vehicle. In a case of miniature assemblies, which must undergo similar vibration, the levels may be considerably higher than experienced by those automobiles. Imagine if you will sitting on the axle of one of those vehicles as it drives down those bumpy paths for three to four hours. As you sit on that axle, you must not only work and think properly, you must do it for three hours without skipping a heartbeat, making a mistake, or in any sense failing. That is the type of operation expected of many of our units. Similarly, when the unit is assembled and dropped from a height of two to three feet to the floor, it suffers what is commonly called transportation shock. That is, in transporting the parts somebody accidentally dropped the unit.

Any part sold commercially is expected to survive such types of shock. Bendix units are no exception. They must withstand such shocks even though many of the parts are so minute that they easily become dislodged; as an example, miniature springs will try to slip off of the pins which hold them. Our units must undergo extensive life tests in many cases. Continual operation and a single failure in 100, 200, or 500 operations means the unit has failed; something is not working properly.

The point made in these latter paragraphs is that a single missed tock in a watch implies a failure although it may be only a very small one. For many of our components, that failure on a single "tick-tock" is simply not allowable.

DEFINITION OF TYPES OF FAILURES

Thus far, we have talked about failure without actually specifying what it meant. There are many types of failures and it would be almost impossible to list each type. For the normal situation, however, a failure could include the following items:

- A single part not moving as required,
- The part moving too far,
- Electrical switches which chatter as they are being shaken,
- Failure to provide adequate voltage or current,
- Excessive electrical resistance between contacts, and
- High voltage short circuits through the atmosphere within each unit.

While the mechanical failures are relatively obvious, some of the other types of failures are less obvious. As an example, human breath covers electrical contacts with a layer of moisture, debris, and germs. In most situations, this layer is so thin it would not affect the function of the part. In many units, however, because of the low voltage and low current which must pass through the contact, any coating on the contacts will prevent adequate electrical signals from passing through them. As an example, a plastic component in the assembly heated up to 165°F as part of environmental testing, will give off vapors of plastic. If the unit is totally enclosed, as it normally is in many tests, those vapors will enter the air within the unit. At some time, those plastic vapors will settle out of the air onto all the components in the unit. When they do, the electrical contacts also will be coated. When this happens, the plastic acts as an insulator and prevents or inhibits the electrical conduction through the contact. On many units, this represents a failure.

As a review of this example, it is obvious that many things interact. The fact that a plastic part was in the assembly resulted in a problem when the unit was tested at high temperatures. Even at room temperatures, however, some plastic produces enough vapors to cause the same type of problem.

Consider a bad electrical connection on the headlight of a car as it travels down a bumpy road. The fact that the electrical connection is bad and the road is bumpy combine to cause the lights to flicker. In some cases, this flicker might only last for 1/1000th second or less. While that is acceptable for many commercial and personal situations, that may not be acceptable on many Bendix assembled units. The open circuit or poor contact during that extremely short period of time may be classified as a failure.

As seen by the examples in the previous paragraphs, there are a wide variety of failures. Some of them are caused by environmental testing which is a necessity because parts will see a similar type of real life environment. Despite the stringency in defining what constitutes a failure, in the high levels of cleanliness involved, failures can still occur by small oversights. It is extremely important that such assemblies do not fail. It is for this reason so much effort is applied to deburring and edge break specifications seen on our miniature parts. That effort is necessary to guarantee that failure does not occur.

ASSIGNMENT

1. Review in the previous chapter the reasons for small edge break requirements.

2. Define in your own words some of the problems to be faced in the assembly of these miniature parts.

3. Describe in your own words some of the tests under which these units must survive.

4. Make a list of the types of failures one could have on an assembly.

5. Operate the plastic mockups of some of the miniature mechanisms. Make a special point to observe the wide variety of motions which occur in the operation of these units.

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CHAPTER 18

BRUSH DEBURRING

Bendix Kansas City uses a number of brushes for deburring and cleaning parts. Commercially, there are over 600 sizes and styles of brushes used for deburring and edge finishing. This discusses only those brushes commonly used on small or hand sized parts. Also, discussions will be limited to only those brushes which are actually used for deburring or edge finishing.

TYPES OF BRUSHES

There are seven basic types of brushes used at Bendix for deburring and edge finishing:

- Radial Brush,
- Cup Brush,
- End Brush,
- Tube Brush,
- Cross Hole Deburring Brush,
- Side Action, Butterfly, or Sibot Brush, and
- Toothbrush.

Figure 1 illustrates the variety of some of the brushes which are available. The small brushes in the upper left of the illustration are the cross hole deburring brushes. The radial brushes are those which look like wheels with spokes extending from them. The same illustration shows a stainless steel toothbrush used for deburring threads on large parts, and in the middle left hand side is a small end brush and a small brush shaped like an inverted cup. Table 1 illustrates the sizes of brushes which are commercially available.

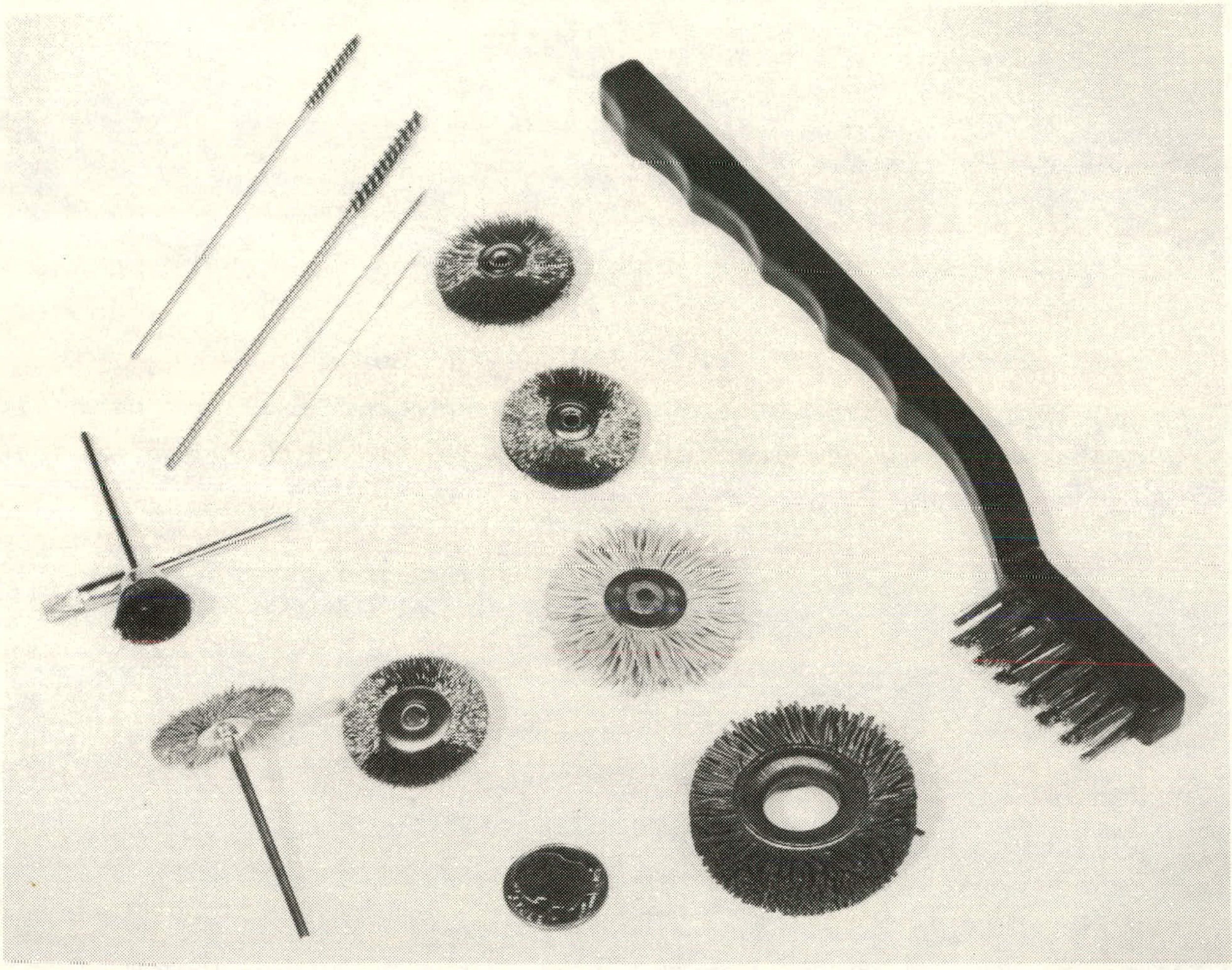

Figure 1. Variety of Commercially Available Brushes

RADIAL BRUSH

The radial brushes are most often used for deburring parts. They come in sizes as small as 3/4-inch in diameter and can be purchased in sizes up to 24-inches in diameter. These brushes are used to deburr external threads, provide a radius on any external edge, and in some cases, to provide an improved surface finish. Some of the brushes are available with a built-in shaft, but the majority require the addition of a mandrel to hold them. These brushes

Table 1. Size Ranges of Commerically Available Standard Brushes

Brush Type	Filler Material	Size Range Available (Inch)
Radial	Stainless Steel	3/4-15
	Brass	3/4-6
	Nylon	3/4-2
	Abrasive-filled nylon	1 3/8-14
	Nonwoven abrasive-filled nylon	2-6
	Tampico	2-16
	Cord filled	1-16
	Abrasive tipped	1/2-2
	Elastomer filled	1 1/4-12
	Flapwheel	1-16
	Felt bob	1/4-3
	Abrasive-filled muslin	3/16-1
Cup	Stainless Steel	3/4-6 1/4
	Brass	3/4-3/4
	Elastomer filled	4-6
End	Stainless Steel	1/4-1
	Elastomer filled	1/2-1
Cross Hole or Tube	Stainless Steel	1/32-3
	Brass	1/4-2
	Nylon	1/4-2
	Elastomer filled	1/2-1
Side Action or Sibot	Stainless Steel	1/4-1 1/4
	Brass	1/4-7/8
	Nylon	1/4-7/8
	Abrasive-filled nonwoven nylon	1/2-3
Flare	Steel	1 1/2-4

are used generally in a bench motor, although they could be used by hand. They are never used in an air motor because of the high speeds involved. There are available a variety of materials that will be discussed in a later section.

CUP BRUSH

As implied by the name, a cup brush is in the shape of an inverted cup. Figure 2 illustrates some of the miniature cup brushes which can be purchased. These are useful for deburring on the edges of relatively large gears, for deburring parts having short shafts extending from them, or for reaching in hard to reach places where a soft action is required. Figures 3, 4, and 5 illustrate these types of applications. While a variety of these brushes are available for the miniature parts, they are not generally applicable because they cannot be obtained in a small enough size. They are handy for hand size and larger parts or features 1/2-inch in diameter or larger. Like all brushes, they can be obtained in a variety of filament materials (fiber material).

END BRUSH

Figure 6 illustrates a close-up view of an end brush. Figure 7 illustrates one application for this brush. The fibers all extend axially out the end of the brush. These brushes are relatively stiff and because of this can often be used in hard to reach places to either clean or remove material. They have been used at Bendix for removing recast molten balls of metal from EDM operations as well as for cleaning. While these can be purchased in sizes down to 1/8-inch in diameter, they generally are less successful for finishing edges to Bendix requirements than other styles of brushes.

TUBE BRUSH

Figure 8 illustrates a tube brush. These brushes are often used to deburr the insides of tubes or through-holes or relatively long and deep holes. They can be obtained in a variety of stiffnesses and workpiece materials as well as a variety of diameters.

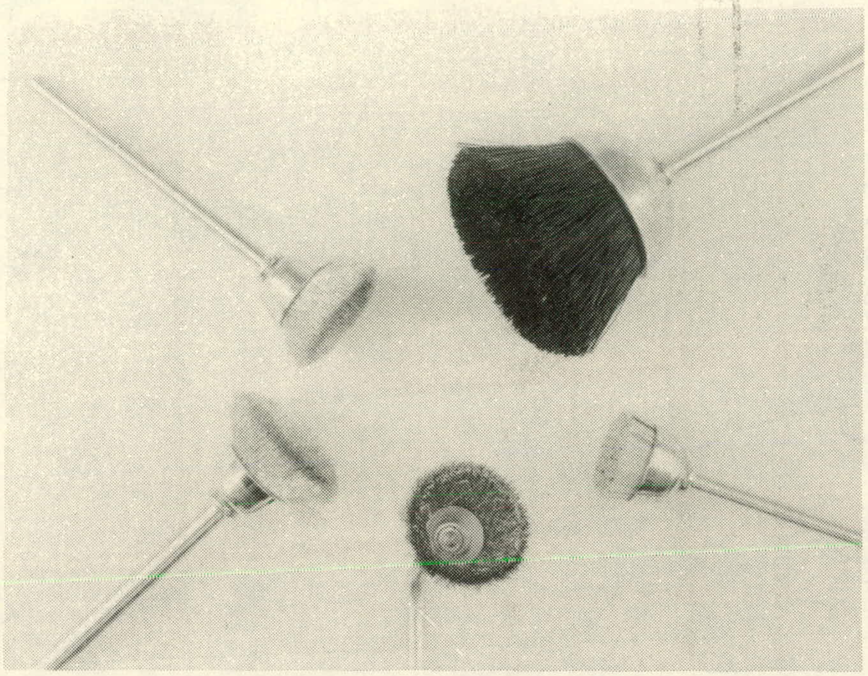

Figure 2. Cup Brushes

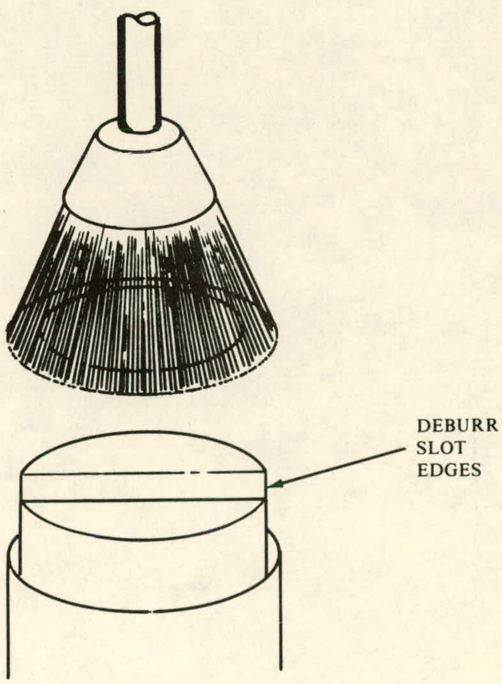

Figure 3. Application for a Cup Brush

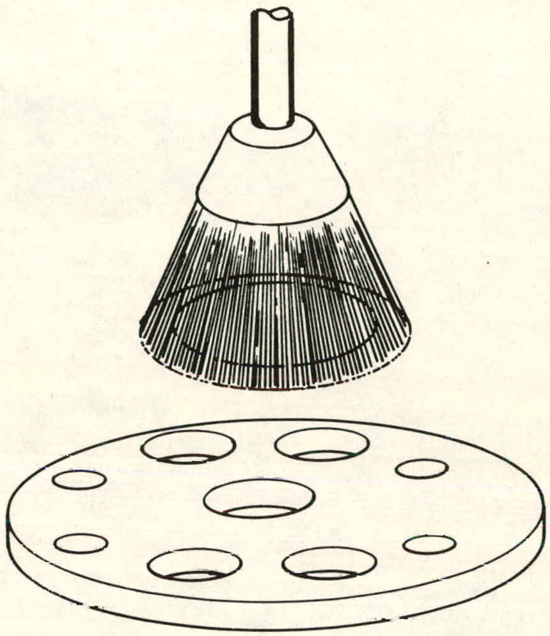

Figure 4. An Application for a Cup Brush

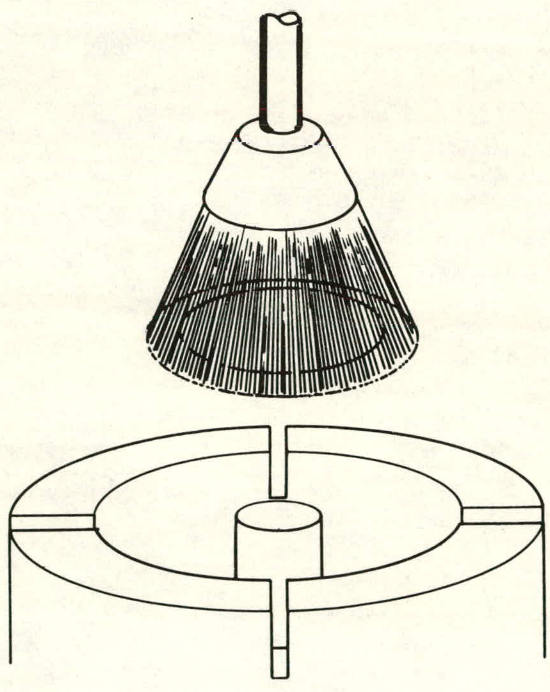

Figure 5. Cup Brush in Use

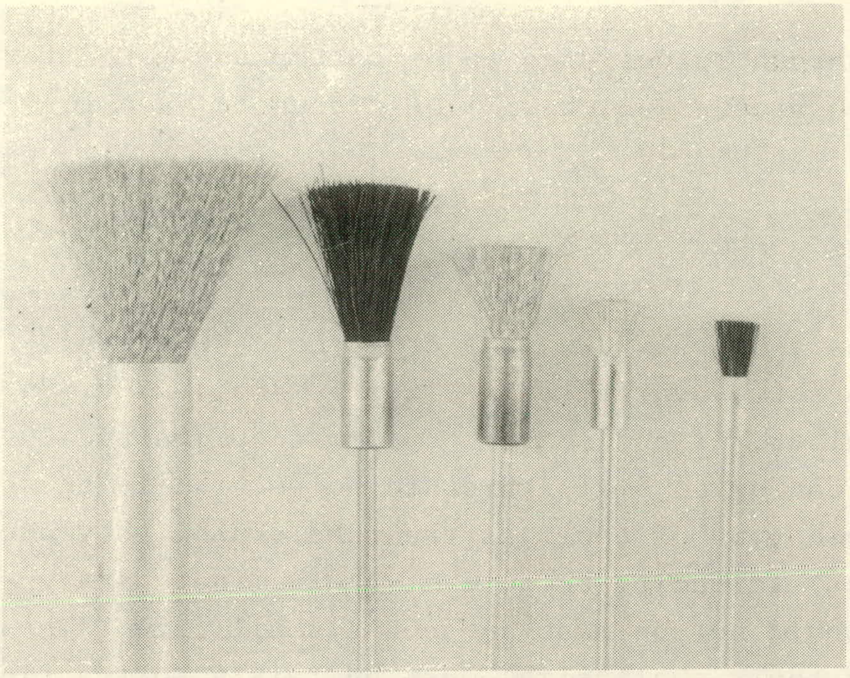

Figure 6. Close-Up View of an End Brush

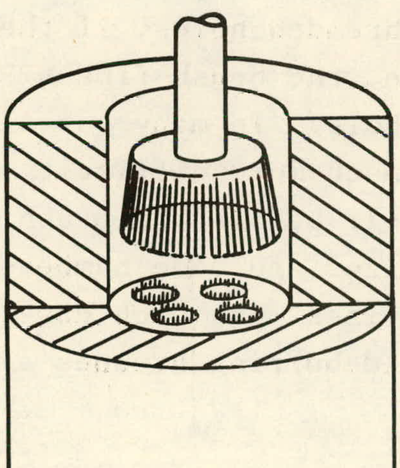

Figure 7. An Application of End Brushing

In general, a tube brush is designed to be softer and more flexible than the side action brushes which will be discussed in a following paragraph.

CROSS HOLE DEBURRING BRUSH

Figure 9 illustrates a brush known as a cross hole deburring brush. These brushes are available in sizes as small as 0.024 inch and can be made smaller, if necessary. The most common use is for deburring or cleaning of small threaded holes. While these are visually the same type of tools as the tube brush, they are classified as a separate entity because of their minute size. A normal tube brush would not be made in such a small size. These brushes, because of their small size, must be fairly soft acting tools. As a result, they are not capable of removing large burrs. They will remove very fine burrs and they will clean threaded holes.

As discussed in the section on deburring threaded holes, if the wrong size brush is used in a threaded hole, the brush fibers will break loose and become lodged in the hole. In many cases, trying to dig out these small fibers is a much more difficult task than trying to clean out the hole itself before the brush was used. Table 2 illustrates the brush sizes and code numbers which should be used for specified thread sizes. In each case, the brushes which are set up as cross hole deburring brushes at Bendix are of stainless steel.

