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A Training Manual for Precision Hand Deburring, Part 1

By L. K. Gillespie

Published May 1980

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

**Kansas City
Division**

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**A TRAINING MANUAL FOR PRECISION
HAND DEBURRING, PART 1**

Published May 1980

By L. K. Gillespie

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A TRAINING MANUAL FOR PRECISION HAND DEBURRING, PART 1

BDX-613-2400, Published May 1980

By L. K. Gillespie

Part 1 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.

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CONTENTS

Section		Page
	PREFACE.	vii
1	INTRODUCTION	1
	Economic Impact of Burrs.	4
	Technical Impact of Burrs	6
	Schedule Impact of Burrs.	13
	Course Objectives	15
	Course Outline.	16
	Assignment.	18
2	HOW TO LOOK FOR BURRS.	19
	Best Direction.	19
	Optimum Lighting.	21
	Tensor Lights	23
	Ring Lights	23
	Nicholas Illuminators	23
	General Purpose Illuminators.	24
	Coaxial Illuminators.	26
	Back Lighting	30
	Fiber Optic Lights.	30
	Polarizing Accessories.	32
	Color of Light.	32
	Otosopes	33
	Sight Pipes	33
	Borescopes.	35
	Problems with Lights.	37
	Probing	37
	Cleaning.	39
	Using Gages to Detect Burrs	40
	Basic Approaches for Specific Features.	41
	Assignment.	43
3	TYPES OF DEBURRING TOOLS	45
	Knives.	45
	Files	45
	Burs.	48
	Scrapers.	52
	Countersink Tools	52
	Brushes	52
	Abrasive Filled Rubber Products	55
	Abrasive Filled Cotton Products	55
	Abrasive Filled Cork Products	56
	Abrasive Paper Products	57

	Felt Bobs	57
	Lapping Compounds	59
	Mounted Points.	59
	Hand Stones	59
	Mandrels.	59
	Pin Vises	62
	Motorized Tools	62
	Miscellaneous Tools	62
	Sources of Additional Information	67
	Assignment.	68
4	KNIVES AND THEIR USE	69
	Using Deburring Knives.	69
	Types of Deburring Knives	72
	Knives Make Burrs	85
	Relation Between the Knife and Part	85
	Assignment.	90
5	MOTORIZED TOOLS AND THEIR APPLICATION.	91
	Bench Motors.	91
	Air Motors.	93
	Flexible Shaft Motor.	98
	Hand Held Sanders	98
	Reciprocating Files	98
	Safety Considerations	100
	Assignment.	104
6	USE AND CARE OF THE MICROSCOPE	105
	Definitions	105
	Focusing.	109
	Magnification	112
	Using the Microscope.	114
	Care and Cleaning	116
	Microscopes With Coaxial Illumination	122
	Miscellaneous Observations.	126
	Sources of Additional Information	128
	Assignment.	129
7	BASIC DEBURRING NEEDS.	131
	Rough Deburring	131
	In-Process Deburring.	132
	Finish Deburring.	132
	Final Deburring	132
	Code Numbers for Deburring Operations	133
	Terminology Used in Machining Operations.	133
	Assignment.	134

8	REVIEW OF DECIMAL NUMBERS.	135
	Written and Spoken Terminology.	136
	Assignment.	139
9	DEBURRING HOLES.	141
	Basic Approaches for Holes.	142
	Approaches for Counterbored Holes	150
	Approaches for Intersecting Holes	151
	Areas of Concern on Holes	153
	Mechanized Processes for Holes.	154
	Assignment.	160
10	DEBURRING THREADED FEATURES.	161
	Types of Burrs Found on Threads	161
	Basic Deburring Approach for Threaded Holes	174
	Potential Problem Areas in Threaded Holes	183
	Basic Deburring Approaches for Threaded Shafts.	184
	Potential Problem Areas for Male Threads.	184
	Mechanized Deburring Processes for Threads	185
	Assignment.	188

PREFACE

Despite the fact that hand deburring has been used for finishing parts for several hundred years, a review of the literature indicates there is not a single manual available describing the techniques and tools commonly used for this purpose. The purpose of this manual is to instruct workers new to this task how to deburr parts, particularly precision miniature parts. The material is meant to be supplemented with approximately six hours of practice and test samples for every lesson. This manual presupposes that the individuals involved in this training course for deburring know very little about machining, inspection needs, or deburring.