SIDE ACTION, BUTTERFLY, AND SIBOT BRUSHES

Figure 10 illustrates three brushes which have very similar actions. The side action or butterfly brush is very similar to the sibot brush or square trim brush. The advantage of the side

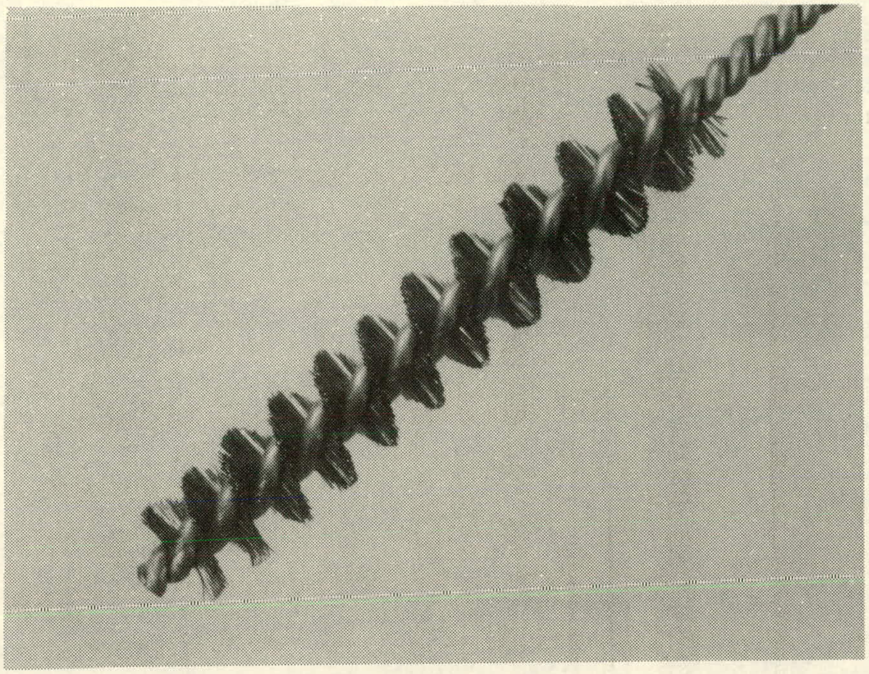

Figure 8. Tube Brush

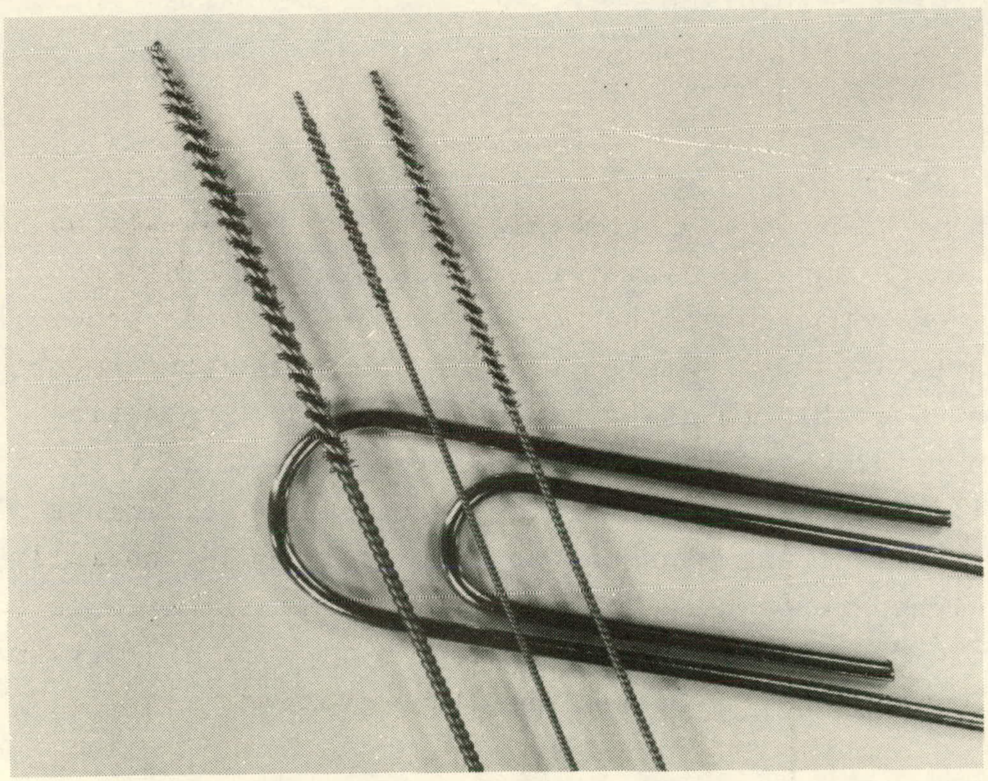

Figure 9. Cross Hole Deburring Brushes

Table 2. Cross Hole Deburr Brush Size and Bendix Code Number

Hole Size	Brush Diameter (Inch)	Bendix Number
0.5 mm	0.024	10207239
0.8 mm	0.032	10207238
1 mm	0.032	10207238
1.2 mm	0.047	10207226
0-80	0.047	10207226
2-56	0.079	10207227
4-40	0.097	10207237
5-40	0.109	10207225
6-32	0.125	10207229
6-40	0.125	10207229
8-32	0.142	10207236
10-32	0.156	10207235
10-24	0.156	10207235

action brush is that it may be obtained in sizes as small as one-quarter of an inch in diameter. These brushes are very aggressive when compared to the normal brushes used on precision miniature parts. As an example, to meet Bendix quality needs, it would not be advisable to use a one-quarter inch side action brush to deburr aluminum threads. This brush might be very satisfactorily used for the same size threads in a stainless steel part. While these brushes can be used by hand, normally they are designed to be used in some form of motorized tools. The cross hole deburring brushes, in contrast, work in very small holes and are used only in a hand held application.

TOOTHBRUSHES

While it is not a common event to use a toothbrush for deburring, the large stainless steel bristle brush shown in Figure 11 is used on large threads as well as for a few small parts. The strength of stainless steel fibers combined with the length of the fibers permits reaching in very hard-to-reach places to clean and provide some small deburring action. This tool is particularly useful in a department making hand size or larger parts. Despite its size, many individuals deburring miniature parts also find a number of applications for this tool.

TYPES OF BRUSH FILAMENTS

While a variety of bristle materials are used in the manufacture of brushes, only eight have been used to any extent at Bendix:

- Carbon steel,
- Stainless steel,
- Brass,
- Tampico,
- Nylon,
- Abrasive filled nylon,
- Nonwoven synthetic material, and
- Elastomer filled wire bristles.

While carbon steel brushes are used because of their low cost and long life, they are not applicable to the majority of parts made in the precision machining area. Carbon steel will rust very easily and carbon steel in a brushing application will deposit particles of carbon steel onto workpieces. This material will rust very quickly on stainless steel and will in turn cause the stainless steel to rust. For this reason, most of the miniature metal brushes are made from stainless steel.

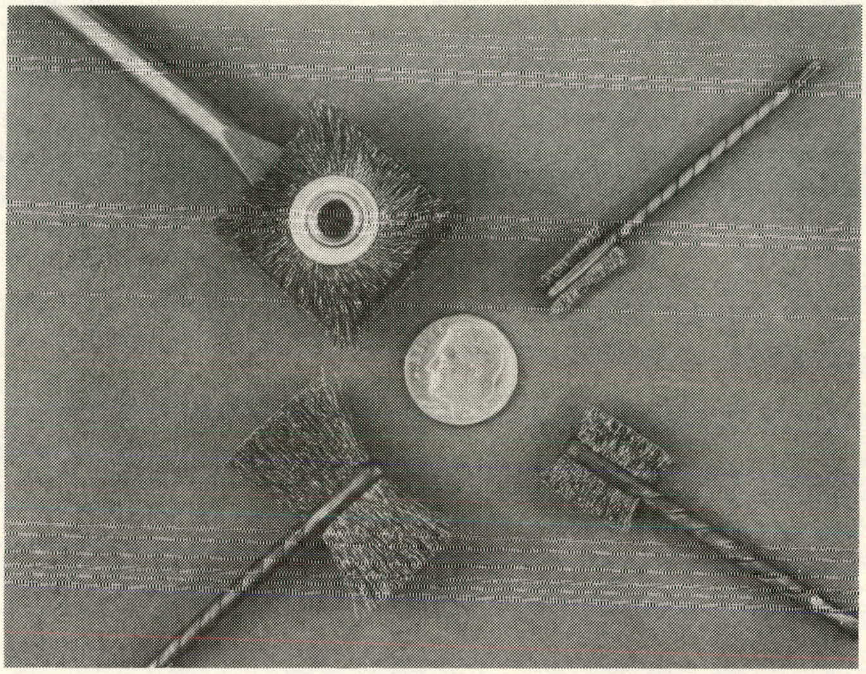

Figure 10. Side Action and Related Brushes

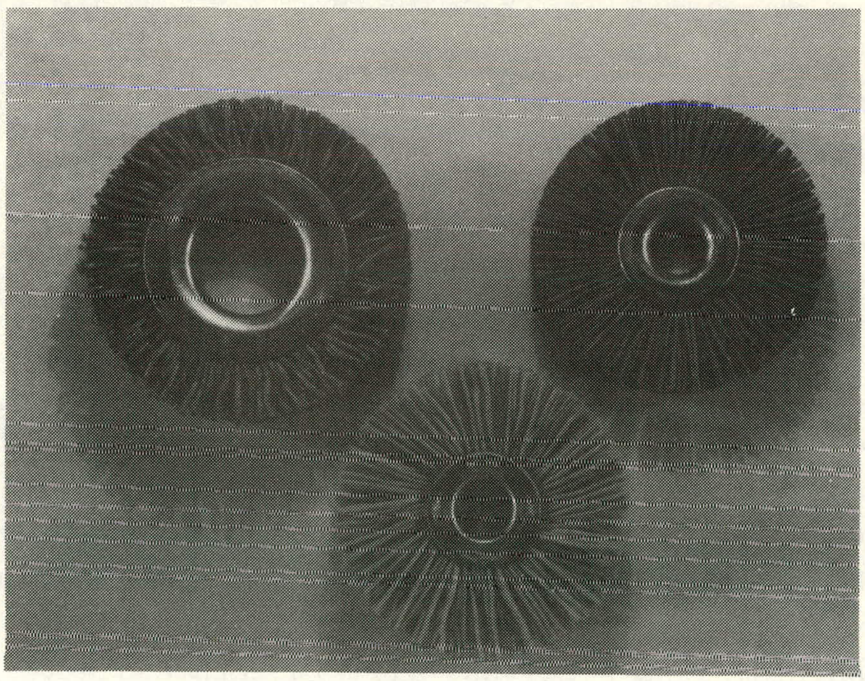

Figure 11. Abrasive Filled Nylon Brushes Used on Precision Miniature Parts

One of the problems with a high-strength material such as stainless steel bristles is that, if not used very carefully, the brush itself will make a very large burr. As one example, turning the spindle too fast with this type of brush, will easily take a sharp edge and make a burr from it. One of the common problems with stainless steel is, that, under normal use, it is easy for the stainless steel filaments to physically weld to the stainless steel part. When a bristle rotates further, the weld is broken. This provides a very rough surface and in many cases, helps the formation of burrs.

Despite these problems, some individuals will find that stainless steel brushes, particularly those which have a softer feel to them, work very well for removing small burrs from parts. It is possible to purchase very stiff stainless steel brushes which will not only remove small burrs but will remove very large burrs. At the same time, however, they will generate a large radius which is not allowable for the types of parts we are considering.

Miniature brass bristle brushes represent one of the finest tools for finishing or radiusing edges. They are soft enough to not generate new burrs yet rigid enough to provide a small edge break. Brass, however, easily deposits on any workpiece in which it is placed in contact. As an example, one will frequently find a yellow color at an edge which has been deburred by brass filaments. This discoloration is not allowable in the finished product but may be allowable in the deburring operation <u>if</u> suitable cleaners are used in subsequent operations. It is important, however, to know ahead of time that brass will be used so that appropriate cleaners can be added to subsequent operations. For this reason, whenever a brass brush is desired, but leaves a yellow stain when used, the supervisor should be requested to determine what additional steps should be added to the production traveler to clean the workpieces.

Tampico is a vegetable fiber which is widely used in some facilities for providing good finishes to parts. It is so soft that it has very little radiusing action on its own but is used with a deburring compound which consists of a glue like substance mixed with fine abrasive particles. Tampico brushes with deburring compounds can provide high luster, fine edge finishes, and aggressive deburring if desired. The use of the compound, however, results in material which is hard to remove from the workpiece. These compounds are very tenacious and in many cases their removal is more difficult on a miniature precision part than was the removal of the burr by other means.

A number of nylon bristle brushes are available commercially and a few are used within the plant. The nylon is soft enough to not generate problems in use. The disadvantages are that they are so soft generally that they will not remove large burrs. They may be useful in cleaning operations.

The most widely used brushes for deburring and edge finishing precision miniature parts are those abrasive-filled nylon brushes, such as shown in Figure 11. These brushes, three of which are in common use, have an abrasive embedded in the fibers. This abrasive can be either aluminum oxide or silicon carbide. Typically, a brush with silicon carbide particles on it will appear to be a dark gray or black color. Those with aluminum oxide tend to be a gray or a white color. The abrasive-filled nylon provides not only the soft action required to finish parts, but an abrasive action which removes the burrs and provides a gentle edge break. With normal use, these brushes will not provide more than a 0.005 inch edge break. In many cases, if used solely by themselves on a perfectly sharp edge to begin with, they will not produce more than a 0.003 inch edge break. The fact that the bristles are soft, yet very ductile and tough eliminates one of the problems common with the metal filled brushes--metal fibers flying from the brush.

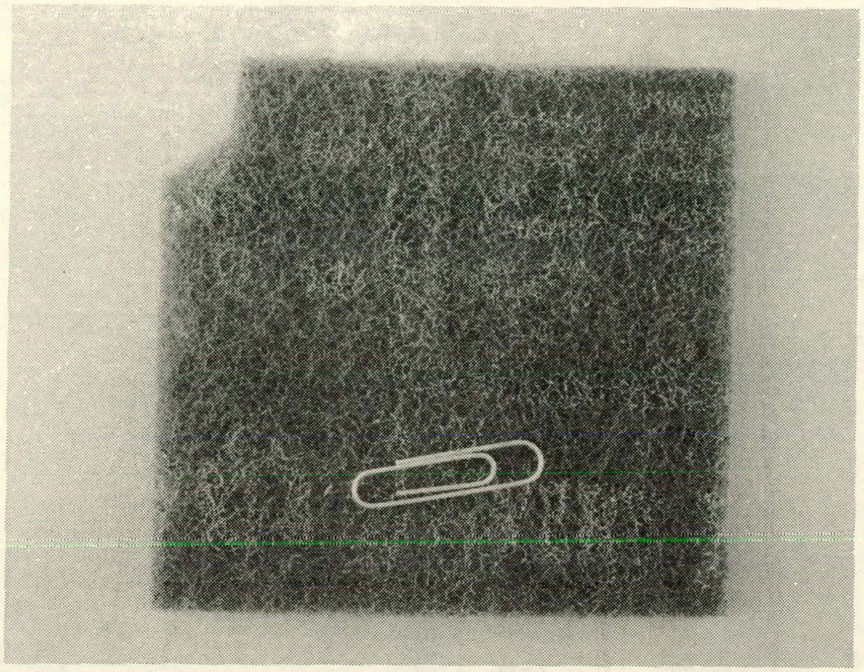

Figure 12. Non-Woven Synthetic Brush Material

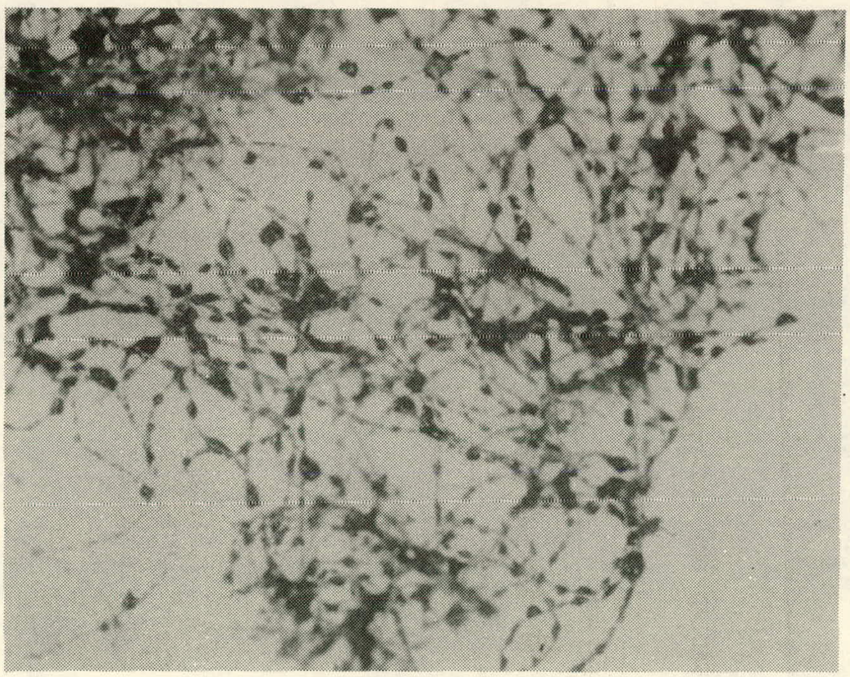

Figure 13. Fibers in Non-Woven Synthetic Brush Material

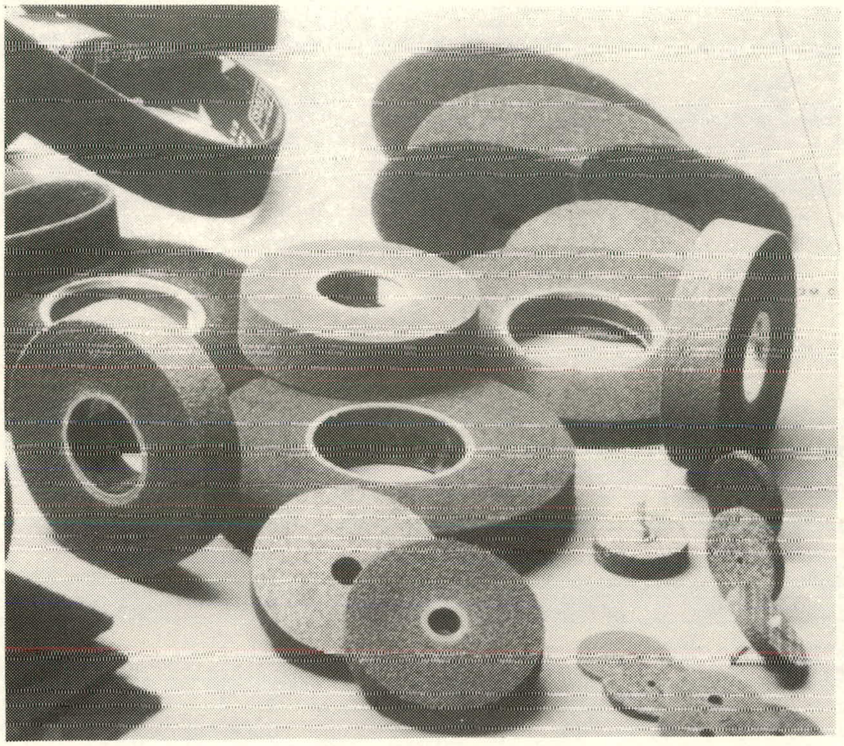

Figure 14. Dense Non-Woven Synthetic Material

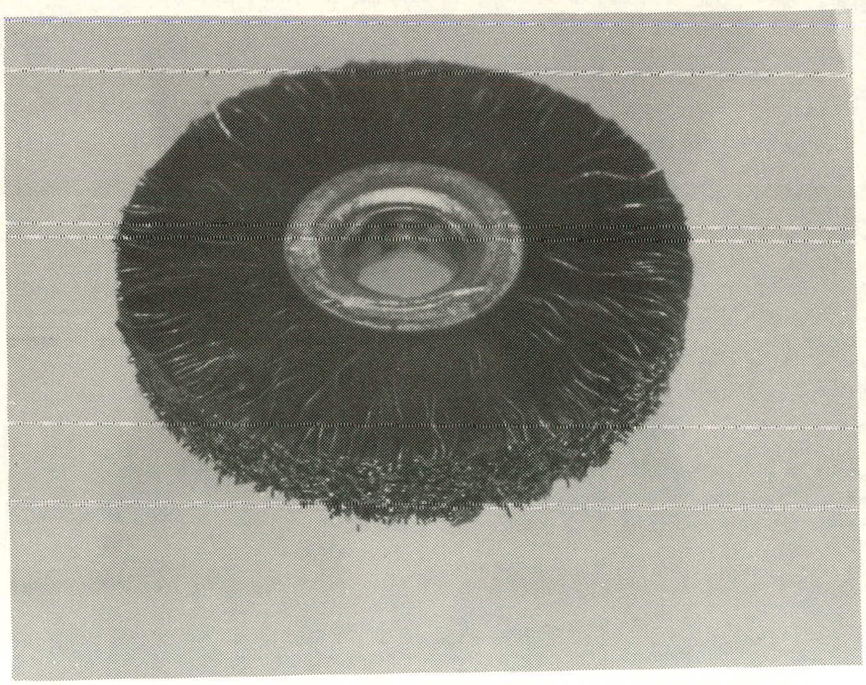

Figure 15. Elastomer Filled Wire Brush

A number of nonwoven synthetic brush materials have been purchased for experimental uses at Bendix. Figure 12, for example, illustrates one of these brushes. This material is very similar to that used for scrubbing or waxing floors, and for scrubbing and cleaning pots and pans. It is filled with an abrasive much like the abrasive used in the abrasive filled nylon brushes but, in inspecting the material closely (Figure 13), one will find that there is no uniform pattern to the fibers in the brush. These brushes are used widely in the aircraft industry because they leave an excellent surface finish yet can provide both gentle or aggresive action. The sizes are quickly changed by the use of a pair of scissors in the case of the square trim or sibot brushes.

Figure 14 illustrates a soft wheel which is denser than that illustrated in Figure 13. This provides more aggressive action.

When very aggressive action is required which will not grossly scratch surfaces, some companies will use a plastic filled metal brush such as shown in Figure 15. The plastic keeps the fibers from spreading apart and wearing out as quickly. This makes the brush a much stiffer tool. But the plastic itself also tends to prevent gross scratching or destruction of the workpiece. This type of brush is not applicable to precision miniature parts but can be used on hand size and larger parts for very quick deburring using brushes alone.

FACTORS AFFECTING AGGRESSIVENESS

There are a number of factors in brushing which determine how gentle or how aggressive a brush will act:

- Diameter of the bristle filaments,
- Free length of the filaments,

- Width of the brush,
- Velocity of the brush,
- Filament material,
- Sharpness of the filaments,
- Contact pressure,
- Filament texture, and
- Density of filaments.

Large diameter filaments increase the aggressive action of the brushes. As an example, if a brush is too soft and the diameter of the filament materials is doubled, then the brush will be four times stiffer than the first brush. The length of the fibers projecting from the spoke of a radial brush, for example, also determines the aggressiveness of a brush. In normal situations for miniature parts, the free length of these fibers is only one-quarter to one-half of an inch (Figure 16 and Table 3).

In many cases when using the miniature brushes, those performing deburring will place two or more brushes side-by-side to make the wheel stiffer (Figure 17). While wider wheels can be purchased, the stacking of wheels eliminates the in-plant storage of one extra brush style and provides both the flexibility of a single wheel and the aggressiveness of double widths.

The speed at which a brush is rotated plays a major role in determining the success of blending edges. Under normal circumstances, with the abrasive filled nylon brushes, the brush can be rotated at 3000 rpm (on diameters larger than 2 inches, slower speeds are used). These speeds on stainless steel brushes may be excessive, however, and one-third this velocity may be adequate.

Steel and stainless steel are much harder and rigid materials than brass, tampico, or nylon. For this reason, a person needing aggressive deburring normally would use a hard filament material

Table 3. Typical Radial Deburring Brush Characteristics*

Description	Bendix Code Number	Brush Material	Filament Diameter (inch)	Free Length (inch)
Stainless Steel	10207230	Stainless Steel	0.0030	0.300
Stainless Steel, elastomer filled	10207231	Stainless Steel	0.0080	0.375
Stainless Steel	10207232	Stainless Steel	0.0030	0.200
Steel	10207244	Steel	0.0050	0.300
Stainless Steel	10207249	Stainless Steel	0.0025	0.500
Brass	10207240	Brass	0.0050	0.300
Abrasive-Filled Nylon	10207251	500-Grit ALO	0.0180	0.400
Abrasive-Filled Nylon	10207256	600-Grit SiC	0.0140	0.400
Abrasive-Filled Nylon	10207257	320-Grit SiC	0.0240	0.250

*See Table 2 for cross hole deburring brush characteristics

like steel or stainless steel. Conversely, a gentle brush would be used on very soft or pliable materials such as nylon.

Abrasive-filled nylon and nonwoven brushes have additional material variables:

- Type of abrasive material,
- Size of abrasive material, and
- Quantity of abrasive material.

For most Bendix applications, only the size of abrasive grit appears significant for normal use on miniature parts. These products can be obtained with abrasives as coarse as 50 grit or as fine as 600 grit.

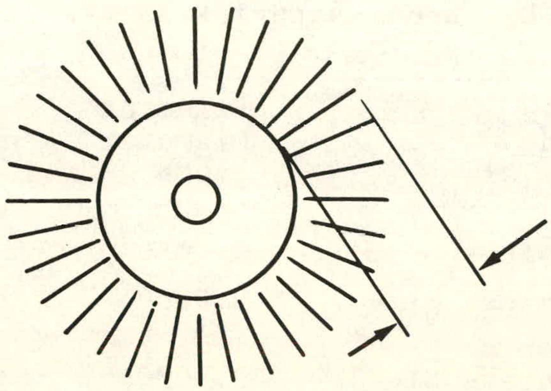

Figure 16. Free Length of Brush Fibers

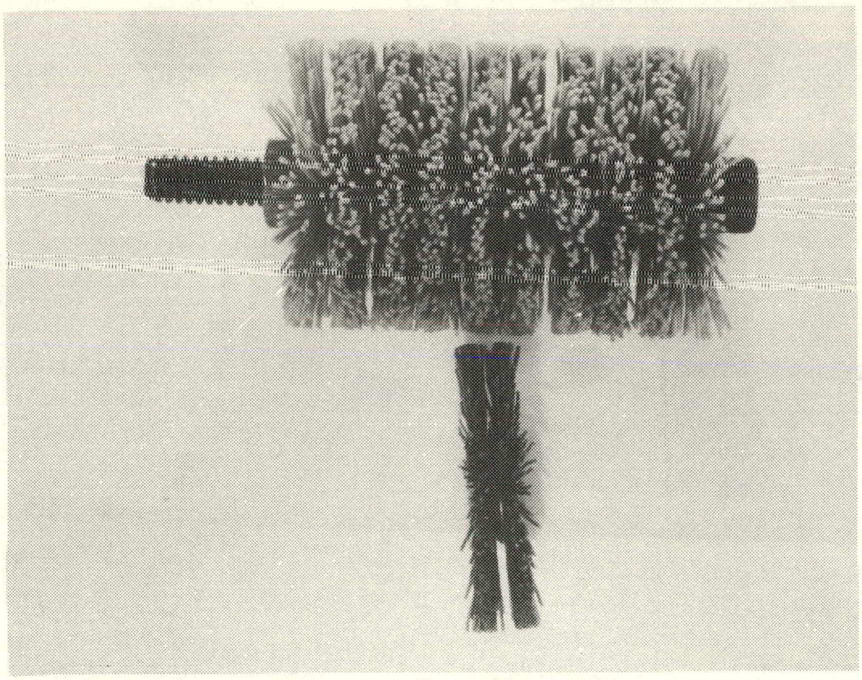

Figure 17. Stacking Brushes to Provide Additional Stiffness

Figure 18 illustrates the ends of the fibers on a new brush. As seen there, these fiber ends are sharp 90° angles. As such, they will act as a sharp cutting tool. When these ends get worn, such as shown in Figure 19, they will loose some of their cutting ability. While radial brushes are not normally thought of as being sharp, these illustrations indicate that some difference will occur with the use of the brush.

Figure 20 illustrates the proper and improper use of brushes. Excessive bending of the filaments will not only wear them out quicker, but in many cases will result in excessive radiusing at edges, and in some cases, will destroy the surface finish near the edge. The abrasive-filled nylon brushes, however, seem to work very well in this otherwise improper application. They are not only long-lived but the fact that a longer length of the bristle passes over the edge results in a smoother radius.

Figure 21 illustrates two wires; one is perfectly smooth and one has an etched pattern. It is not difficult to see that the one with the etched pattern has a rougher surface and would abrade edges faster than the smooth one. Texture can be provided by the filament manufacturer, or if a brush is allowed to rust or otherwise corrode, the same effect will occur.

Brushes can be purchased with a large number of filaments around the diameter. As an example, in Figure 22, note that the larger brush has approximately twice as many filaments as the smaller one. Because the filaments are roughly the same size, the more densely packed brush will act more aggressive than the others.

SIDE EFFECTS OF BRUSH DEBURRING

Brushing can cause five major side effects which must be considered when deburring:

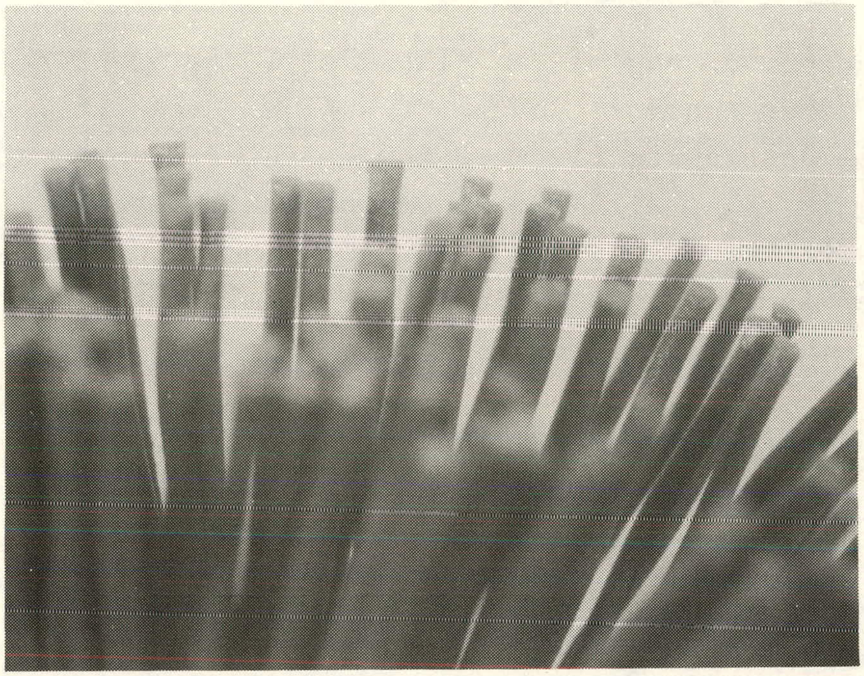

Figure 18. Ends of New Nylon Bristles

Figure 19. Ends of Worn Nylon Bristles

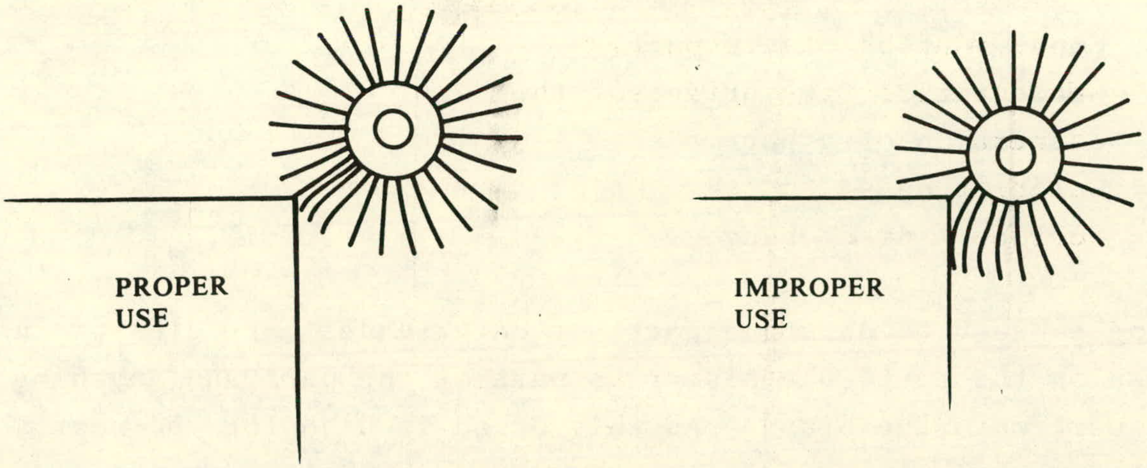

Figure 20. Proper and Improper Use of Brushes

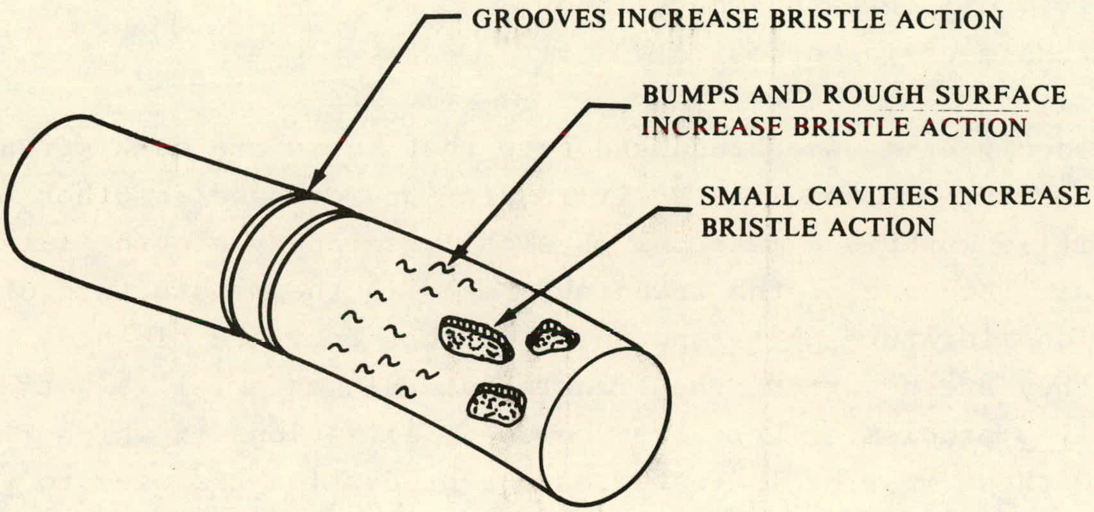

Figure 21. Surface Texture on Brush Filaments

- Contamination of the part,
- Hardening of the surface of the part,
- Generation of a burr,
- Color changes, and
- Surface finish changes.

Using a brush to deburr a part not only leaves particles of the brush on the part, but also rubs part of the part and anything on the part onto the brush. As this brush is used for the next part, it not only deposits the brush on the next part but also any contamination picked up from the first part. As such, brushes cause two types of contamination:

- Dirt, oil, grease smears, and
- Brush material deposits

Look closely at a used brush and note that there are dark streaks on the brush. In some cases, it is dirt and oil and in other cases it is workpiece material physically scraped into the filament material. Because of the techniques used in the manufacture of precision miniature parts and the fact that they are cleaned after they are deburred, the transfer of this material is not normally a problem. There are, however, situations in which it is, and these must be indicated on the production traveler to prevent undue problems after deburring.

Rotating a nylon brush in a high speed motor will deposit nylon on the workpiece. In some cases, a black layer of plastic will be deposited. In other cases, a plastic film invisible to the eye will occur. This film may be detrimental to both subsequent operations and the function of the part. For this reason, it is important not to run nylon materials at excessive speeds or to cause excessive friction in their use. For example, pressing a brush too hard into the workpiece will cause high friction to generate high temperatures which will in turn melt nylon onto the workpiece.

A yet unexplained phenomena in brushing is that the brush will make the surface of the workpiece or the deburring area harder than it was before. In some cases, the hardness is much higher than is obtainable by any other means. This is not normally a problem on parts, particularly on the edges. In a few applications, this side effect of hardening could be detrimental. Whenever that is the case, the production traveler will indicate not to use a brush.

Brushes will change the color of many parts, and it will brighten them and darken them. In some cases, it is hard to define exactly what the difference is but a difference is obvious. This is not a major concern on the majority of parts because we do not manufacture parts by color. Many commercial parts, however, have a luster requirement and for this reason cannot tolerate the use of some brushes.

Brushes can change the surface finish of some parts. For the majority of applications at Bendix Kansas City, this is not a disadvantage. Using the abrasive-filled nylon brushes, for example, may improve the surface finish from a 32- to a 16-microinch finish.

GENERAL COMPARISONS BETWEEN BRUSHES

Table 4 illustrates some general comparisons between the brushes most commonly used at Bendix on small or hand size parts. These comparisons are for general use only and may not always hold true in practice. They may be useful, however, in initial selection and experimentation.

Table 4. Comparative Results of Miniature Brushes

Brush Description	Workpiece Material (BHN) and Resulting Edge Hardness			
	303Se Stainless Steel (BHN226) (Inch)	Beryllium Copper (BHN187) (Inch)	7075-T6 Aluminum (BHN150) (Inch)	6061-T6 Aluminum (BHN95) (Inch)
Stainless Steel Brush 0.0030 Filaments	0.0064	0.0085	0.0174	0.0186
0.014 Diameter Nylon Filaments with 600 Grit Silicon Carbide	0.0064	0.0053	0.0070	0.0082
0.018 Diameter Nylon Filaments with 500 Grit Aluminum Oxide	0.0058	0.0079	0.0062	0.0066

SAFETY CONSIDERATIONS

There are six basic concerns which must be faced for safe operation when using brushes:

- Filaments flying from the brush while rotating,
- Hands being scraped by the brush,
- Bent shanks because of too high a velocity,
- Clothes caught in the brushes,
- Parts being thrown out of hands by the brush, and
- Brushes flying from the motor because of inadequate holding tension.

It is important whenever using miniature brushes always to use a safety shield found on the bench motor (Figure 23). The metal filament brushes throw filaments from the brush very easily. If safety shields do not cover the brush, then these fibers could stick in hands and clothing. It is easy to scrape hands when using miniature brushes. These miniature brushes are generally soft enough that they will not hurt the hand but the abrasion will be felt.

As indicated in previous chapters, never use high speed air motors with miniature brushes. The high speeds accelerate the throwing out of filaments, they cause shanks to bend, and catch hands in clothes and, in some cases, the speeds will cause shanks to break.

NOTE: <u>Never use miniature brushes in air motors</u>.

As in the case of scraped hands, clothes can be caught in the brush. For this reason, clothing should not extend beyond the cuffs.

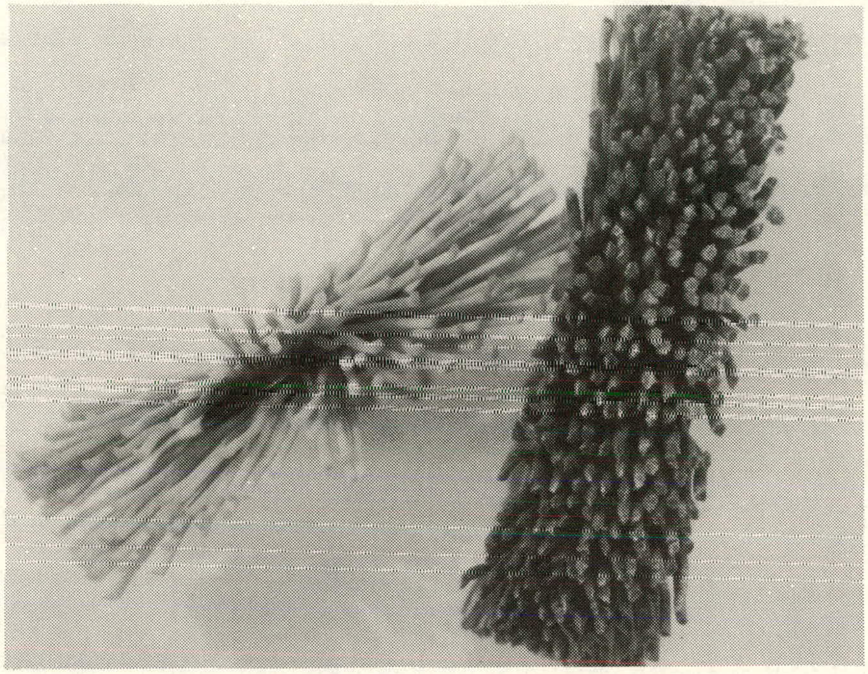

Figure 22. Filament Density

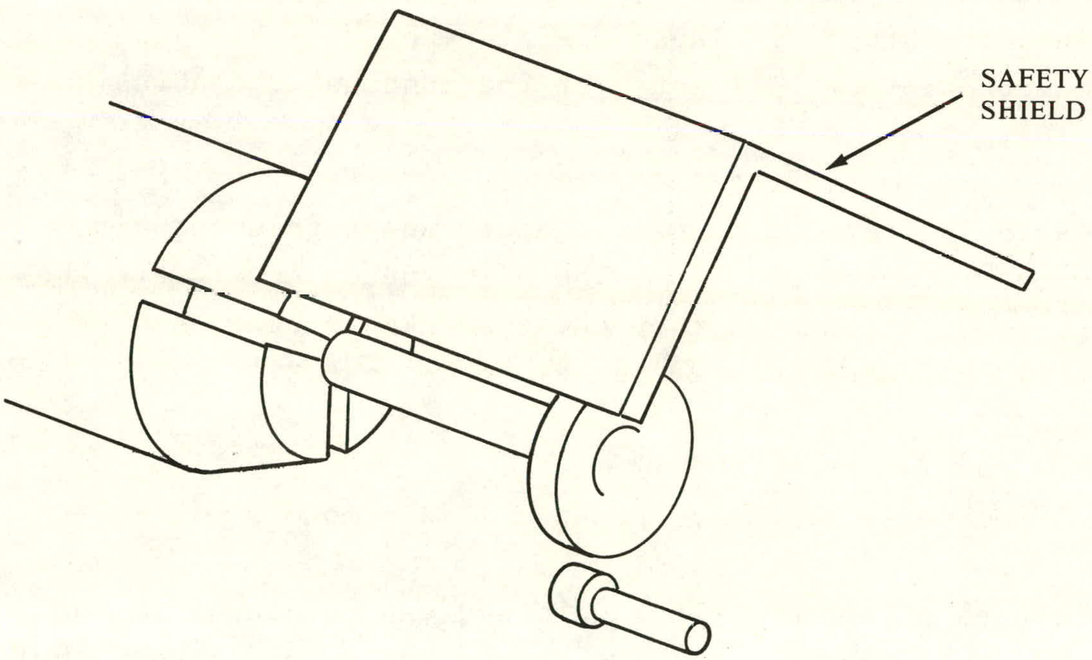

Figure 23. Always Use a Safety Shield on Bench Motors

Holding small parts against a rotating brush is very difficult. It is very difficult to maintain the grasp and yet provide all the radiusing action in all the locations desired. Because of this, it is not unusual for parts to be gently pulled from one's hand by the brush and thrown to the table top. Because of the direction of rotation of the brush, into the table rather than up into the air, this represents no major problem other than possible damage to the part (Figure 24). It is important, however, for safety reasons to have the motor rotating in the correct orientation as shown in Figure 24 to prevent parts from being thrown into the air such that individuals surrounding the worker might be hurt.

As mentioned in previous chapters, when using a three-jawed chuck or collet to hold parts, it is important to make sure that tools are held tightly while they are rotating. Similarly, the chuck key must never be left in the chuck after it is tightened. These chuck keys develop tremendous force when thrown from a rotating spindle and can cause serious injury to anyone hit by such a flying tool even though it is small.