This training manual is based on approximately 10 years experience of working with individuals performing this type of work on a day-to-day basis. It is based on discussions with hundreds of vendors and users of both hand and mechanized deburring processes, a review of over 2,000 publications on deburring, and extensive research. Insofar as possible, photographs and illustrations are used to demonstrate the basic principles. It is impossible, however, in printed words to convey all the actual motions that must be used to deburr or handle any part. To overcome this limitation, a series of short videotapes are being prepared to cover such specific areas as deburring threaded parts and gears.

The basic outline and material presented in this manual have been used to train several hundred individuals since 1978. The results of the comments and the observations made during that training have been compiled and introduced into this manual.

The information presented is meant to be as practical as possible and, insofar as possible, explanations of why certain techniques are better have been introduced. Recognizing that any publication can miss important points, the authors of this manual would like to have comments on how to improve this training guide.

CHAPTER 1

INTRODUCTION

Since the early Stone Age, man has had to finish the parts which he has either chipped, machined, or filed into shape. While early records do not indicate how edges were finished, it is fair to assume that stones and other abrasive types of products were used to provide a smooth, blended, rounded appearance on the edges of parts. For hundreds of years this handwork did not change. In the days of the crusades, a mechanized finishing process was developed called barrel tumbling. It has only been lately that other mechanized deburring processes have been developed which can be used on the tremendous variety of products made in industry today. Many of these mechanized processes have been described in detail in many publications, books, and even training films. The one process which has been almost totally ignored in the printed literature and yet is the most widely used of all of these deburring processes is hand, or manual, deburring.

This training manual is written to provide a very broad base and yet in-depth background to the techniques of deburring, the reasons for deburring, and quality requirements. This training manual is designed for the needs at Bendix Kansas City. However, the techniques, approaches, and even the problems are not very different from those of other companies in the U.S. or throughout the world. Many of the products made at Bendix Kansas City require higher levels of skill and technology than are required for most commercial parts in the United States. Consequently, it is important to provide as much detail as possible about the requirements for those doing the work.

Many people believe that deburring is a simple job, requiring very little skill, very little effort, and very little knowledge. In many companies in the U.S. that is true; but it's not the case for Bendix precision miniature parts in particular and for many of our larger parts. The authors of this training manual have had considerable experience teaching deburring and observing the problems faced by those who have to deburr daily or those who have to deburr on a machine while they are making parts.

Bendix Kansas City has made more than 50,000 measurements of burrs. These are measurements of how burrs form, how big they are, and the ability of various deburring processes to remove the burr and put on a desired edge radius or break. Bendix has been making and deburring parts at Kansas City for more than 30 years. In addition to the research and the day-to-day responsibilities for solving deburring problems, Bendix has had to purchase a wide variety of deburring equipment, and Bendix has had to establish basic approaches for reducing deburring time and costs. The individuals involved have talked with hundreds of users and vendors on the subject of deburring, and in order to provide the detail necessary, Bendix has documented its deburring findings in more than 60 publications.

This training manual is designed to be self-explanatory. It is designed to provide approximately two hours training every day to be used in conjunction with another six hours of actual deburring practice.

This training manual is divided into 44 sections, in four volumes. Each section defines a specific area of deburring in which the reader is expected to be knowledgeable. Many sections are designed to be covered in a two hour presentation. The following subjects are covered in this training guide:

- How to look for burrs.
- Various levels of quality required.
- Available tools.
- General approaches to hand deburring.
- Approaches to specific parts.
- Human capabilities.
- Motorized tools.
- Machines for deburring.
- Microscope usage.
- Shop instructions.
- Effects of part size.
- Effects of part shape.
- Detailed discussions on the 17 types of hand tools.
- Cleaning.
- Inspection.
- Deflashing plastic parts.
- Finishing of ceramic parts.
- Economics.
- Minimizing burrs.
- Burr formation.
- Time standards for deburring.