HOW BRUSHES WORK

Brushes are designed to cut with the tips of the fibers (Figure 25). The tips actually act as miniature cutting tools to cut out very small particles from the workpiece. Slight bending of the filament wires also provides a radiusing action after the cutting has occurred. It is not totally out of place to draw the analogy that the tips are cutting and the surface of the filaments are abrading away metal from edges. Also, there is a very difficult and as yet not fully explained chemical and thermal action which assists in the deburring and in the hardening of surfaces when brushes are used. As previously mentioned, brushes are not generally meant to be bent like that shown in Figure 20. The

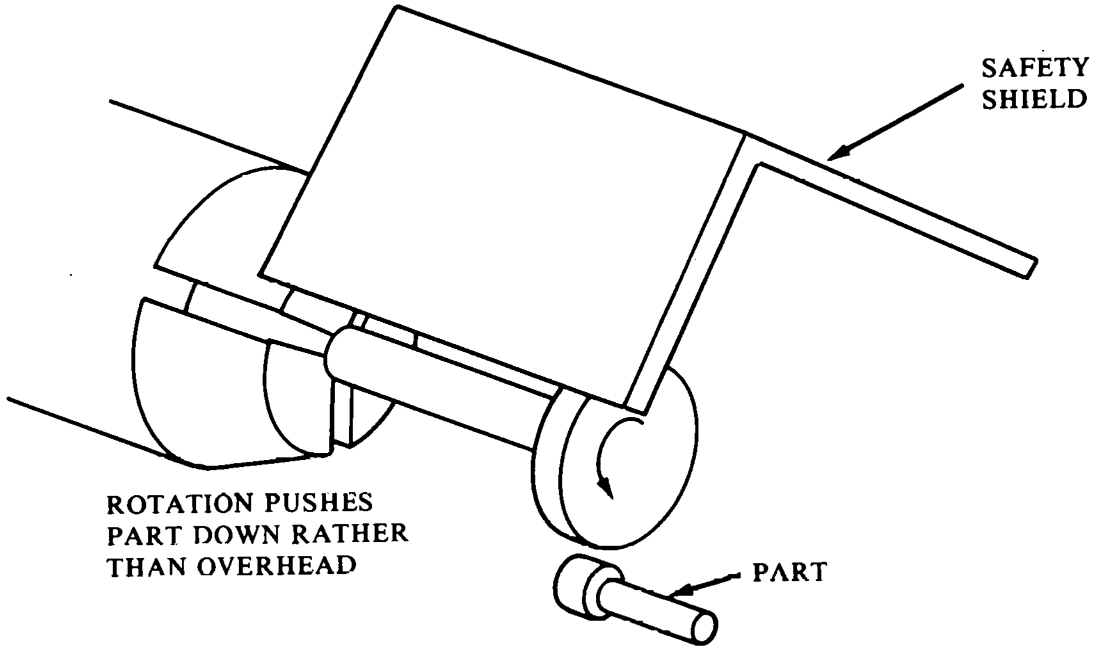

Figure 24. Use Correct Spindle Rotation

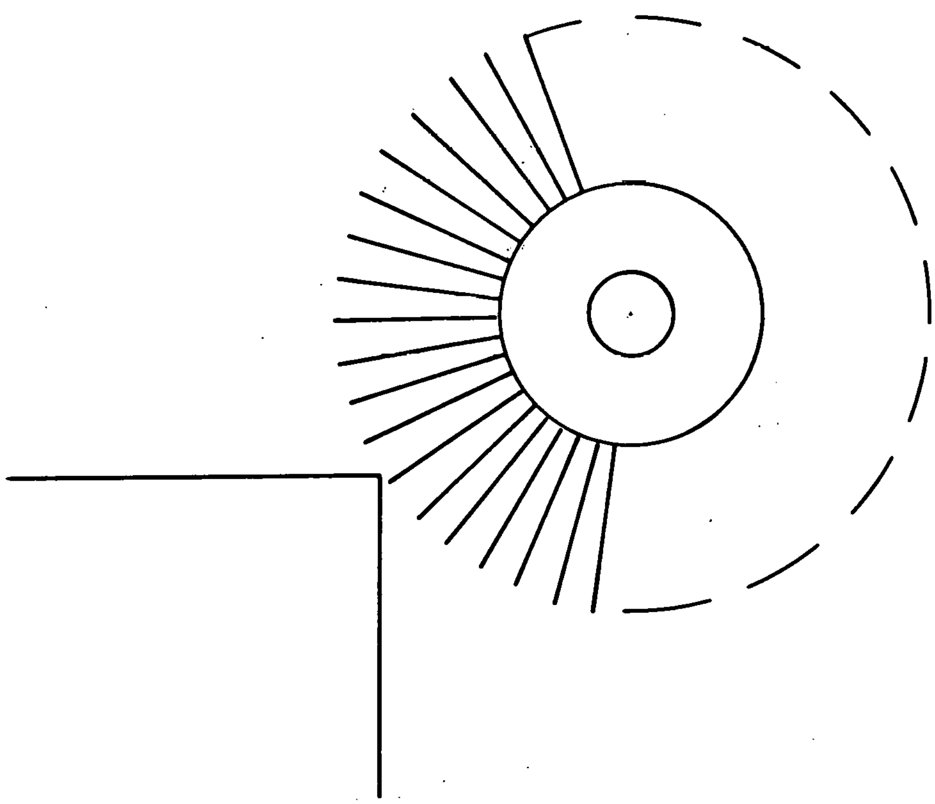

Figure 25. Brushes Cut With the Tips of the Bristles

abrasive filled nylon brushes, however, may be used in this manner without harm.

AUTOMATIC BRUSHING EQUIPMENT

Machines can be purchased which will automatically brush deburr an entire part. These machines are used very widely in high production industries. They are used widely on large parts. An analysis of these machines indicates, however, that they are not generally applicable to precision miniature parts being made in very small quantities.

SOURCES OF ADDITIONAL INFORMATION

1. L. K. Gillespie (editor), Deburring Capabilities and Limitations, SME, 1974.

2. L. K. Gillespie (editor), Advances in Deburring, SME, 1976.

3. L. K. Gillespie, "Give Your Deburring Problems the Brush Off," Machine and Tool Blue Book, April, 1979, pp 107-117.

4. Edward P. Fisher, "Power Brush Cleaning and Finishing." Metals Handbook, Volume 2, pp 371-386.

ASSIGNMENT

1. Use each of the cross hole deburring brushes in the threaded hole sample provided. Inspect the hole after using each brush and record your observations.

2. Use stainless steel radial brush 10207230 or 10207232 in the bench motor to radius a stainless steel part. Use maximum spindle speed then radius the second part at half speed. Describe edge differences.

3. Use stainless steel brush 10207249 and brass brush 10207240 on a stainless steel part and record your results.

4. Measure the diameter of a turned part to the nearest 0.0001 inch. Brush this part with a nylon bristle brush for 2 minutes and remeasure the diameter. Record the results.

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CHAPTER 19

FILES FOR DEBURRING

Files are one of the oldest metal cutting and stone working tools. The oldest known metallic file, for example, is 3400 years old. The early Egyptians used files and rasps between the years 3200 and 1800 BC. Despite the presence of many sophiscated machining and finishing processes, filing remains one of the necessary hand operations for many parts. Even on the precision parts that are used at Bendix Kansas City, in precision aerospace and in many automotive assemblies, hand filing is still required on edges having close tolerances. This chapter will describe some of the files which are available and the techniques for using them. Chapter 41 represents detailed information on the use of files for very large parts. The materials presented in this chapter will pertain specifically to miniature parts and definitions of differences between files.

TYPES OF FILES

There are at least 2300 different types of files in existence today. Despite efforts to standardize between manufacturers and countries, there is considerable difference between files produced by different facilities. Because of this, it is difficult to categorize and describe all the variations which are commercially available for use on deburring and finishing of parts. Basically, however, there are five general types of files:

- Swiss precision files,
- Swiss precision rifflers,

- American pattern files,
- Millenicut files, and
- Diamond plated files.

There are basic differences between these files:

- Variations in shape,
- Variations in size, and
- Variations in tooth configuration.

There are two more distinctions which must be considered. A file may be either single cut or double cut as shown in Figure 1. As seen there, a single cut file has the teeth running at an angle to the edge of the file. The double cut file has another series of cuts running across the first series of cuts. Most deburring files are double cut files. Unless otherwise indicated, assume that the files discussed in this chapter are double cut files.

One of the interesting aspects of files is that they are formed by a tool which raises a sharp edge. A close look at many brand new files will show that there is a burr on the very tips of the teeth. It is this burr (Figure 2) and the sharp tips which perform the deburring of parts. In this case, the burr is an advantage but the orientation of the burr must be noted before using the file to obtain optimum cutting. Table 1 provides some comparisons between the number of teeth per inch on Swiss, American, and British files. In general, the American files are seldom finer than a #2 cut although exceptions can be found. As seen in Table 1, the small numbers indicate coarse files. Figure 3 illustrates the actual size of some of these cuts and the sizes available on various types or kinds of files.

During precision deburring at Bendix most individuals will be using Swiss precision files or, in a few instances, diamond-plated

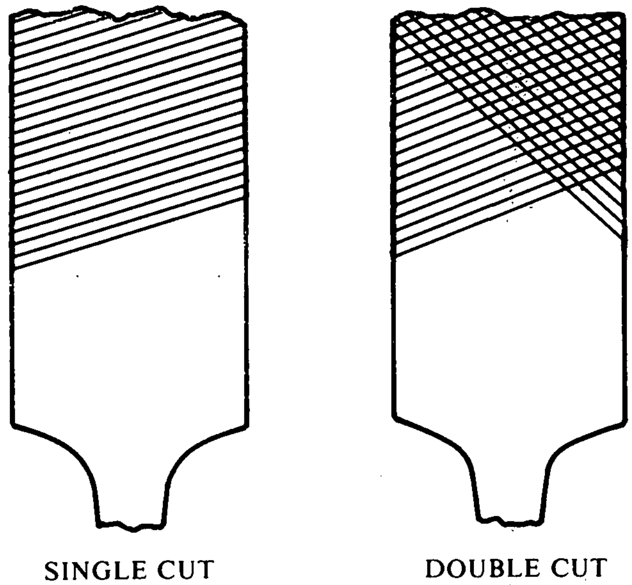


Figure 1. Single and Double Cut Files

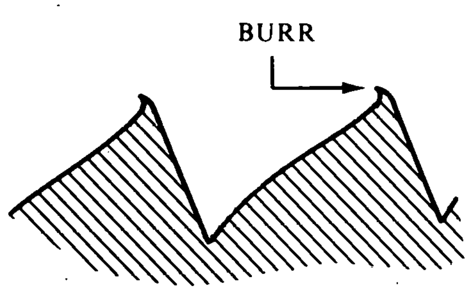


Figure 2. Burr on Tips of File Teeth

miniature files. The primary difference between the Swiss precision and American files are that the Swiss files generally have a finer taper and the teeth extend to the very ends and edges of the file. Generally, they are also narrower and smaller than ordinary files. There are several types of precision files as shown in subsequent paragraphs and tables, there are, however, three principal groups:

Table 1. Comparison of Swiss, American, and British Files

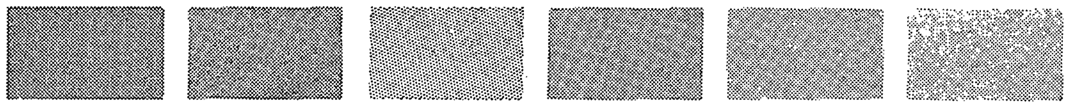
Cut Number	Corresponds Approximately to Cut Type	Teeth per inch* Swiss Files	USA Files	Stub's (British) Files
000	Rough Cut			
00	Bastard		27-50	
0	Between Bastard and Second Cut	40-70	35-60	42-65
1	Second Cut	75-88	55-75	57-80
2	Smooth	88-104	80-95	72-95
3	Dead Smooth	100-130	80-120	87-110
4	Dead Smooth	120-160	125-135	102-125
6	No Equivalent	180-200	160-200	132-155
7		213		147-170
8		295		162-185

*Note that there may be a wide variety of actual number of teeth per inch from different manufacturers.

- Tanged needle files,
- Escapement files, and
- Riffler files.

The needle files, which are sometimes called "wire files" or "French files", have round handles which are integral part of the file. Note that most American files require a wooden handle to hold the file. The French files were made originally for the jewelry, watch, and clock trades in Europe. Escapement files are also self-handled, but the handle is square. As their name implies, they are made primarily for the delicate work involved in filing watch escapements and clock interiors.

	30	38	51	64	79
Teeth per inch (upcut)	30	38	51	64	79
Files 10" and over in length	00	0	1	2	3
Files 4" to 8" in length		00	0	1	2
Files 3" in length			00	0	1
Escapement Files				0	
Needle Files 4" to 7¾"				0	
Regular Rifflers				0	



	97	117	142	173	213	295
Teeth per inch (upcut)	97	117	142	173	213	295
Files 10" and over in length	4		6			
Files 4" to 8" in length	3	4		6		
Files 3" in length	2	3	4		6	
Escapement Files	2	3	4		6	8
Needle Files 4" to 7¾"	2	3	4		6	
Regular Rifflers	2	3	4		6	

*NUMBERS SHOWN UNDER THE NUMBER OF TEETH PER INCH ARE NUMBERS INDICATING FINENESS OF CUT FOR SPECIAL FILES

Figure 3. Scale of Cuts Used on Files

The term "Swiss precision files" or "Swiss files" is used to designate a group of shapes and scales of cuts which were originally developed in Switzerland over 160 years ago. These shapes and cuts while generally known as "Swiss pattern files" have been widely imitated and produced by many companies outside of Switzerland. As will be shown in several illustrations, they are quite different from the other common types of files known as hardware, commercial, or American pattern files.

Swiss precision files and rifflers are made in over 700 shapes today. They are available in a wide range of sizes and the rifflers alone are available in over 600 variations.

Let us now look at some Swiss precision files. As shown in Table 2, a wide variety of these files exist but the majority of them range in size from 2 to 6 inches in length and are very narrow. In some cases, they are only 1/4 inch wide and 1/16 inch thick. They are designed to work in very small areas to deburr small slots, holes, and hard to reach crevices. Figures 4 and 5 illustrate many of these precision Swiss files. As previously mentioned, escapement files are essentially square-handled versions of round-handled needle files. Escapement files and needle files are both Swiss files.

The Swiss precision rifflers are a unique series of essentially bent files. As shown in Figure 6, these take a wide variety of configurations. Any individual who has worked with wax carving tools will note that these are very similar to those tools in configuration but they have teeth on the ends rather than the smooth surfaces. Many of these are shaped like button hooks or trowels and some have gentle or sharp curves with needle or bayonet points. Some of them are extremely narrow and delicate while others are relatively heavy. Each has different profiles and contours. They range in lengths from 6 to 12 inches and have teeth as fine as a #6 cut. These tools are sometimes called die sinkers, rifflers, die maker's rifflers, silver smiths, or tool-maker's rifflers, because they were made and used by the craftsmen whose titles have just been indicated. Others are designed for pattern making in the mold industry or cabinet work.

Curved tooth or "vixen" files (Figure 7) have innumerable variations in the design, cut, form of the teeth, and the methods by which they are made. Every file producing country appears to have its own variety of these types of files. The main purpose of a curved form to the teeth is to provide a shearing cut, which means that instead of filings building up between the teeth, each tooth automatically clears itself as it cuts. This is very similar to the teeth of a milling cutter clearing themselves in a

Table 2. Types of Precision Files

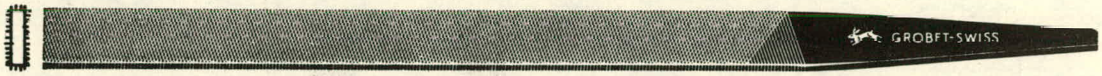
Type of File	Length (Inch)	Width (Inch)	Thickness (Inch)	See Figure
Hand or Pottance	2-10	9/32-1 1/32	5/64-9/32	
Pillar	2-10	3/16-45/64	5/64-15/64	
Narrow Pillar	2-10	1/8-25/64	5/64-13/64	
Extra Narrow Pillar	2-10	3/32-11/32	5/64-11/64	
Half-Round	2-10	5/32-1 1/32	1/16-5/16	
Half-Round Ring (High Back)	6	1/2	11/64	
Crossing	2-10	5/32-1 1/32	1/16-5/16	
Threesquare (Rectangular and Thin)	2-10	1/8-7/16 (thin) 1/8-5/8 (normal)		
Knife	2-10	3/16-63/64	1/16-13/64	
Round Edge	4		0.016-0.065	
Square Edgejoint	4			
Slitting	3-8	15/32-5/8	5/64-9/64	
Taper Flat	2-10	13/64-63/64	1/32-15/64	
Entering	2-10	13/64-63/64	1/32-15/64	
Warding	2-10	13/64-45/64	19G-12G*	
Equalling	2-6	1/4-1/2	0.24-0.79	5
Joint	4-6	7/16-9/16	0.180-0.048	5
Barrette	2-10	13/64-61/64	1/16-7/32	5
Cant (or Ridge Back Nicking)	3-8	11/32-23/32	3/32-5/32	5
Round (or Rat-Tail)	2-10	Dia (1/16-25/64		5
Parallel Round	2-10	Dia 1/16-25/64		5

Table 2 Continued. Types of Precision Files

Type of File	Length (Inch)	Width (Inch)	Thickness (Inch)	See Figure
Square Taper (Four sides cut)	2-10	Sq 1/16-25/64		
Square Taper	6	3/16		
Crochet (or Hook Files)	3-10	9/32-5/8	3/32-13/64	
Pippin	3-8	7/32-15/32	5/64-11/64	
Pivot	2-8	9/32-33/64	1/8-9/32	
Double-Ended Pivot File and Burnisher in Tube	7	17/64	1/8	
Screw Head	2-6	23/64-9/16	17-28*	4
Checking	6-8	1/2-29/32	5/32-3/16	4

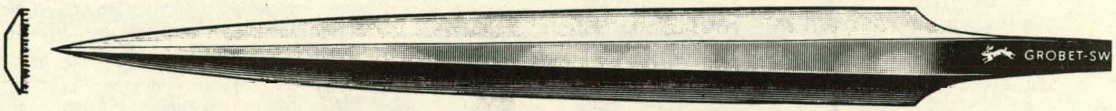
*Stubs iron wire gage size.

EQUALLING



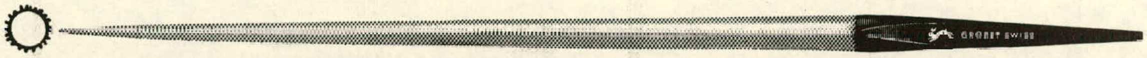
Parallel in width and thickness. Used primarily for filing slots and corners.

BARRETTE



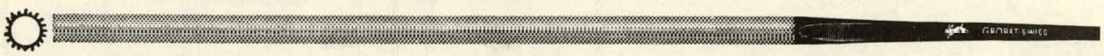
Cut flat side only. Tapered in width and thickness. Used mainly for removal of burrs from keyways, dovetail ways and similar sharp angled slots.

ROUND



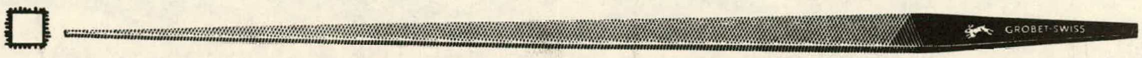
Gradually tapered. Cut and workable to the point. Used where it is necessary to enlarge a hole or round off a radius. Files with chisel cuts are used for rapid removal of material and etched cuts for fine finishing.

PARALLEL ROUND



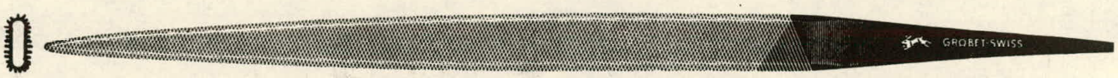
Cut over the entire surface. Chisel cut files for rapid removal of material and etched cuts for fine finishing.

SQUARE



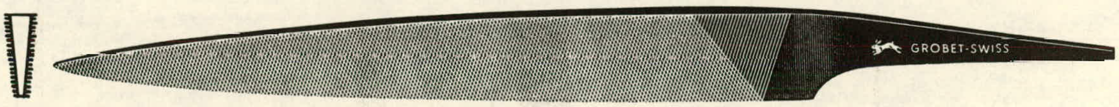
Gradually tapered and cut on four sides. Cut and useable to the point. A general purpose file.

CROCHET



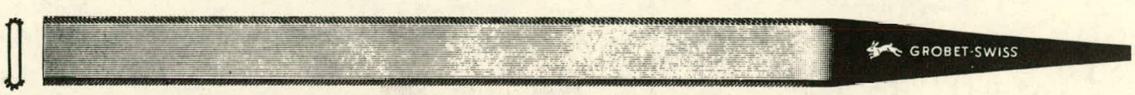
Tapered in width and gradually tapered in thickness. Used in filing junctions between a flat and curved surface. Useful in developing slots with rounded edges in prototypes where machinery set-up is too costly.

KNIFE



Tapered in width and thickness but the knife edge has the same thickness from point to shoulder. The included angle of the sharp edge is approximately 10°. Generally used to file in a slot or wedge shape opening. Curved knife edge allows for easy filing in restricted areas.

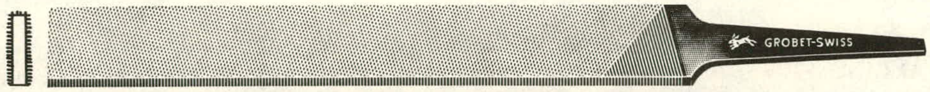
ROUND EDGE JOINT



Parallel in width and thickness, with rounded edges, these files are cut on the edges only. Used primarily to file slots and the bottom of grooves having rounded edges.

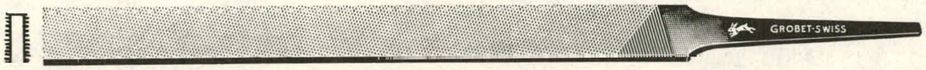
Figure 4. Swiss Files Used for Deburring

HAND



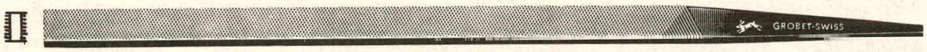
A general purpose file used primarily for working on flat surfaces. Finer cuts are used for precision finishing. Parallel in width. Tapered in thickness to make possible perfectly flat filing.

REGULAR PILLAR



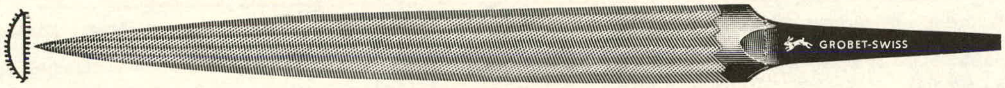
A general purpose file used primarily for working on flat surfaces. Because this group of files is available in various widths, they are adaptable for filing in slots, keyways, splines and similar applications. While parallel in width they are tapered in thickness to make possible perfectly flat filing.

NARROW PILLAR



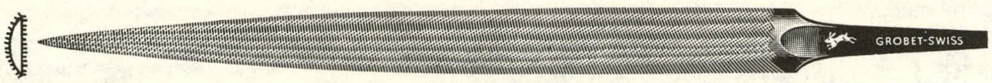
EXTRA NARROW PILLAR

HALF ROUND



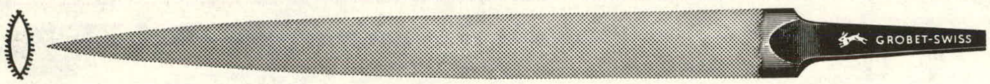
Primarily used for filing in curved surfaces and in corners. Gently tapered in width and thickness they are cut and useable right to the point. Chisel cut files are used for rapid removal of metal where contour and finish is not too important. Etched cuts are used where shape and finish must be held.

HALF ROUND SLIM OR RING



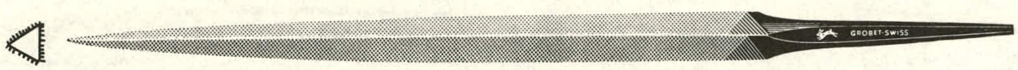
For applications similar to half round files. Thinner in width and tapered in both width and thickness. The half round side is on a smaller radius. Cut and useable up to the point. Half round files and half round slim files are the most versatile of files. They are found on almost every bench.

CROSSING



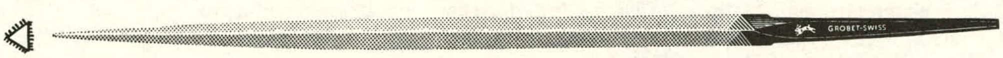
Half round on two sides with one side having a larger radius than the other. Tapered in width and thickness. Cut and useable to the point. Used primarily for filing interior curved surfaces such as in dies. The double radius makes possible the filing at the junction of two curved surfaces or a straight and a curved surface.

THREE SQUARE



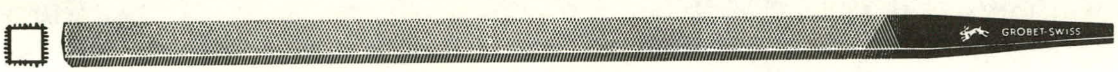
Gradually tapered and cut and workable right to the point. Primary use is in filing corners and edges such as in extrusion dies where sharp edges must be held.

THREE SQUARE SLIM



Same application and use as three square files except thinner tapered shape permits working in smaller areas.

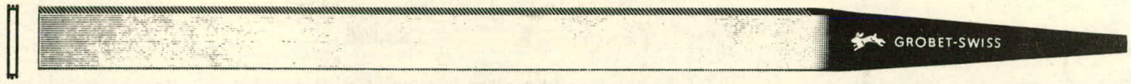
PARALLEL SQUARE



Parallel in width and thickness and cut on four sides. For general purpose use.

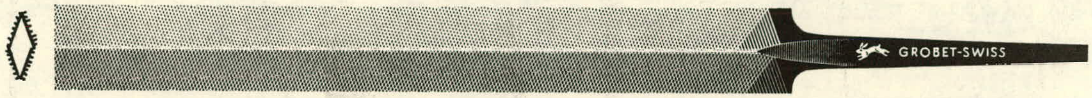
Figure 4 Continued. Swiss Files Used for Deburring

SQUARE EDGE JOINT



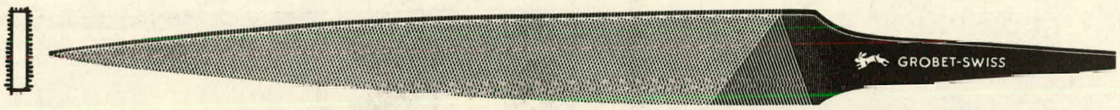
Parallel in width and thickness with square edges, these files are cut on edges only. Used primarily to file slots and the bottom of grooves having square edges.

SLITTING



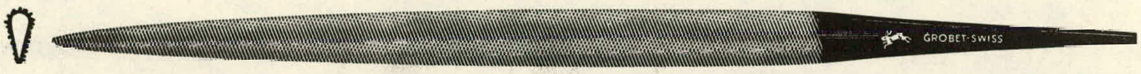
Parallel in width and thickness. While formerly used primarily for repairing and finishing gears their main use is now for fitting in slots too thin for knife files because of their finer edges.

WARDING



Parallel in thickness and tapered in width. Used for precision removal of burrs after milling operations on office machines and other similar parts. Standard sizes are made to close tolerances.

PIPPIN

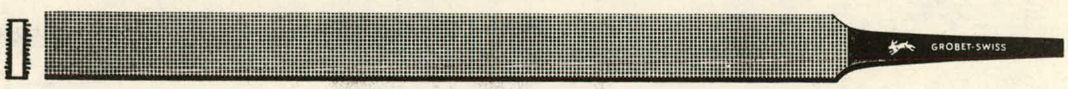


Tapered in width and thickness. Chisel cuts for use in rapid removal of material, etched cuts for fine finishing. Combines the cross sections of the round with the crossing file and having the edge of a knife file for finishing the junction of two different curved surfaces and for opening slots when a "V" shape is required.

SCREW HEAD

Available in thickness ranging from No. 1 (thickest) to No. 8 (thinnest). Unless otherwise specified, No. 4 thickness will be furnished. Used for repairing the heads of screws and filing in fine slots. All files are supplied in the same cut.

CHECKERING



Parallel in width and gently tapered in thickness. Overcut is made parallel to file edges and up cut is made at 90° to overcut. Used by cutlers to put serrations on the edge of knives after regrinding and by gunsmiths to put a checkered area on a gun to make a firm hand grip. Also made in the form of a riffler for working in smaller areas. Grobet-Swiss Checkering Rifflers are available only through gunsmith supply houses.

Figure 4 Continued. Swiss Files Used for Deburring

Used in fine watchmaking, in finishing fine extrusion dies and for fine jewelry repair work and other similar work. Available in a wide assortment of shapes and cuts.

Length of cut varies according to shape from 1 9/16" to 2 9/16", overall length 5½", weight per dozen ¼ lb.

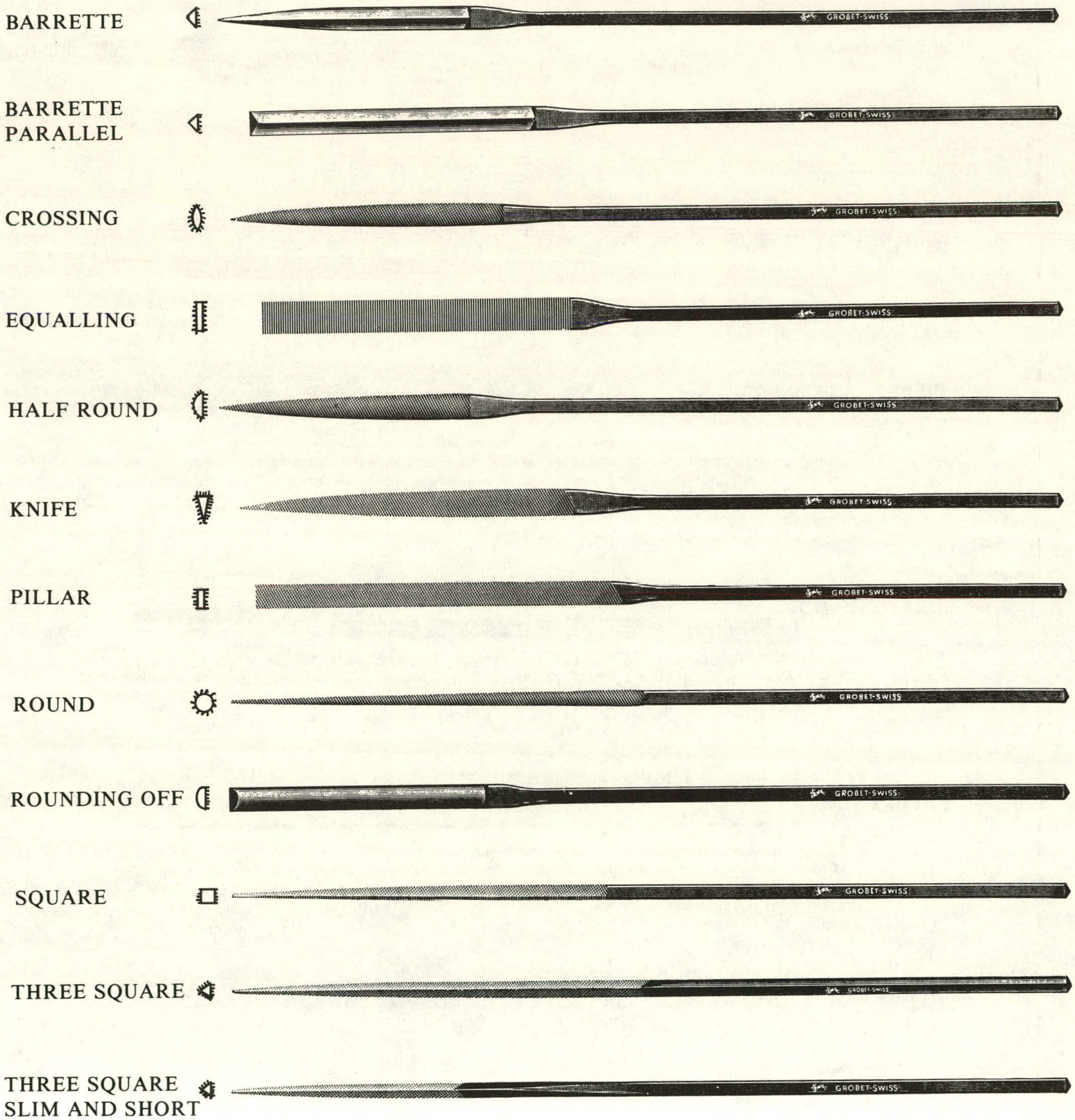


Figure 5. Escapement Files (Square Handle Needle Files)

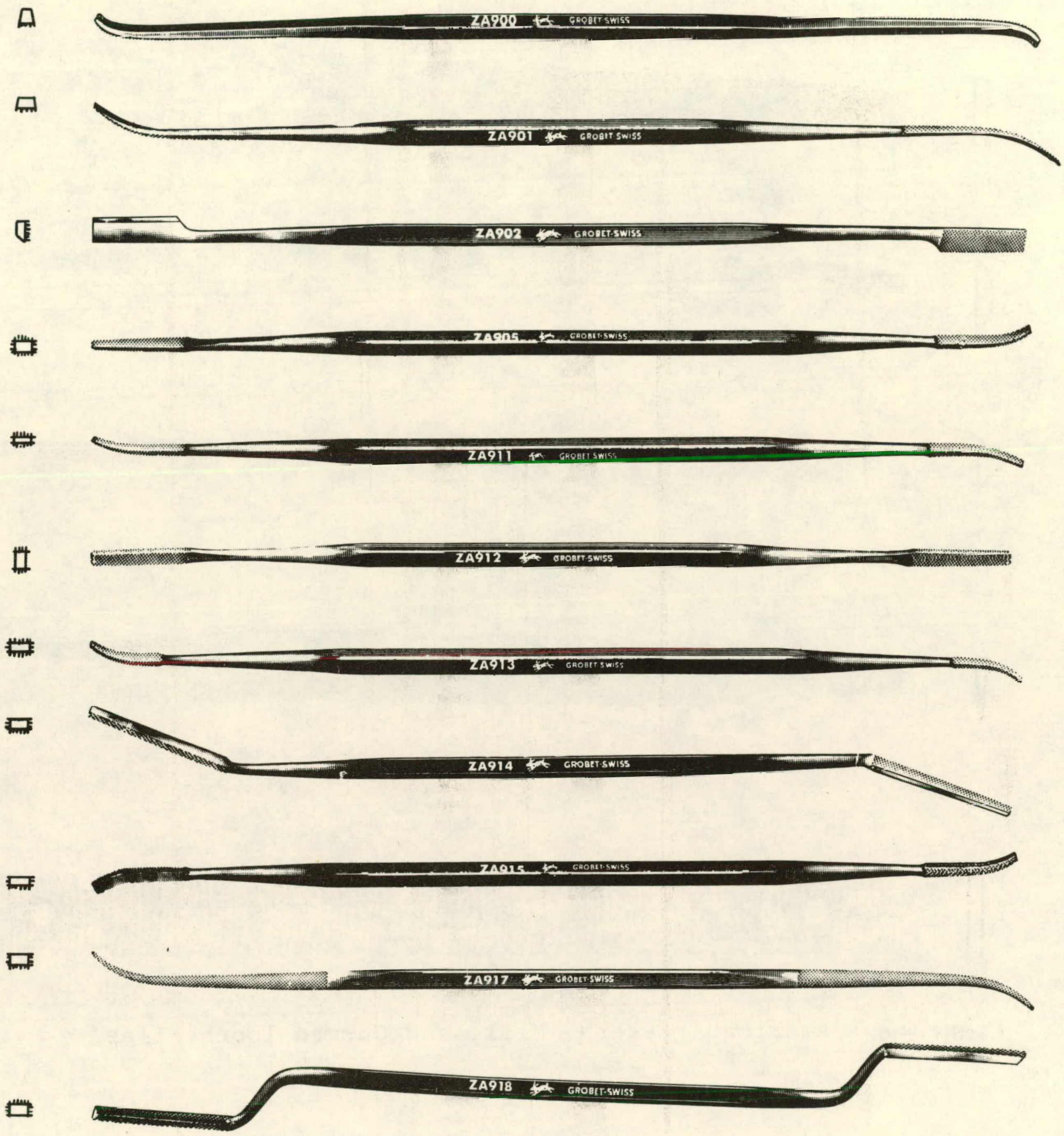


Figure 6. Die Sinkers' Regular Riffles

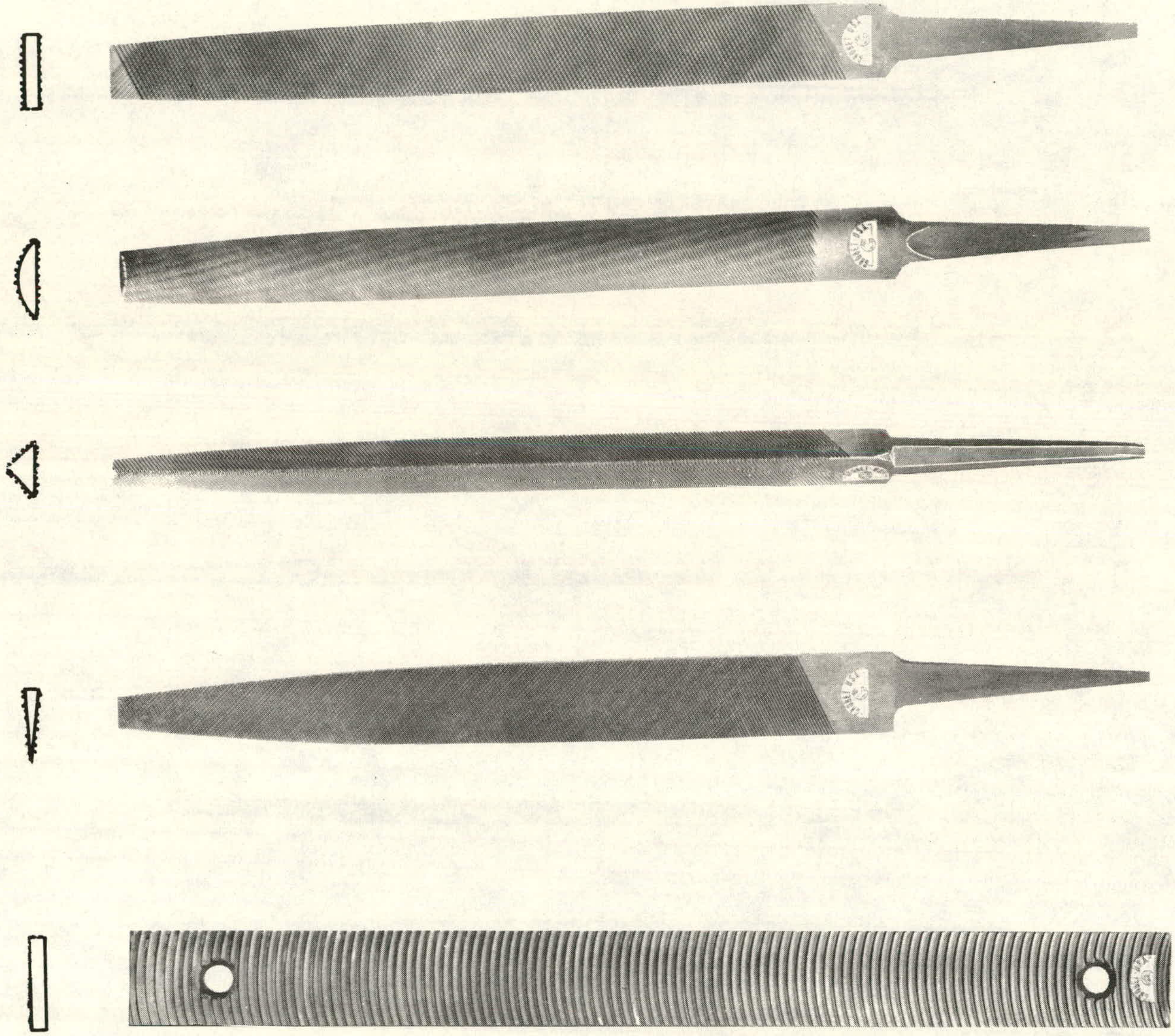


Figure 7. American Pattern, Mill, and Curved Tooth Files

machining operation. In general, the radius of the arcs made by the teeth will be nearly equal to the width of the file.

The curved tooth file is generally used on soft materials, such as wrought iron, low-carbon steel, brass, and aluminum. These tools are also used for fibrous or tough materials.

The "Millenicut" file initially produced in England has a pronounced undercut and intermittent interruptions in each file tooth. The teeth may be clean and unnotched or they may have wavy interruptions (Figure 8). These tools do not clog when used on such soft materials as mentioned above. They are particularly suitable for filing stainless steel, tough alloy steels, copper, brass, and aluminum.

A number of files today are made in an entirely different manner than the normal steel types of files. These files use particles of tungsten carbide, Borazon, or diamond, plated onto a smooth surface. The shapes of these files are the same as the other Swiss files which have previously been discussed. The advantage of these files are that they are relatively inexpensive, long lasting and can be applied to any basic shape which is desired. An additional advantage is that any grit size can be plated onto these files. As an example, for the file shown in Figure 9, grit sizes of 100-150 microns, 140-200 grit (100 micron), or 270-325 grit (50 micron) can be obtained. Other sizes could also be purchased if needed. In many cases since these files are harder than conventional steel files, they will last considerably longer and for this reason are more economical in many applications. For those files which can be placed in a reciprocating motorized file, these plated files can be used at faster speeds and higher temperatures than steel files.

There is one category of file which is not normally called by the nomenclature of "file." Electrical contact cleaners are essentially a very fine grit file. To the fingernail they are entirely smooth and yet there is enough roughness that they will remove oxide surfaces from between electrical contacts. For a few miniature parts, these electrical contact files are used to provide an extremely fine finish which will not exceed a critical edge break. These files can be obtained in thicknesses as small

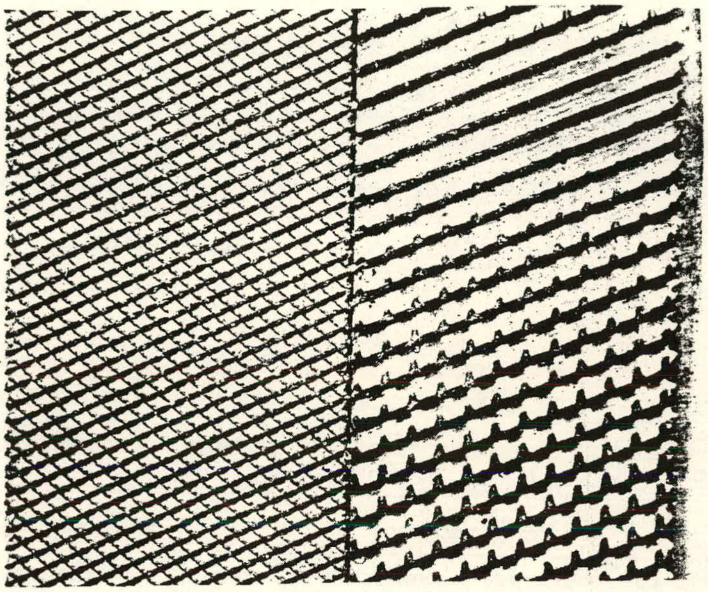
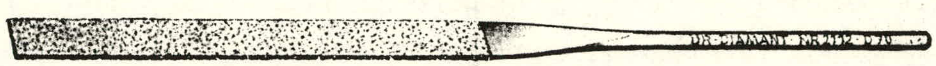


Figure 8. Millenicut File

DIAMOND NEEDLE FILES can be used on carbide, hardened steel, and ceramics. They are made with a hard chrome bond that gives a long life and wears extremely well. They are available in three grits 200/240 which is the fine grit, 120/160 medium, and 80/100 coarse.



Total length 5.5118", diamond-impregnated length 2.7559"

Figure 9. Diamond-Plated File

as 0.008 inches. Despite the fact they are not called files, they are used in such a manner they should be considered as another variation in commercially available files.

SELECTING AND USING FILES

Because of the wide variety of files which can be purchased and found in many tool cribs, it is difficult to define the proper file for each job. While the illustrations in this chapter provide some basic guidelines into usage, each individual will have to develop his own storehouse of knowledge in the selection of use of these tools.

There is more to file selection than just finding a suitable shape. The type and form of material to be finished is one determining factor; the coarseness of cut to be used is another. In general, for rapid removal of stock, a coarse #0 cut might be indicated, while working on narrow surfaces requires a #2 cut file. The final finishing on precision miniature parts might call for a #4 or #6 file. Table 3 provides a general guideline to potential uses of each file, and Table 4 lists properties of those most commonly used on precision miniature parts. It is, however, only a general guideline. Both supervisors and process engineers will assist in obtaining appropriate files if they are not already available or if there is some difficulty in their use. Whenever one finds potential application for a file which is not already available in the Bendix tool cribs, it should brought to the attention of the appropriate supervisor and/or process engineer.

MATERIALS USED IN FILES

Typical Swiss precision files are made from the tough, chrome alloy steel. These files are heat treated to provide the necessary hardness and both the material used and the heat treatment can dramatically influence the life and usefulness of many of these files. Not all Swiss files are made from the same alloy, however.

Table 3. Selection of Appropriate File

Name	Basic Application
Hand	Flat Surfaces
Pillar	Flat Surfaces; Slots
Half Round	Curved Surfaces; Corners; Holes
Crossing	Curved Surfaces; Junctures of Curved and Flat Surfaces; Corners; Holes
Three Square	Corners; Holes; Edges
Knife	Slots; Wedge Shaped Openings
Sitting	Corners; Slots
Warding	Slots
Equalling	Corners; Slots
Joint	Edges; Joints
Barrette	Flat Surfaces; Corners; Keyways; Dovetail Ways; Gear Teeth; Deburring
Cant	Corners
Round	Rounded Inside Corners; Holes
Square	Corners; Holes
Crochet	Rounded Corners; Slots; Flat Surfaces Junctures between Carved and Flat Surfaces
Pippin	Rounded Corners; Holes; "V" Slots
Checkering	Roughening Surfaces For Hand Grips, etc.
Screw Head	Slots

It is possible that some manufacturers use materials which are less conducive to long life. A few are highly susceptible to moisture and will rust immediately upon contact with moisture.

Table 4. Typical Swiss Files Used on Precision Miniature Parts

Bendix Code Number	Description	Cut Number	Smallest Thickness (Inch)
52506190	Screw Head File	8	0.014
52506195	Screw Head File	8	0.024
52506205	Screw Head File	8	0.036
52506208	Narrow Pillar	4	0.070
52506215	Equalling	2	0.014
52506216	Equalling	0	0.014
52506217	Equalling	2	0.018
52506218	Equalling	0	0.018
52506220	Equalling	4	0.029
52506222	Equalling	6	0.041
52508050	Round Needle	0	0.032
52509000	Square Edge Joint	2	0.028
52509629	Pattern Pillar	6	0.076
52510000	Set Needle/Jewelers	4	Varies
52510001	Square Needle	4	0.025
52510003	Set Needle	2	Varies
52510004	Set Needle	0	Varies
52510005	3 Square Needles	2	0.019
52510006	Square Needle	2	0.024
5251007	Barrette	2	0.028
52510010	Equalling	4	0.050
52510011	Equalling	6	
52510045	Pillar Escapement	4	0.041
52510050	Knife	8	0.036
52510055	Pillar	8	0.035
52510060	Half Round	8	0.020
52510062	Round Escapement	8	0.018

TECHNIQUES FOR USING FILES

The use of files (particularly larger ones), is something of an art in itself. There is little published information on the use of the precision miniature files. However, there are some basic criteria to be considered:

- The work piece must be properly supported,
- The file must be held correctly,
- The proper pressure must be used,
- The file must be cleaned, and
- The correct cut and size of the file must be used.