At the end of every section is an assignment list. In a formal classroom presentation at the end of every week, a test will be given to determine how well you have learned the material in this text. Actual piece parts which you deburr will be measured or analyzed to determine if the parts are actually burr free and where problem areas could exist. In some cases, the deburring efforts will even be timed. You will be working on sample parts and actual production parts in this training.

Most classes will include a lecture, a discussion, and in some cases, a demonstration. Insofar as possible, a brief session will be provided in which each individual will get a chance to try the

assignment for that day. After that, your supervisor and lead man will work with you if you have any questions.

This chapter is directed at defining the impact that burrs have specifically on Bendix Kansas City and why both management and production personnel are concerned and interested in this subject.

ECONOMIC IMPACT OF BURRS

Consider the cost of deburring at a large facility such as Bendix. If only one or two individuals are doing deburring, then the cost of deburring on a yearly basis is something slightly larger than the salary of those one or two individuals. At most it is less than twice the salary of those two individuals. Consider an instance where 100 individuals are responsible for deburring on essentially a full-time basis.

If a facility such as Bendix Kansas City has 100 individuals doing this work at a salary of \$7/hour, the direct cost as shown by the calculation below is at least \$1.4 million a year.

100 people x \$7.00/hour x 2064 hours/year = \$1.4 million

In actual fact, for 100 workers the deburring cost would be much greater for the following reasons:

- It ignores overtime costs.
- Actual labor rates increase yearly.
- It ignores the cost of overhead factors such as social security, insurance, and medical costs.
- It ignores the fact that a number of general machinists and plastic fabricators also remove burrs during machine cycles.

- In large companies, there is a very large inventory of deburring tools.
- All knives and related tools must be reground which adds additional costs.
- It ignores the costs of bench motors, microscopes, and related tools.

Motors alone may cost up to 300 or more dollars each. The microscopes used on our precision miniature parts may cost from 500 to 5,000 dollars depending upon the quality and the nature of the microscope. Each new worker must have tools to do the deburring. It is not unusual for new workers to have 500 to 1000 dollars worth of tools in their tool kits.

These items do not include all of the extra costs of deburring but do provide a general guideline to emphasize that deburring in a large facility with a large number of people is a very expensive effort. If direct costs were \$1.4 million a year or more, indirect cost would increase that figure to a total of something on the order of \$2 million a year for deburring. Fewer workers, of course, lower costs and additions would increase costs.

While the economics of burrs within an individual plant are cause for considerable thought, it is important to realize the total magnitude of burrs within the entire country as well as within a single plant. It has been estimated that in the U.S. alone, in the late 1970's, that \$2 billion a year is spent on deburring. That's \$2 billion every year to remove something that nobody wanted. Our neighbor, Canada, has spent something in the order of \$100 million a year to remove burrs. Canada, of course, is a small country compared to the United States. The same individuals who made those projections indicate that the world-wide cost of burrs in terms of U.S. dollars can be as high as \$5 billion a year.

From this, it is easy to see that you're working in an area which deserves a great deal of attention. This training manual is one approach to providing that attention.

TECHNICAL IMPACT OF BURRS

Burrs cause many problems. The following list provides some basic examples of the types of problems that burrs will cause in a variety of assemblies:

- Cut hands.
- Electrical short circuits.
- Jammed mechanism.
- Interference fits.
- Metal contamination.
- Blocked filters.
- Closed port holes.
- Scratched surfaces.
- Improper seals.
- Stress concentrations.
- Excess weld metal.
- Changed rotor torque.
- Increased friction.
- High wear.
- High voltage breakdown.
- Disrupt signals in microwave guide tubes.

Most individuals who have worked around the house or on cars understand the problem of sharp edges or burrs cutting hands. Those who have had to repair electrical motors also understand the problem sharp edges cause when electrical wiring passes over them. It is also obvious on miniature mechanical watches that a burr or any piece of material in the gears of a small watch will stop it.

(Figure 1). Many assemblies cannot allow loose particles of metal in the assembly. For example, ceramic insulators cannot have metal particles floating around them because metal will cause electrical short circuits or jamming.

In hydraulic systems, burrs block filters. It is possible for a brand new automobile engine filter to be almost covered with metal particles after only 10,000 to 15,000 miles. It is possible that they will totally block very small fluid flow nozzle carburetors. Every time key parts are assembled together, it is easily possible for a burr to scratch the surface, or prevent two parts from fitting together. In addition, burrs on small parts will cause other manufacturing problems:

- They prevent making accurate size measurements (Figure 2).
- They prevent proper location in subsequent fixtures (Figure 3).
- They accelerate plating buildup on edges (Figure 4).
- They cut hands.
- They scratch gages.
- They scratch other parts in the same container.
- They increase wear of fixtures.

One of the most vivid examples of why burrs are not allowable and why edge radii are desirable is on aircraft wings. Aircraft wings have to flex to avoid building large stress concentrations which would literally break the wing in half. For example, if a coat hanger is flexed fast enough and often enough, it will break. The same is true of an aircraft wing. Burrs or sharp edges on aircraft wings increase the stress concentrations tremendously. Without a burr the wing might flex a hundred million times with no problems. With a burr or sharp edge, it might flex only a hundred thousand times before it broke or developed a serious crack. The aircraft industry is just one example of industry's concern for burrs and sharp edges. Bendix is not an aircraft

Figure 1. Foreign Material Will Jam Precision Mechanisms

Figure 2. Burrs Prevent Accurate Size Measurements

Figure 3. Burrs Cause Mislocation in Fixtures

Figure 4. Burrs Accelerate Plating Buildup at Edges

manufacturer but the same needs are there; the same stress concentrations exist on any part. Some parts, after prolonged vibration or flexure, will break in a small assembly just as they do in an aircraft.

There are many unique electrical problems associated with sharp edges and burrs. Lightning rods, for example, are very small in diameter because sharp pointed objects attract electricity. In some cases, that is desired and in other cases it is not. In many of our electromechanical assemblies this feature is totally undesirable (Figure 5). Not only will it attract electrical energy, but the sharp edges and burrs influence the magnetic fields and many of the Bendix units have magnetic components in them.

In a few rotating parts and mechanisms, burrs will increase friction as they cause the mating parts to dig into each other (Figure 6). That in itself is enough to slow a unit down and cause failure.

Bendix has a variety of different types of edge requirements for a number of electronic nonfunctioning parts. Parts such as these in which burrs do not move might not be a very large problem. Some large parts are so massive that a burr is almost insignificant. You will find that some noncritical sheet metal parts and very large hand size parts may not require the extensive deburring that others will.

On miniature mechanism such as switches, timers, and actuators, burrs represent a real problem if the size of the burr is large compared to the part size. As an example, Bendix now makes several electromechanical units which have 50 to 100 parts for each cubic inch. Consider a mechanical watch. A watch is very small and yet it probably has 30 or 40 working components in it. Some of the Bendix units have 435 parts in a three cubic inch volume. A burr on any one of those parts could cause a mechanical or electrical

Figure 5. Burrs Reduce High Voltage Breakdown Limits

Figure 6. Burrs Increase Friction

failure. A number of parts have very close tolerances, such as ± 0.0002 inch. Burrs will interfere with such close tolerance components. As an example, the hair on the head of most individuals is approximately three thousandths of an inch (0.003) in diameter. When you are dealing with parts that have two ten-thousandths of an inch tolerance, that's equivalent to slicing a hair lengthwise into 15 different segments (Figure 7). A number of these parts in miniature mechanisms also have very close surface finishes such as 8 microinches (a roughness of eight millionths of an inch). Many of these parts must operate under very low torque conditions. Burrs cause enough friction to increase this torque.

Many of these problems will be discussed in more detail in later chapters. It is important to note, however, that many assemblies must function during shock loads, and while being vibrated. They must work in both hot and cold temperatures and while they are under high "G" loads.

At some point the question will be asked, "How big a burr could we allow on our parts; what size is not allowed?" On precision miniature parts in particular, a burr only two ten thousandths of an inch (0.0002) is too big. On larger parts, they may not be a problem but on precision miniature parts, a two ten thousandths of an inch burr is too big.