In contrast to the use of knives, typically the workpiece is held against a solid surface with one hand and a precision file used with the other. On small parts it may be necessary to hold the part in the jaws of a vise, or some other device which is covered with soft material, to prevent marring of the work piece.

While there are four basic types of filing operations, only the use of precision files will be discussed. In this type of filing, the small files are held in much the same manner as a pen or pencil. Only enough pressure should be applied on the file during its forward motion to keep it cutting throughout its entire stroke. The file should be lifted during the return stroke. Too little pressure on the cutting stroke especially when working with tool and chrome alloy steels will quickly dull the teeth of the file. Similarly, too much pressure will result in excess metal being removed and will cause the teeth of the file to become filled with small chips. This will prevent effective cutting. As noted elsewhere,[1]

> "Filing should always be carried out on the forward, never on the backward, stroke. No saw user would

ever dream of running a circular saw backwards and expecting efficient cutting to result. In precisely the same way it is absurd to assume that a file will cut efficiently on the return stroke. The reason so many continually file both ways is probably that the large number of teeth to the inch on a file appear to render damage to a few of them insignificant. This, however, is a fallacy. Every tooth is of value and importance to the work.

Although all filing should be carried out on the forward stroke, it is not necessary to lift the file entirely off the work during the return stroke, except when special files are used. The point to be noted is that no pressure must be exerted on the backward movement. The best results from the forward stroke will be obtained by giving the file a slight sideways motion, alternating to right and left with every few strokes. Narrow surfaces should be filed in the direction of their length, i.e. not across. Sharp edges should not be filed with an upward stroke. Single-cut files are best for very thin work as their teeth are stronger and less likely to break than those of the double-cut file, and they also cut more smoothly on this type of work."

Frequently, the inexperienced file user employs a file too large or too small for the work he wishes to do. For example, one will use a single file and do all deburring when a faster and more efficient method would be to use a coarse one first, followed by a smoother one. This enables one to remove the metal quickly and yet provide a good finish on the work piece.

New files should not have too much pressure exerted on them on each stroke or some of the teeth may break off at the base. The proper method is to work lightly, preferably on brass or bronze until the fine tooth points are slightly worn, then employ more pressure as the teeth become blunter.

The file used for iron or steel is often not suitable for brass. In filing steel, it is better to use second cut files than those with coarser teeth.

A sharper file is needed for the non-fibrous metals, such as brass, copper, aluminum, zinc, and cast iron, than for wrought iron or hard steel. A sharper file is also needed for a broad surface than for a narrow one. There are also files specifically for working on such plastic type materials such as vulcanite or bakelite. When filing aluminum better results may be obtained using a lubricant such as lard oil. While this may not be feasible on miniature parts, it is on hand size parts.

Some file users have noted that filing crosswise to the direction in which steel has been rolled is more effective than other directions.

CLEANING AND CARE OF FILES

Precision Swiss files are, as the name implies, precision tools which must be cared for. It is easy with the use of such tools for metal chips to clog the spaces between the teeth. When this happens, effective cutting is prevented and this clogging or "pinning" will leave deep scratches in the work piece. If this pinning cannot be avoided, it can at least be lessened by thorough cleaning of the file at frequent intervals.

In some cases, the file may be cleaned by gently rapping the edge of the file against a hard surface. If this is not effective, one may use a fine wire brush or a file card (Figure 10). For working on wrought iron and steel, a soft iron or copper "scorer" may be used. For filing aluminum, one may need to use turpentine or paraffin on file surfaces to prevent this pinning. When the files are clogged with dirt and grease, either a wire brush or an ultrasonic cleaning treatment may be necessary. If ultrasonic cleaning is used, however, it is important that water not be left on any surfaces as it will rust the tools and completely erode many of the teeth.

If files come in contact with magnets the file will become magnitized. This will cause many of the chips to remain in the spaces between the teeth. As a result the file may not be usable until demagnitized.

For prolonged life, particularly in coarser cut files, do not merely toss them into a drawer or pile them on the back of a bench since treatment will damage teeth and in many cases, allow the files to rust. If a file becomes rusty, the teeth are being eaten up and will crumble away into a fine dust.

SPECIFIC APPROACHES IN FILING

There are a number of approaches that can used to modify files or select them for appropriate tasks. As an example, a file only 0.014 inch thick cannot be used in a slot which is only 0.010 inch thick. Steel files, however, can be readily electropolished or chemically polished to reduce the size of the files and still maintain most of the sharpness of the teeth. These operations can be accomplished in only a minute or two per file, if necessary. There are a number of companies that resharpen used files.

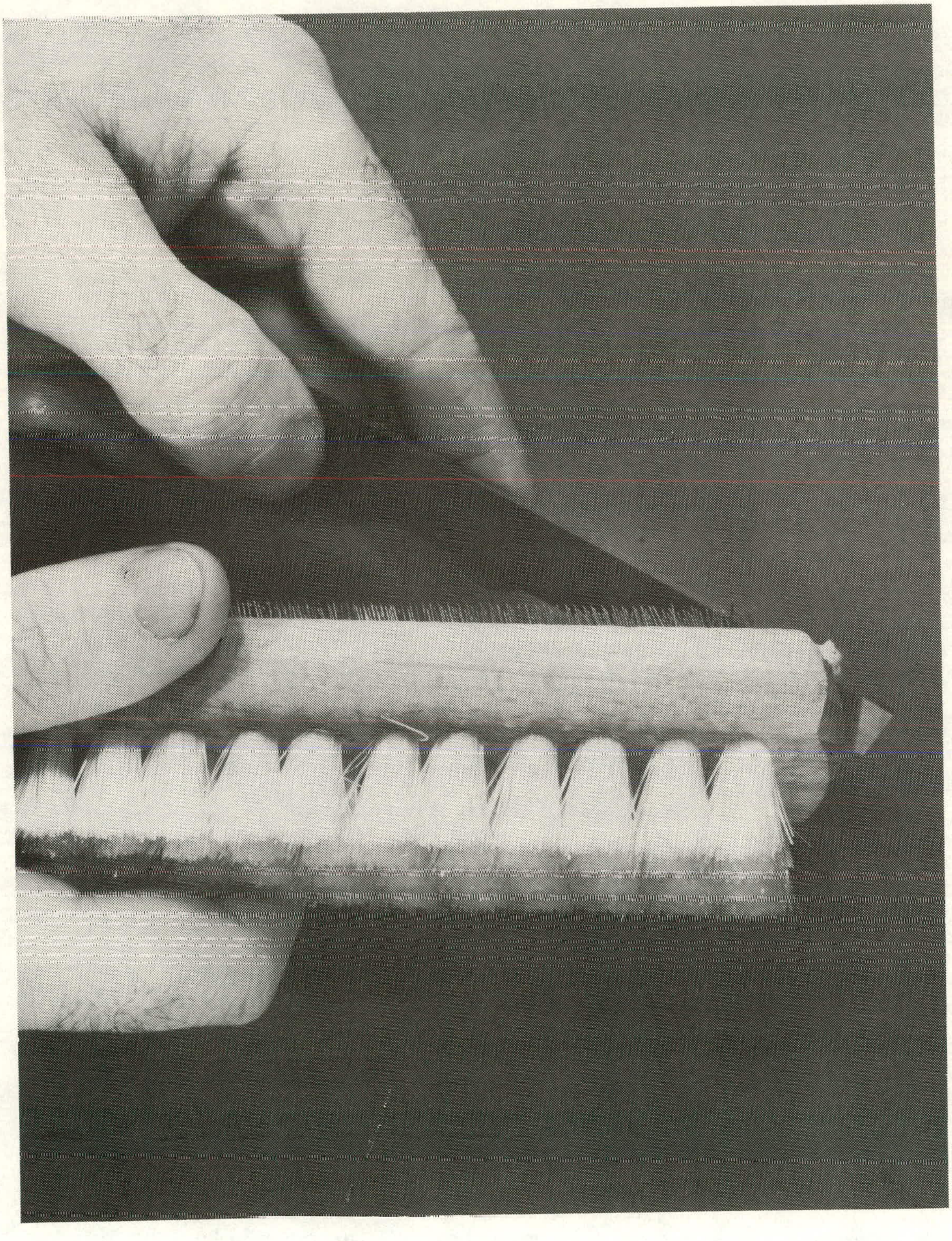


Figure 10. Cleaning a File with a File Card

In some applications, the finishing of high nickel aerospace materials, files work extremely fast. Some companies have found that applying a thin chrome flash plating before use will extend the life of these files by three or four times.

While the thrust of this section is primarily on handheld file usage, many of the files discussed are commonly being used in reciprocating motorized handheld machines. These handheld reciprocating files greatly speed the finishing task that uses the very same tools one would use by hand. Both the plated files and the steel files are available for use with such equipment. It should be noted, however, that for general use on precision miniature parts at Bendix, these motorized files are not generally recommended.

SOURCES OF ADDITIONAL INFORMATION

There are a few publications which describe information for selecting files:

1. Eric N. Simons, Steel Files, Pitman and Sons, Ltd., London, 1947.

2. "Files," Grobet Catalog #56C, Grobet File Company of America, Inc., Carlstadt, New Jersey, 1977.

The following glossary of Swiss file terminology may also prove useful for those wishing to further study or select appropriate files. This glossary is reproduced from Reference 2.

ASSIGNMENT

1. Deburr the edges of the sample provided using only a file having a #0 cut. Provide no more than a 0.010 inch edge break.

2. Deburr the edge of the sample provided using only a file having a #2 cut. Provide no more than 0.010 inch edge break.

3. Deburr the edges of the sample provided using only a file having a #6 cut. Provide no more than a 0.005 inch edge break.

4. Deburr the edge of the sample provided using a file having a #8 cut. Provide no more than a 0.003 inch edge break. Use only the file indicated for deburring these samples (i.e., do not also subsequently use sandpaper, abrasive filled products, etc.).

5. What type of file would deburr the bottom of a round-bottom slot?

6. What file would deburr the bottom of a flat bottomed slot?

7. What files might deburr slots only 0.030 inches thick?

8. Where would Swiss riffler files be used?

9. Use one of the abrasive plated files provided and provide no more than 0.005 inch edge break of the samples provided.

10. Using the reciprocating motorized file provided, finish all edges on the sample provided. Use only the file provided in this assignment.

11. Using a #6 Swiss file, deburr the sample provided after the file has been magnitized.

GLOSSARY OF SWISS FILE TERMS

AURIFORM FILE A die sinkers' file having a cross section that combines 1/2 of a pippin file with 1/2 of a crossing file.

BACK In a half round, barrette, cant, or files of similar cross section, this is the convex side.

BARRETTE FILE Cut on wide nat face and safe on sides and back. Tapered in width and thickness.

BENCH FILING MACHINE FILE Parallel files of various cross sections for use in filing machines.

BLANK A steel forging from which a file is made. The basic shape of a file before teeth are cut or etched.

CANT FILE Triangular in cross section with one side wider than the other two. Cut on three sides and tapered.

CHECKERING FILE Rectangular in cross section and parallel in width and thickness. Teeth cut at 90° angle with edge. Safe on edges.

CHISEL CUT A method of cutting teeth into the surface of an annealed file blank by striking it with a series of repeated blows as the blank is moved beneath a chisel at a uniform speed. In the cutting operation, the chisel is placed obliquely to the length and is inclined to the surface of the file. This is done either by hand or machine. Generally used to produce files of No. 2 cut and coarser.

CROCHET FILE Rectangular in cross section with rounded edges. Cut on both faces and edges. Tapered in length and slightly tapered in thickness.

CROSSING FILE Oval cross section with same radius as half round files on one side and other side curved to a larger radius. Cut on both sides. Tapered in width and thickness.

CUT The number of teeth per inch, the degree of coarseness of a file's teeth, from No. 00 to No. 8 in Swiss precision files. Also used to describe the type of file such as single cut or double cut etc.

DIE MAKERS' RIFFLERS Various cross sectional shapes. Teeth cut on a small area of each end leaving a long middle portion as a handle. The cut ends are of various designs. Length is overall. Originally designed and hand forged by die makers for their specific purposes now a generic term for this particular group of rifflers.

DIE SINKERS' FILES See Die Makers' Rifflers. This group of rifflers has smaller cross sectional shapes.

DOUBLE CUT The arrangement of file teeth formed by two series of cuts. The first is the overcut which is followed by the upcut at an angle to the overcut.

EDGE The narrow cross section or side of a file.

EQUALLING FILE Thin rectangular cross section, parallel in width and thickness and cut on both faces and edges.

ESCAPEMENT FILE Also called Square Handled Needle Files. A group of files of various cross sectional shapes with a length of cut varying from 3/4 to 2 1/2" and long square handles. Widely used by jewelers, watch makers, die makers, and fine mechanics.

ETCHED CUT A method of cutting teeth into the surface of a file blank by drawing an etching tool, under sustained pressure, obliquely across an annealed file blank in a series of cuts. This may be done either by hand or machine. This method of cutting is used where it is necessary to retain the true cross section of a file. Generally used to manufacture files finer than a No. 2 cut.

FACE The working surface of a file upon which teeth are cut.

FILING BLOCK A block of wood, soft metal or other material used to protect the material being filed from damage from the jaws of a vise of other holding device. It may contain a series of grooves to hold work securely.

FLAT FILE Also called a Warding File. A form of escapement or square handled needle file. Parallel in thickness. Cut on four sides, tapered in width.

HANDLE A wood or plastic piece that is placed over the tang of a file to protect the hand of the user.

HALF ROUND FILE A cross section that is flat on one side and has a radius (not half circle) on the other side. Cut on both sides. Width and thickness taper.

HALF ROUND SLIM FILE Also called Ring Files. Same as half round except thinner in width.

HEEL The end of the file at a location where the body ends and the taper leading into the tang begins. Also called the shoulder.

JOINT FILE, ROUND EDGE Rectangular cross section with rounded edges. Cut on edges only. Parallel in width and thickness.

JOINT FILE, SQUARE EDGE Rectangular cross section. Cut on edges only. Parallel in thickness and width.

KNIFE FILE Knife shaped cross section that is tapered in width and thickness. Edge has same thickness from point to shoulder.

LENGTH OF CUT The length of a file measured between the shoulder or heel and the point.

LOZENGE FILE Diamond shaped cross section parallel in width and thickness.

MACHINE FILE A file made specifically for use in a filing machine. Various cross sectional shapes. Parallel in width and thickness.

NEEDLE FILE SQUARE HANDLED Also called an escapement file. A group of files of various cross sectional shapes with a length of cut varying between 3/4" and 2 1/2" and long square handle.

NEEDLE FILE, ROUND HANDLED A group of files of various cross sections with a knurled round handle. Knurling gives the file a positive, non-slip grip for precision filing.

OVAL FILE An oval cross section tapering in width and thickness.

OVERCUT The first of a series of cuts in a double cut file. Its function is to act as a chip breaker. The second or upcut is made over this cut.

PARALLEL MACHINE FILE A group of parallel files of varying cross sectional shapes made specifically for use in reciprocating filing machines.

PARALLEL ROUND FILE A round cross section parallel in width.

PARALLEL SQUARE FILE A square cross section parallel in width and thickness.

PILLAR FILE A rectangular cross section with thickness greater relative to width, than in other types. Cut on face or flat sides only. Parallel in width, tapered in thickness. Also demi-narrow, narrow and extra narrow widths.

PIN OR PINNING The tendency of small particles of materials to fill or clog the gullets between the teeth of a file. When the teeth become clogged the file causes scratches on the work. When this occurs, the file is pinned.

PIPPIN FILE A section that combines the cross section of a round file with that of an equalling file. Tapered in thickness and width.

POINT The front end of a file as contrasted with the tang end.

POINTED BACK BARRETTE FILE A triangular cross section with one side wider than the other two wides out on wide or face side only tapered in width and length.

RASP CUT A cut used on wood rifflers that is made by a punch raising a series of individual cutting teeth.

RIFFLERS From the German riefeln, to channel, chaufer, flute or groove. Originally used and hand forged by die sinkers, die makers, silversmiths and other skilled artisans in shapes and cross sections appropriate to their work. Teeth are cut on small areas on each end that can be shaped like everything from trowels to button hooks. A long middle portion serves as a handle.

RING FILE Also called a half round slim file.

ROUND FILE Round in cross section tapered in width.

ROUNDING OFF FILE An escapement or square handle needle file half round in cross section. Cut on flat side. Parallel in width.

SAFE The side or edge of a file that has no teeth cut in it so as not to mar a work surface that does not require filing.

SCREW HEAD FILE A narrow diamond shaped section with short bevels to form sharp edges. Cut on beveled edges, safe on flat sides. Parallel in width and thickness.

SECTION The cross section or end view of a file if it were cut squarely at the place of greatest width and thickness from the tang.

SILVERSMITH'S RIFFLERS A group of various cross sectioned shapes originally designed for use by silversmiths. Teeth are cut on small areas of each and leaving a long middle portion as a handle. The cut ends are of varied designs.

SINGLE CUT The teeth formed on a file by a single series of cuts.

SLITTING FILE A flat diamond shaped cross section. Cut on all sides. Parallel in width and thickness.

SQUARE FILE Square in cross section. Cut on all sides. Tapered.

SWISS PATTERN FILES Files made to the same shape and cut as the files originated by F. L. Grobet in Switzerland over 150 years ago. Made in cuts from No. 00 to No. 6.

SWISS PRECISION FILES The original Grobet-Swiss files made in hundreds of sizes and shapes and in cuts from No. 00 to No. 8. Made to exacting measurements and very fine cuts.

TANG The Part of the file that tapers from the shoulder that is intended to be fitted with a handle.

THREE SQUARE FILES Equilaterally triangular in cross section. Cut on all sides with sharp corners. Tapered.

TOOL MAKERS' RIFFLERS Various cross sectional shapes with teeth cut on a small area at each end leaving a long middle portion as a handle. The cut ends are of various designs to meet the needs of tool makers.

UPCUT The second series of teeth cut in double cut files made over the first series of cuts called the overcut. This cut is made of an angle to the overcut.

WARDING FILE A rectangular cross section with teeth cut on all sides up to 4" in length and on 3 sides with one safe edge on files 6" and longer. Tapered in width, parallel in thickness.

WOOD RIFFLERS Various cross sectional shapes cut with rasp teeth on both ends leaving a long middle portion as a handle. Used by cabinet makers and pattern makers.

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CHAPTER 20

ROTARY BURS AND COUNTERSINK TOOLS

A frequently used type of deburring tool is known as a rotary bur. These tools can be used for edges, holes, hard-to-reach areas, and for a variety of applications other than deburring. Their principal advantage is that they leave a smooth edge and, in many cases, an edge more burr-free than that left by a knife. They are designed to be used, in many cases, in a power tool such as an air motor, although for precision miniature parts which require small edge breaks, they must be used in a handheld pin vise.

DEFINITIONS OF ROTARY BUR AND COUNTERSINK TOOLS

One of the first observations an individual may make in this chapter is the spelling of the word "bur." While there is not total uniformity in the printed literature, the majority of manufacturers use the spelling "bur" to indicate the tool to remove "burrs." It becomes confusing in reading the literature if one uses a "burr" to remove a "burr." For this reason we will stick with the most widely used nomenclature and refer to "bur" as a tool which is often used in removing a "burr."

These tools have a variety of names more specific than just "bur" as shown in Table 1. As seen there, in addition to being known as burs, they are also called rotary files, mills, cutters, and combinations of these and many other names.

As seen in Figure 1, one of the principal differences between a bur and a conventional countersink or similar cutter is that a bur has a relatively large number of very small teeth. In many

Table 1. Nomenclature Used for Rotary Burs

Disc Cutters	Finish Mills	Burs
Rotary Cutters	Die Mills	Rotary Burs
Deburring Cutters	Lab Mills	Midget Burs
Microcenter Reamers	Surgical Mills	Midget Rotary Burs
Routers	Chamfering Mills	
Rotary Files	Edging Mills	
	Grinding Mills	

cases, there will be 2 to 5 times as many teeth on a rotary bur as there will be on a countersink tool. It is these many small teeth which give the bur its smooth finishing action. The small teeth prevent excessive cutting into the edges and reduce the chatter which in turn improves surface finish. These tools can be used at very high cutting speeds which also increase the amount of edges which can be finished in a given time.

VARIETY OF SHAPES AVAILABLE

Burs and related tools can be purchased in a wide variety of diameters, shapes, tooth coarsenesses, and materials (Figure 2). One company alone lists 1028 different burs and rotary files in its catalog. Although bur balls are the most frequently used of these tools, pointed cones and flame-like shapes are also in frequent use.

It is possible to draw distinctions between two types of burs. Commercial burs are typically relatively large, for example, two inches in diameter. Dental burs are normally very small. They are used in the dental industry to reach into mouths and work in and around teeth. These distinctions are not hard and fast and

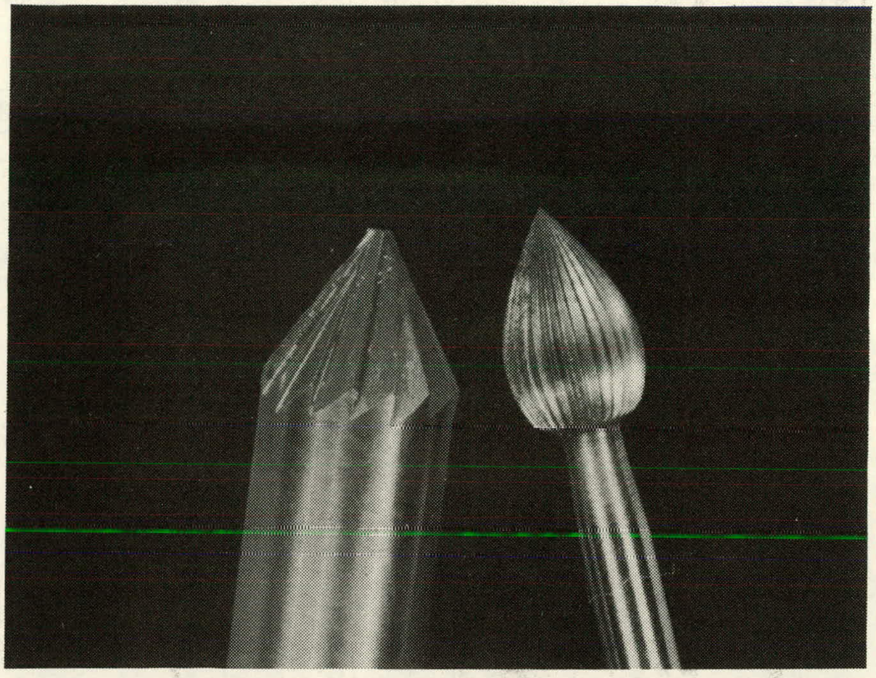


Figure 1. Comparison Between a Countersink Tool and a Rotary Bur

in many catalogs these tools are often intermixed or not specifically identified by typical usage. Miniature bur balls which are only 0.004 inch in diameter can be purchased. The smallest standard ball diameter, however, is 0.020 inch (Figure 3).