SCHEDULE IMPACT OF BURRS

Burrs are of great concern for other reasons. They also influence production schedules. As an example, in previous years, two departments at Bendix alone making mechanical parts typically shipped 450,000 parts a year to the Inspection department. It's important for Bendix to maintain fixed schedules on the delivery of these parts to Inspection, Production Stores, and to the next assembly. If for any reason schedules are not met, there is a real possibility

Figure 7. A Human Hair Sliced Into
15 Uniform Segments Is
Approximately 0.0002 Inch

of a production shutdown in the assembly department. In many cases, the difference of an hour, or a few hours, or a day or two is not important; but in many other instances it is significant because it means Bendix cannot ship on schedule.

An aircraft company has a slogan which characterizes their company; that slogan is, "schedule is king." Bendix needs both high quality and schedules to maintain its position within the Department of Energy. If we miss delivering parts from the plant, it has a significant impact on the way others view the capability of this plant. It's important to maintain schedules, not only for this reason but because the parts are used in our country's defense.

In the precision machining department, Bendix ships up to 30,000 parts a month to Inspection. It is very easy with such a large quantity of parts to have a backlog of several thousand hours of parts waiting to be deburred, and these several thousand hours may represent 10 to 20,000 different parts. Deburring is one of

the very last operations performed on these parts. That means that deburring may be the last, and possibly most obvious, operation which will affect the timely delivery of parts.

COURSE OBJECTIVES

The objectives of this course are to provide you, as an individual who will be doing deburring, or you as an individual who must be associated with deburring, with the training required to make your job easier. The objective is not only to teach to deburr, but to also indicate insofar as possible, the quality requirements on many of the parts which have to be deburred. One of the objectives is to reduce deburring costs within the plant.

The individuals who complete this training and begin deburring regardless of their classification, are going to be some of the finest and most skilled artists in the world. They will be artists because the result is totally dependent upon their ability. A machinist has a machine which does the work once the proper setup is made and the cycle button pushed. In hand deburring, you, the individual, are the machine, you're the artist, you're the one in total control of the final product. You won't get to sign your name to the part, and the rest of the world may not see it as prominently as a famous painting. But it is there none the less. You are a skilled artist using tools which are unfamiliar to many in the rest of our world, trying to meet demands which others have not even comprehended yet. You will or may be working on a variety of minature parts which are almost too small to be seen without magnification. You will be joining many of the world's most skilled artists in this field already. There are very few people in the world who have to do the expert work that you have to do.

COURSE OUTLINE

This course is designed to follow in logical progression each of the areas in the following listing. Each area is treated individually with little or no reference to preceding sections. Insofar as possible, each section is self-contained although in some, additional reading material is listed for those who desire to obtain more information.

The following sessions are contained in these four training guides.

<u>Section</u>	<u>Description</u>
1.	Introduction
2.	How to Look for Burrs
3.	Types of Deburring Tools
4.	Knives and Their Use
5.	Motorized Tools and Their Application
6.	Use and Care of Microscopes
7.	Basic Deburring Needs
8.	Review of Decimal Numbers
9.	Deburring Holes
10.	Deburring Threaded Features
11.	Deburring Turned Parts
12.	Deburring Flat Parts
13.	Inspection Standards for Burrs
14.	Standards for Surface Finish
15.	Written Deburring Instructions
16.	Research on Hand Deburring
17.	Assembly Requirements
18.	Brush Deburring
19.	Files for Deburring
20.	Rotary Burs and Countersink Tools
21.	Mounted Stones

22. Scrapers and Related Tools
23. Hand Stones
24. Abrasive Filled Rubber Tools
25. Abrasive Impregnated Cotton Fiber Products
26. Abrasive Paper Products
27. Felt Bobs and Lapping Compound
28. Mandrels and Holding Devices
29. Miscellaneous Tools
30. Personal Techniques for Assuring Quality
31. Cleaning Parts
32. Deburring Gears
33. Deburring Plastic Parts
34. Barrel Tumbling
35. Vibratory Deburring
36. Centrifugal Tumbling
37. Abrasive Blast Deburring
38. Electropolish Deburring
39. Electrochemical Deburring
40. Time Studies and Methods Engineering
41. Deburring Large Parts
42. General Characteristics of Common Bendix Materials
43. The Burr and Machining Process
44. Finding the Best Deburring Method

ASSIGNMENT

1. Make a list of the types of training that you expect in this course.
2. Make a list of the reasons burrs cause a problem on any part.
3. Inspect a part for burrs. While you are inspecting, write down the things that you are doing to find burrs (that is, specifically, how do you look for burrs?).

CHAPTER 2

HOW TO LOOK FOR BURRS

Many burrs are difficult to see particularly to those unaccustomed to looking for the very minute ones. While this ability to see burrs improves with experience there are a few approaches which may help. Basically these approaches fall into the following five categories:

- Looking in the best direction,
- Using the correct lighting,
- Probing,
- Using gages to detect burrs, and
- Looking at clean parts.

BEST DIRECTION

Many burrs are almost impossible to see even when looking at the correct edge but in the wrong direction. For example, burrs on holes might not be visible if viewed only from the bottom of the hole. By looking through the hole to the bottom surface many of these burrs can be located (Figure 1). To verify that all burrs have been removed, look at the top surface first; then look through the hole to see if any burrs are thrown over into the hole; then turn the part over, look at the new top side, and again look down through the hole to verify that the hole is completely burr free.

Looking through the hole to the backside is only one aspect to finding the best direction. On most parts, in order to be able to see the burr correctly, it is important to tip the part to an

BURR MAY NOT BE
VISIBLE WHEN VIEWED
FROM SIDE ONLY.

LOOKING DOWN THROUGH THE
HOLE WILL REVEAL BURRS
ROLLED INTO THE HOLE.

Figure 1. Finding Burrs on Opposite
Side by Looking Through
Holes

angle to your eyesight (Figure 2). It is difficult to define the best angle because each part has so many different geometries. This ability comes with experience, but in general do not look straight down on a part; look down at a 30 to 60 degree angle to any edge.

It is also important to have the lighting at the correct angle. The lighting you choose and the angle at which it strikes the part will make a major difference in whether or not you can see the burr. The difficult task is to be able to define how to hold the light in relation to the part to see the burr adequately. Figure 3 illustrates the proper method for these angles to be effective.

OPTIMUM LIGHTING

There are 11 basic lighting techniques for use with microscopes. These techniques offer certain advantages when deburring or inspecting for burrs:

- Tensor lights off the microscopes
- Ring light (fluorescent tube around the lens)
- Nicholas illuminators mounted on the microscope frame
- Nicholas illuminators off the microscope
- Fluorescent illuminators off the microscope
- General purpose illuminators off the microscope
- Coaxial illuminators (through the microscope)
- Back lighting
- Polarizing accessories
- Color filters
- Fiber optic lights

Figure 2. Tip the Part at an Angle to Look for Burrs

BAD LIGHTING ANGLES

GOOD LIGHTING ANGLES

Figure 3. Representations of Lighting Angles

TENSOR LIGHTS

Tensor lights (Figure 4) provide high intensity light for easier viewing in most cases. The fact that they create strong shadows is an advantage when inspecting burrs, because any burr will cast a visible shadow. This type of light is recommended when inspecting for very minute burrs. Typically, one light is not adequate, two opposing lights are used during deburring and even during inspection. The disadvantage of this type of light is that it consumes needed space in the working area and it can burn hands.

RING LIGHTS

Fluorescent ring lights (Figure 5a) provide uniform lighting across the entire workpiece. This results in less eyestrain as well as providing a shadowless light. The shadowless light is adequate for many deburring situations but not for very minute burrs or burrs in very hard to see locations. When mounted around the microscope lens, these lights reduce the allowable working height. Burr tools, particularly knives, can easily break the ring light.

An off-microscope fluorescent illuminator may also be purchased (Figure 5b). A flexible arm may even be attached to the microscope body.