VARIETY OF TOOTH PATTERNS AVAILABLE

Just as there is a wide variety of sizes and shapes of rotary burs, there is a wide variety in the configurations of the teeth found on these burs:

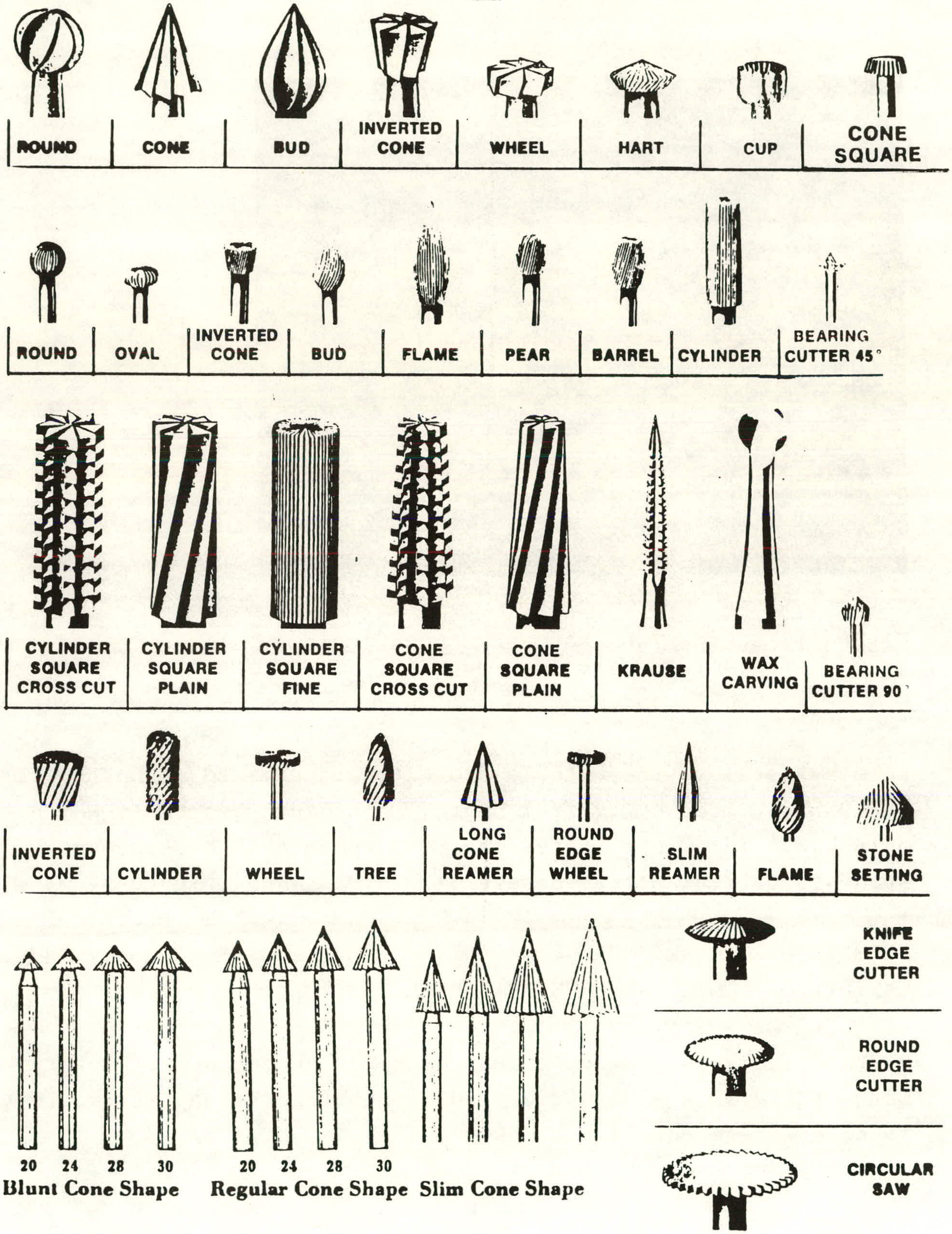


Figure 2. Common Shapes of Burs

- The fineness of cut,
- The way the teeth were produced,
- The angles of cut,
- The rake angle on the teeth, and
- The basic tooth shape.

As an example of the fineness of cut, Figure 4 illustrates one of the commonly used ranges of fineness of cut. Note that the number 1 cut in this instance has 62 teeth per inch. The coarse number 14 cut has only 5 teeth per inch. In many instances, the manufacturers do not describe the number of teeth per inch but merely designate "fine" or "finish" cut versus "normal" or "coarse" cut. "Fine," however, often does not imply the same cut if manufactured by different companies. In many cases, "Fine" for one type of bur is not the same fineness of cut as fine for another shape or style even when made by the same manufacturer. A number of manufacturers also will provide special fluting or fineness of cut for specific applications. Figure 5 illustrates that the angle of cut can also be varied on these tools.

Figure 6 illustrates what is known as the rake angle on teeth. As seen there, radial cut teeth have a leading edge which is the extension of a straight line passing through the center of the cutter. Positive cut teeth have a very small included angle at the tips. Positive cut teeth are very similar to the teeth found on the cutters of a radial arm saw or a table saw. Negative cut teeth have a very large included angle. This provides a stronger tooth but also increases the amount of force required to cut metal. Figure 7 illustrates some of the basic styles of cuts available. The following six are standard configurations which are ground into the tool:

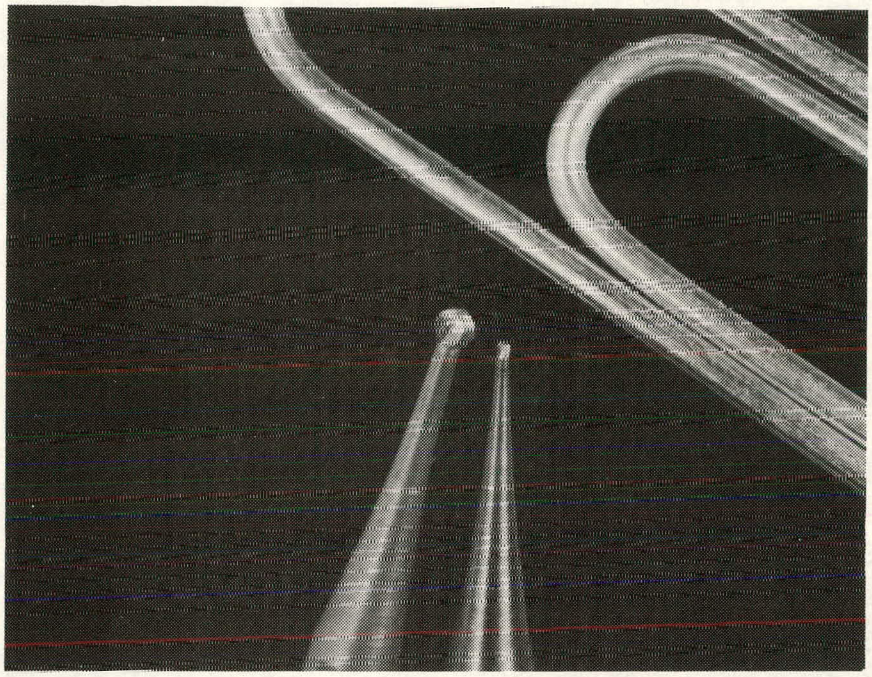


Figure 3. Two of the Smallest Standard Bur Balls

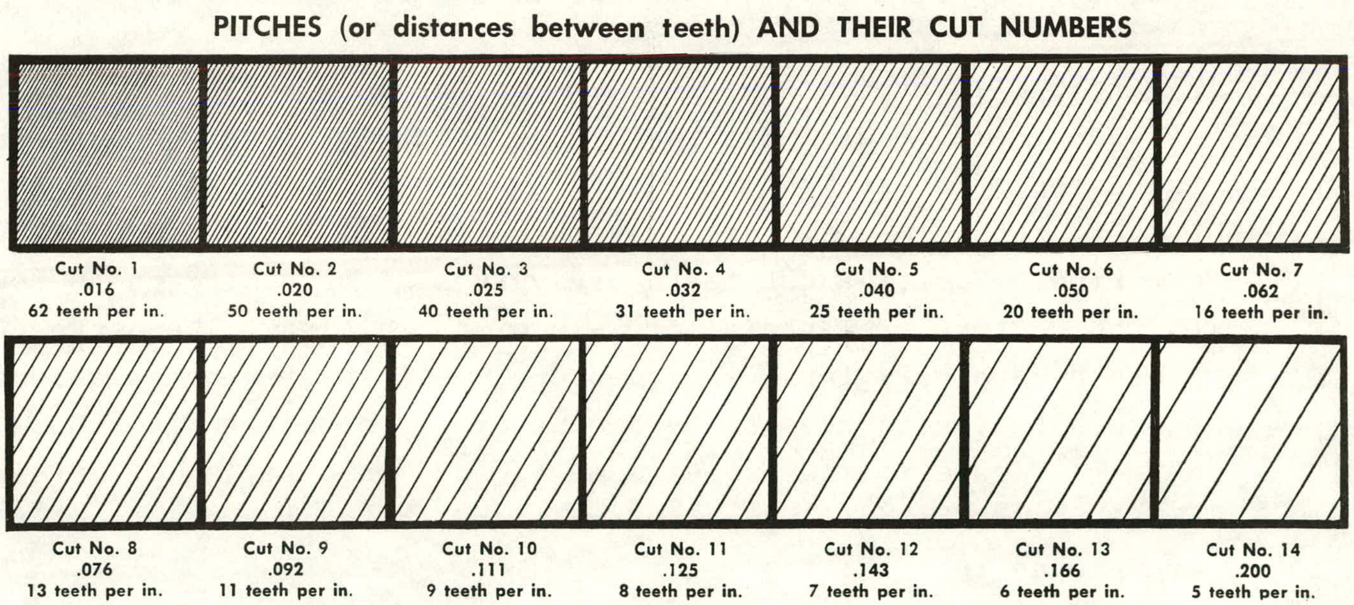


Figure 4. Standard Cut Sizes for Rotary Industrial Burs

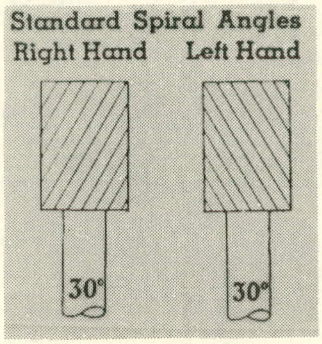


Figure 5. Helix Angle Variations
Found on Rotary Burs

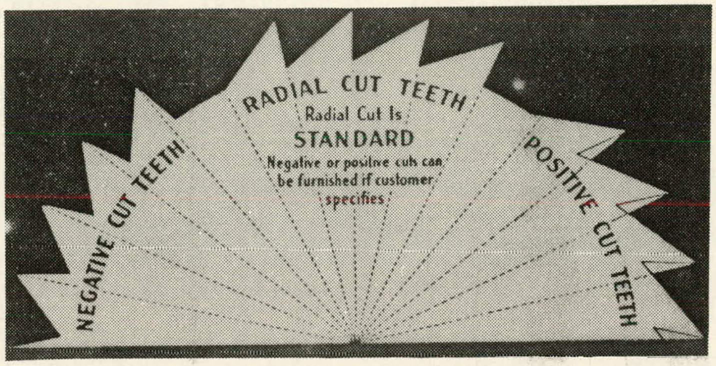


Figure 6. Rake Angle Variations Used
on Rotary Burs

- Standard pattern,
- Herringbone,
- Rasp,
- Double cut, and
- Cutters having chip breakers.

A number of manufacturers also produce a tool which has a diamond cut. The chisel cut tools are coarser, generally not well suited to working precision miniature parts.

Note that the chisel (hand) cut rotary files have teeth which are staggered, in contrast to the smooth flutes of the ground tools. The chisel tools are, therefore, particularly well suited for work on dense, or tough materials. Ferrous metals such as die steels, steel forgings, are good materials for the chisel files. These are best suited for work at lower speeds such as in handheld flexible shaft machines, drill presses, and lathes.

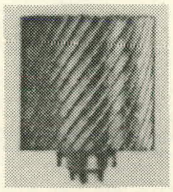
Those tools which are ground after hardening the tool shank are used for finishing ductile and stringy materials, particularly nonferrous metals, such as aluminum, brass, magnesium, and others.

They are also very effective on some plastics. These tools are used at medium speeds, in flexible shaft machines, and air motors as well as in handheld applications.

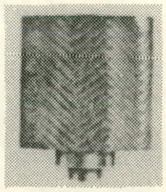
Some additional nomenclature is used for burs produced for the dental industry. The following dental tools are included in Figure 8.

- Plain cut,
- Cross cut fissure; straight cut,
- Cross cut fissure; spiral cut, and
- Fine cut.

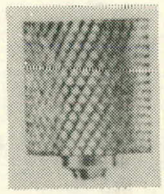
Many of these tools may not be fully appropriate for use on hard metals. The cross cut fissure tools, for example, may grab very thin work pieces. These dental tools, however, in addition to providing a wide variety of shapes, also provide a similar wide variety of flute configurations. Some of these are shown in Figure 9. Published literature does not indicate a uniform nomenclature for fineness of flute for many of these tools.



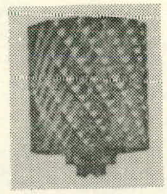
STANDARD



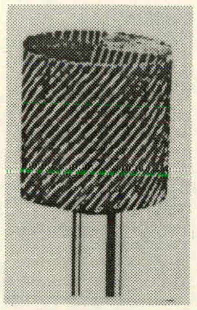
HERRINGBONE



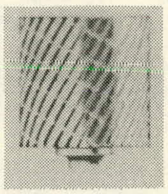
RASP



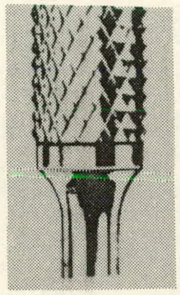
DOUBLE CUT



CHISEL

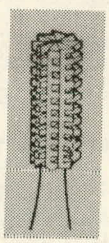


CHIP BREAKERS

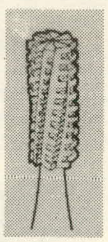


DIAMOND

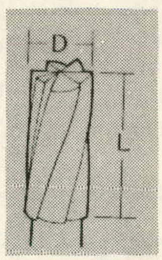
Figure 7. Basic Styles of Cut Used on Industrial Burs



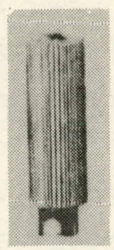
CROSS CUT
FISSURE:
STRAIGHT
CUT FLUTE



CROSS CUT
FISSURE:
SPIRAL
CUT FLUTE



PLAIN FISSURE
STRAIGHT FLUTE



FINE CUT
STRAIGHT FLUTE

Figure 8. Basic Styles of Cut Used on Dental Burs

VARIETY OF ROTARY BUR MATERIALS

The following rotary burs are made from a variety of tool materials:

- High speed steel,
- High speed vanadium steel,
- Tungsten vanadium steel, and
- Diamond plated materials.

The high speed steel tools are adequate in many situations for which one will be using only handheld pin vises to rotate the tools. They can also be used on very low speed handheld motors. The addition of vanadium and/or small quantities of tungstun provide a tougher tool which can be used at higher speeds. Tungsten carbide can be operated at speeds considerably higher than the steel burs. They also have the advantage that they will not rust when used in areas of high humidity or moisture.

BASIC USE OF ROTARY BURS

In a majority of cases, bur balls will be used extensively for the chamfering and finishing of hole entrances and exits. Because the wide variety of these tools which are available in the relative ease in which they may be ground they are available in a tremendously wide variety of sizes. Figure 10 illustrates the use of an inverted cone bur. As seen there, that may be a useful tool for reaching hard-to-reach undercuts. In a few instances, one may find the end cut burs to be suitable also for otherwise difficult-to-reach areas (Figure 11).

In a few instances, bur balls may be less desirable than the cone- or hart-shaped burs. Remember that even these tools can leave fine burs when they are used (Figure 12). In some cases,

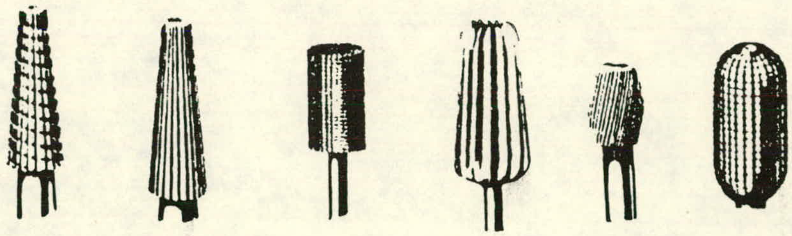


Figure 9. Flute Configurations Available in Dental Burs

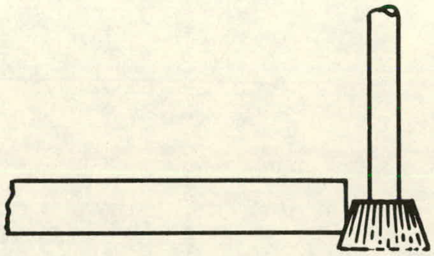


Figure 10. Inverted Cone in Use

Figure 11. End Cut Bur

the use of a small angle cone followed by a flat or hart-shaped bur will provide the necessary edge break and provide a nearly burr-free edge (Figure 13). Some individuals rely exclusively on the use of these latter two types of tools rather than the use of

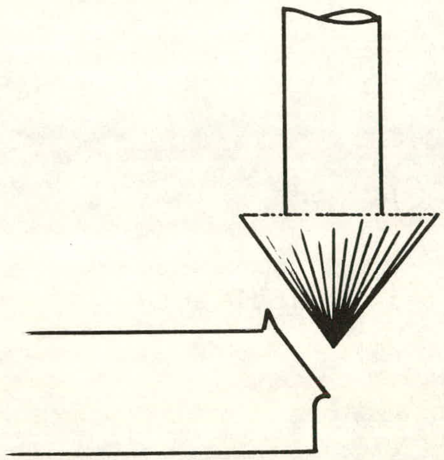


Figure 12. Rotary Burs Produce Burrs

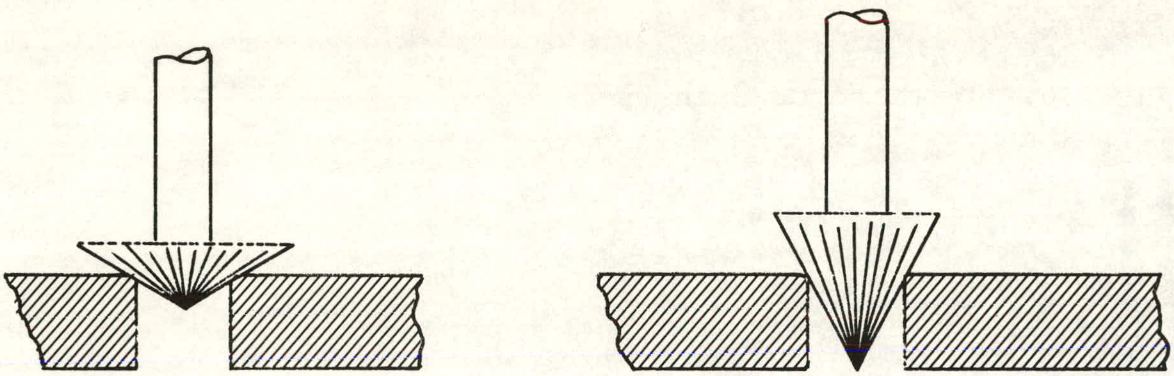


Figure 13. The Use of Two Cone Shaped Burs to Produce Near Burr-Free Holes

bur balls. Others follow the bur with a knife to wipe out any burrs created by the bur.

The concave cutters or cup cutters can be used to deburr the ends of small pins. Because of the difficulty of cutting inside these cups, it is difficult to get such a tool with such fine tooth spacing (Figure 14).

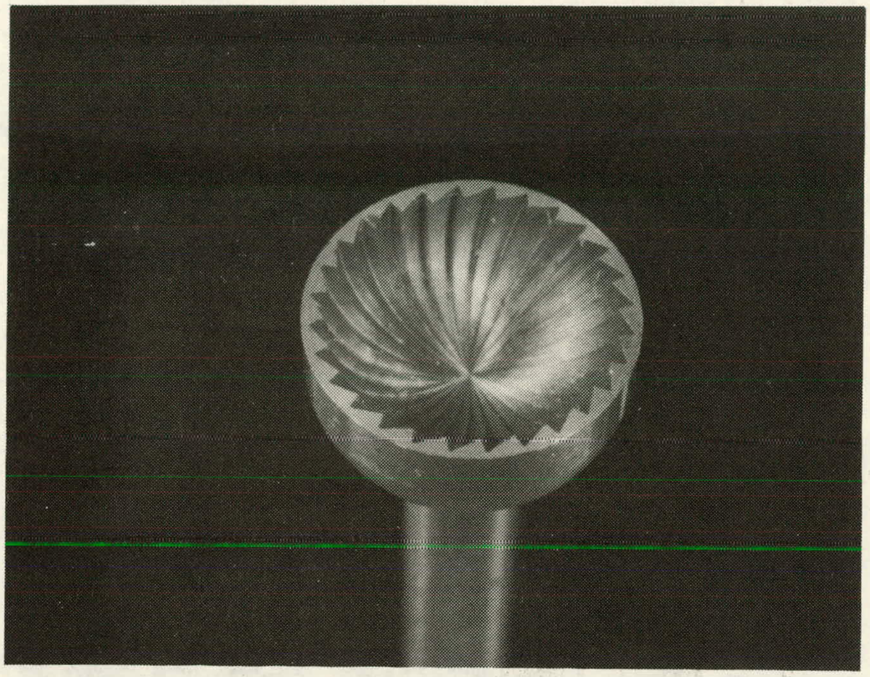


Figure 14. Cup Bur for Finishing Ends of Rods

The cone shaped tools can also be used to break the corner of external edges (Figure 15).

There are special cutters to deburr and finish both the inside and the outside of tubing (Figure 16). These tube hole cutters, while available for larger sizes, provide both a chamfer and remove the burr produced when the tube is cut in half. A disc bur is similar to the end bur other than it is much larger in diameter (Figure 17). Figure 18 illustrates two other approaches for using burs to finish holes in tubes.

In shallow counterbored holes and for holes next to shoulders, it may be difficult to use a standard bur ball. Bur balls can be easily altered, however, as shown in Figures 19 and 20 to meet these types of conditions. This simple alteration can frequently save a number of hours digging or cutting with knives.

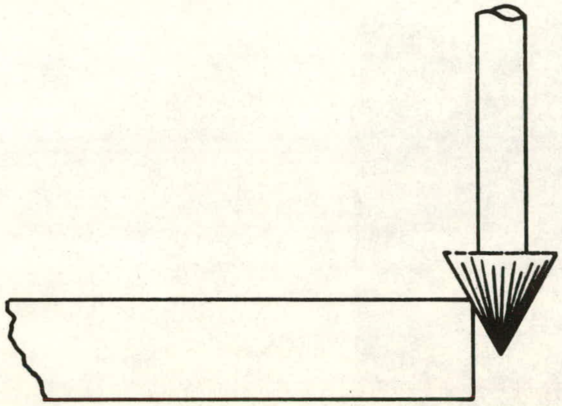


Figure 15. Cone Shaped Tool Used for Chamfering Contours

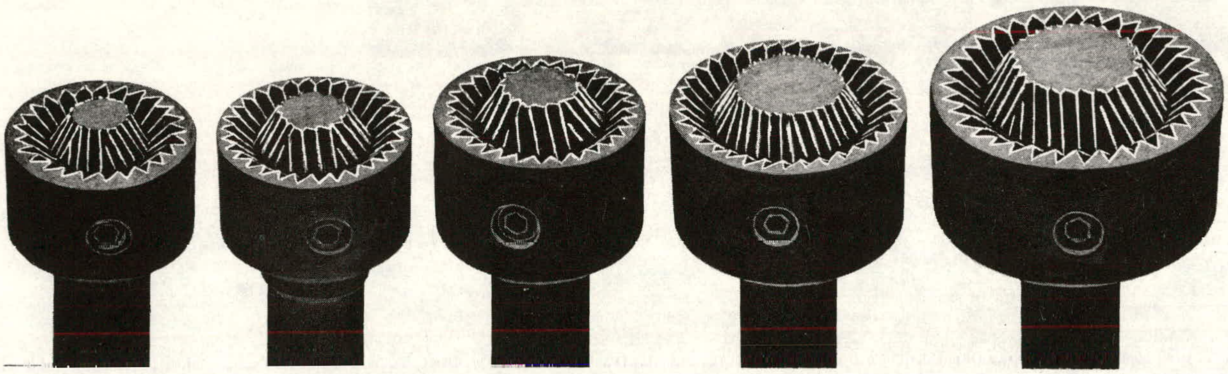


Figure 16. Tube Deburring Burs

Rotary burs and bur balls should be used with even more care than precision files. The teeth are very susceptible to breakage because they are so small. The carbide burs should not normally be cleaned in an ultrasonic cleaner because the ultrasonic action fractures the ends of the teeth.

The choice of fine, medium, or coarse flute spacing will depend upon the material to be deburred. The medium cut is used for general purpose deburring of steel, cast iron, and other iron

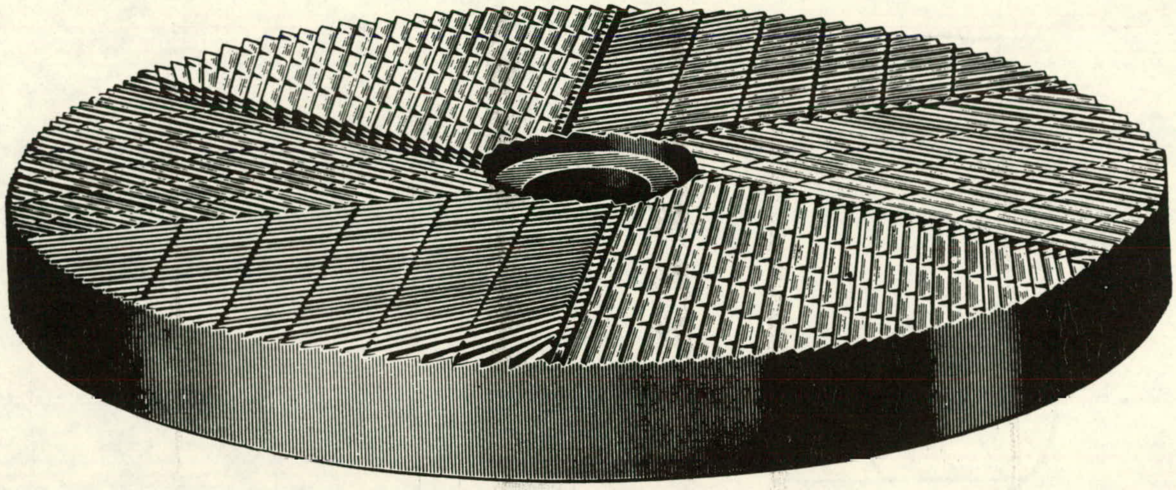


Figure 17. Disc Rotary Bur

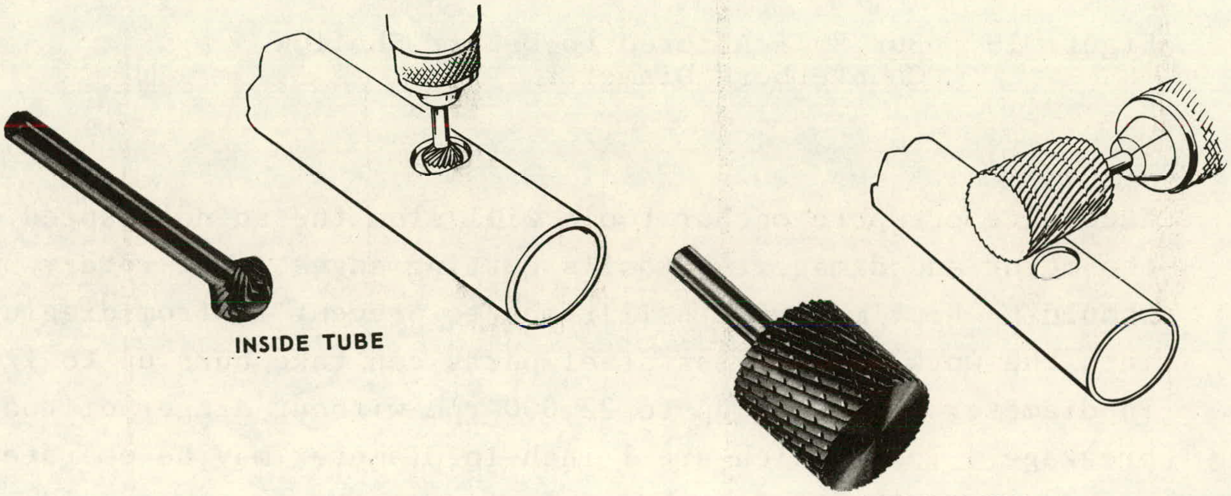


Figure 18. Finishing Intersecting Holes With Burs

base materials. The finer burs are used to provide a finer surface finish. The diamond cut flute configuration will cut fast and will provide better control when the tool is used in a handheld motor. Stringy materials cut easily with this diamond pattern because it produces a powder-like chip with its hundred of chisel like edges.

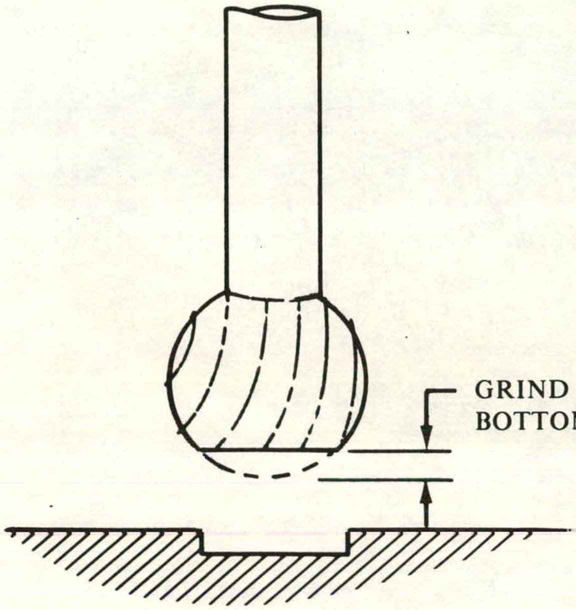


Figure 19. Bur Ball Altered to Deburr Shallow Counterbore Diameter

Excessive pressure on bur tools will slow the spindle speed of the motor and damage the tool's cutting edges. The rotary bur should be kept moving at all times to prevent it from digging into the work. Stainless steel parts can take burs up to 1/4 inch in diameter at speeds up to 22,000 rpm without danger of tool breakage. Tools which are 1 inch in diameter may be operated at speeds up to 12,000 rpm and, on softer work pieces, considerably higher. Tables 2 and 3 provide some working speeds recommended by one manufacturer for these types of tools.

As in the case of diamond plated files, almost any bur shape can be coated with diamond particles. This permits reaching in places otherwise unaccessible with conventional tools. While these tools are slightly more expensive than steel or carbide rotary burs in the smaller sizes, in many cases they will also outperform the less expensive rotary tools.

Rotary burs come in a variety of shank configurations and sizes. Commercial industrial tools typically have standard shank sizes of 1/8 inch, 1/4 inch, or multiples of 1/8 inch. There are five basic shanks used in the dental industry as shown in Figure 21. As mentioned previously in other chapters, the dental shanks typically are 1/16 inch or 3/32 inch in diameter.

Table 4 describes the rotary burs most commonly used at Bendix for deburring precision miniature parts.

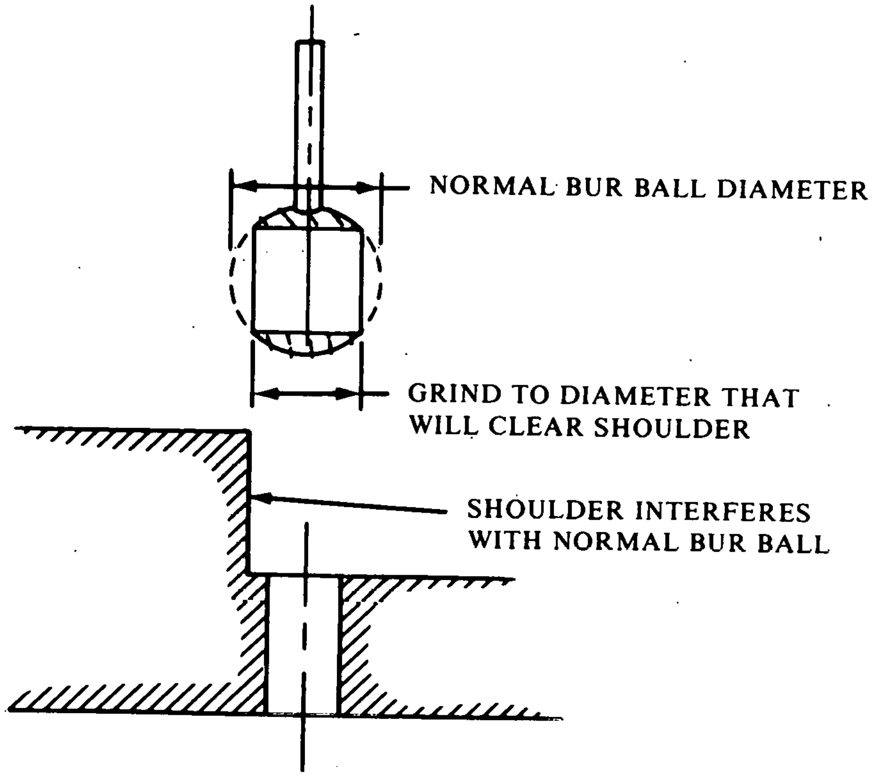


Figure 20. Bur Ball Altered to Finish Hole Next to Shoulder

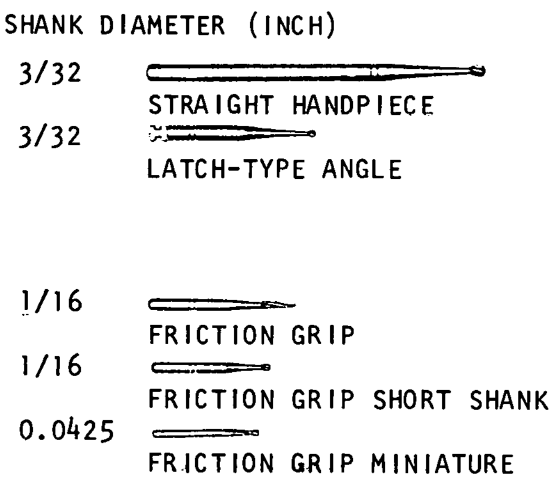


Figure 21. Standard Dental Bur Shank Configuration

Table 2. Maximum Speeds Recommended for Carbide Burs Having 1/4 Inch Diameter Shanks on Stainless Steel Workpieces*

Bur Diameter (Inch)	Fine Cut		Standard Cut		Coarse Cut	
	Number of Flutes	Speed (rpm)	Number of Flutes	Speed (rpm)	Number of Flutes	Speed (rpm)
1/16	20	45000	14	75000	8	98000
3/32	22	38000	16	60000	10	83000
1/8	26	30000	18	53000	12	68000
3/16	30	24000	20	38000	14	59000
1/4	34	21000	24	33000	16	53000
5/16	38	18000	26	30000	16	48000
3/8	42	17000	28	27000	18	44000
7/16	46	15800	30	26000	18	41000
1/2	50	15000	32	24000	20	38000
5/8	54	14300	34	23000	22	35000
3/4	58	13500	36	21000	24	30000
7/8	60	12700	38	20000	26	29000
1	62	12000	40	18000	28	27000

*For diamond cut or high-speed steel burs, reduce listed speed by 1/2.

Table 3. Maximum Speeds Recommended for Carbide Burs Having 1/4 Inch Diameter Shanks on Malleable Iron, Cast Iron, Die Steels, Aluminum, Steel Welds, Tool Steels, Naval Bronze, and Brass*

Bur Diameter (Inch)	Fine Cut		Standard Cut		Coarse Cut	
	Number of Flutes	Speed (rpm)	Number of Flutes	Speed (rpm)	Number of Flutes	Speed (rpm)
1/16	20	30000	14	50000	8	65000
3/32	22	25000	16	40000	10	55000
1/8	26	20000	18	35000	12	45000
3/16	30	16000	20	25000	14	39000
1/4	34	14000	24	22000	16	35000
5/16	38	12000	26	20000	16	32000
3/8	42	11000	28	18000	18	29000
7/16	46	10500	30	17000	18	27000
1/2	50	10000	32	16000	20	25000
5/8	54	9500	34	15000	22	23000*
3/4	58	9000	36	14000	24	20000*
7/8	60	8500	38	13000	26	19000*
1	62	8000	40	12000	28	18000*

*For diamond cut or high-speed steel burs, reduce listed speed by 1/2.

Table 4. Characteristics of Rotary Burs Used at Bendix

Bendix Code Number	Shape	Size (inch)	Material	Flute Fineness	Type Fluting	Shank Diameter (inch)	Overall Length (inch)
52620050	Ball	0.094	HSS	31/inch	Standard		1.250
52620055	Cylinder		HSS		Standard		
52620057	Ball	0.059	Carbide			0.062	
52620069	Ball	0.195	HSS	40/inch	Standard	0.125	1.50
52620071	Ball	0.280	HSS	31/inch	Standard	0.125	1.66
52620073	Ball	0.390	HSS	25/inch	Standard	0.125	1.75
52620075	Cylinder	0.062	Carbide	40/inch	Standard	0.125	1.50
52620140	Cylinder	0.0938	HSS	50/inch	Standard	0.094	1.50
52620150	Ball End Cylinder	0.0938	Carbide	40/inch	Standard	0.125	1.50
52620180	Ball	0.125	HSS	25/inch	Standard	0.250	2.50
52620190	Cylinder	0.187	HSS	20/inch	Standard	0.250	2.25
52620194	Cone	0.250	Carbide	20/inch	Straight	0.250	2.00
52620200	Flame	0.250	Carbide	25/inch	Double Cut	0.250	2.00
52620203	Ball	0.250	HSS	16/inch	Standard	0.250	2.500
52620204	Ball End Cylinder	0.250	HSS	20/inch	Standard	0.250	2.500
52620205		0.250					
52620206	Micro-center Reamer	0.250	Carbide	20/inch	Straight	0.250	2.000
52620210	End Cut Cylinder	0.310	Carbide	25/inch	Standard	0.250	2.500
52620215	End cut Cylinder	0.310	Carbide	25/inch	Standard	0.250	3.250
52620449		0.310	Carbide				

Table 4 Continued. Characteristics of Rotary Burs Used at Bendix

Bendix Code Number	Shape	Size (inch)	Material	Flute Fineness	Type Fluting	Shank Diameter (inch)	Overall Length (inch)
52620450	Cone	0.375	HSS	25/inch	Standard	0.250	3.000
52620451	End Cut Cylinder	0.375	HSS	25/inch	Chisel	0.250	2.500
52620452	Tree	0.375	HSS	16/inch	Standard	0.250	2.250
52620453	Cylinder	0.375	Carbide	20/inch	Standard	0.250	2.500
52620454	Ball	0.375	HSS	16/inch	Standard	0.250	2.250
52620455	End Cut Cylinder	0.375	Carbide	16/inch	Standard	0.375	3.500
52620457	Cylinder	0.375	Carbide	16/inch	Double	0.250	2.500
52620458	Ball End Cylinder	0.375	Carbide	20/inch	Double	0.250	2.750
52620459	Ball	0.375	Carbide	20/inch	Standard	0.250	2.000
52620470		0.434	HSS	31/inch			
52620475	Ball	Set*	HSS	25/inch	Standard	0.094	1.750
52620480	Bud	Set*	HSS	25/inch	Standard	0.094	1.750
52620485	Hart	Set*	HSS	50/inch	Standard	0.094	1.750
52620490	Cone	Set*	HSS	25/inch	Standard	0.094	1.750
52620495	Ball	Set**	HSS	33/inch	Standard	0.125	1.500
52620496	Ball	Set***	HSS	25/inch	Chip Breaker	0.094	1.750
52620500	Ball	0.357	HSS	33/inch	Standard	0.125	1.625
52620502	Ball	0.288	HSS	33/inch	Standard	0.125	1.625
52620504	Ball	0.310	HSS	33/inch	Standard	0.125	1.625
52620505	Ball	0.368	HSS	33/inch	Standard	0.125	1.625
52620565	Ball End Cylinder	0.500	Carbide	16/inch	Standard	0.250	2.750
52620569	Ball	0.500	HSS	31/inch	Standard	0.250	2.750
52620570	Ball	0.625	HSS	11/inch	Chisel	0.250	2.750
52620571	Bullet	0.625	HSS	13/inch	Standard	0.250	2.750

Table 4 Continued. Characteristics of Rotary Burs Used at Bendix

Bendix Code Number	Shape	Size (inch)	Material	Flute Fineness	Type Fluting	Shank Diameter (inch)	Overall Length (inch)
52620572	Tree	0.625	HSS	13/inch	Standard	0.250	2.750
52620574	Tree	0.625	HSS	16/inch	Standard	0.250	2.750
52620575	Bullet	0.625	HSS	13/inch	Standard	0.250	2.750
52620585	Ball End Cylinder	0.750	Carbide	25/inch	Standard	0.250	2.750
52620591	Ball	0.750	HSS	16/inch	Chisel	0.250	2.500
52621215	Ball	0.750	Carbide	16/inch	Standard	0.250	2.500
52621300	Ball	1.000	HSS	20/inch	Standard	0.250	2.250
10200595	Flame	0.062	Diamond	---	---	0.094	1.250

*Set consists of 15 burs, with a maximum size of 0.150 inch and a minimum size of 0.040 inch.

**Set consists of 8 burs, with a maximum size of 0.250 inch and a minimum size of 0.040 inch.

***Set consists of 5 burs, with a maximum size of 0.350 inch and a minimum size of 0.125 inch.

SOURCES OF ADDITIONAL INFORMATION

1. E. W. Skinner and R. W. Phillips, Science of Dental Materials, Fifth Edition, W. B. Saunders Co., Philadelphia, 1960.

2. Pfingst Catalog No. 31, Pfingst and Company, Inc., New York, New York.

3. Severance Catalog No. 37-A, Severance Tool Industries, Inc., Saginaw, Michigan, 1975.

4. Rotary Files and Tools, Grobet Catalog No. 61-B, Grobet Files Company of America, Inc., Carlstadt, New Jersey.

5. "Specification #23: Dental Excavating Burs," American Dental Association, Chicago, Illinois, 1979.

ASSIGNMENT

1. List ten different names of types of rotary burs.

2. Describe the various materials from which rotary burs are made.

3. List the different types of tooth patterns which are available.

4. How do you measure the fineness of teeth on a rotary bur?

5. Using only the two rotary burs provided, deburr the edges of the samples provided.

6. Using only the two bur balls provided, deburr the holes in the samples provided.

7. Using only sharp pointed and hart burs, deburr the holes on the sample provided.

8. Describe the various shanks available on dental rotary burs.

9. How would you deburr the bottom side of a hole in an otherwise inaccessible tube?

10. What is the difference between a rotary bur and a countersink?

11. Deburr the samples provided using only the countersink tools provided.

BDX-613-2534

A TRAINING MANUAL FOR PRECISION HAND DEBURRING, PART 2, L. K. Gillespie, December 1980

Part 2 of 4 parts of a training manual to be used by machinist trainees, production workers, and others removing burrs from precision miniature parts. The manuals are written to be self-teaching and are intended to be used with two hours of training each day along with another six hours of bench work in deburring.

MECHANICAL: Deburring Training

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