NICHOLAS ILLUMINATORS

Nicholas illuminators (Figure 6) provide a directional concentrated beam of relatively high intensity light. On some lights a single power setting is available while other illuminators offer two or three levels of light intensity. These lights can be placed at

Figure 4. Tensor Lights Used for Deburring

the side of the microscope or they can be inserted in most microscope stands at the back of the stands to provide nearly vertical lighting. Many microscope stands have two positions in which these lights can be mounted (Figure 7). On some microscopes the illuminator may be mounted on a flexible arm at the side of the microscope (Figure 8).

GENERAL PURPOSE ILLUMINATORS

General purpose lights (Figure 9) are available to provide an intense spot of light concentrated in a relatively small field. These lights may be focusable. Also, many have an adjustable intensity level. They may be mounted on or off the microscope with the addition of an arm. On some, it is possible to adjust the diameter of the light beam.

a. Fluorescent Ring Light

b. Off-Microscope

Figure 5. Fluorescent Illuminators

Figure 6. Nicholas Illuminator Mounted on a Variable Transformer

COAXIAL ILLUMINATORS

When it is necessary to see into relatively deep holes or look at flat reflecting surfaces, coaxial illuminators are best. These devices direct all light down the line of sight (Figure 10). Because the light is straight down on the workpiece, it eliminates shadows unless the part is tipped at an angle to the line of sight. There are several advantages to these types of lights. The first advantage is that the light is always in the plane of the part--the light is always shining directly on the part regardless where the part is. The second advantage is that the light is never close

Illuminator Positioned in Rear Port

Illuminator Positioned in Front Port

Figure 7. Mounting Positions for
Illuminators in Microscope
Stands

Figure 8. The Illuminator Can Be Mounted on the Power Body

Figure 9. General Purpose Illuminator

Figure 10. Coaxial Illumination for Microscopes

to the hands or to the tools--the light is completely out of the way of the working area. Coaxial illuminator attachments can be purchased for most microscopes.

BACK LIGHTING

Many modern microscopes can provide light from the base of the microscope, up underneath a part, and up through the lens system. This back lighting is not normally used in deburring, but there are instances where it is an advantage (on some through holes for instance) (Figure 11).

FIBER OPTIC LIGHTS

Fiber optic lights can concentrate a high intensity light source into a very small area. The fiber optics permit maneuvering the light in almost any direction. Figure 12 illustrates one fiber optic light commonly used with a microscope. These lights frequently provide so much light that their intensity must be adjusted to the lowest setting to be useful.

In any of the microscope lights it is important to use no more light than is necessary, not only in order to see the burr but also to extend bulb life. One of the widely used fiber optic lights will last some 500 hours at the low setting. At the high setting it will last only 40 hours. The advantage of fiber optic lights is that they permit looking down deep holes and in hard to reach areas not otherwise accessible by conventional lighting.

While these lights are widely used, they may be less convenient than coaxial lights. Whenever the part is moved or tipped at an angle, the fiber optic light must be readjusted. In contrast, the coaxial light is always in the correct location.

Figure 11. Back Lighting

Figure 12. Fiber Optic Light As Used With Microscope

POLARIZING ACCESSORIES

In some instances, the glare from the lighting makes it almost impossible to see the features of the part which require deburring. In these instances it is possible to use polarizing accessories on the lens to reduce the glare. Polarizing accessories are very similar to the polarizing sun glasses commonly found at beaches. While eliminating the glare, polarization makes it possible to see the areas which must be deburred.

COLOR OF LIGHT

In other instances, the color of the light makes it possible to see the burr. This may not be an important factor on steel parts but it is on odd-colored, white, or dark colored parts. White

ceramic parts or copper colored parts may require color filters. Some microscopes come with a built in system to allow the use of green or blue filters in addition to the normal white light.

OTOSCOPES

Otosopes are hand-held flashlights, used to see inside ears (Figure 13). These light sources include a small magnifying lens and concentrate the light in a very small beam. On hand size and larger parts this combination lighting and magnification source is adequate to determine if burrs have been successfully removed. These are commonly used in situations where holes 1/4 inch or larger must be inspected.

SIGHT PIPES

Sight pipes are hand-held plastic cylinders with a 45-degree end, used to inspect hole walls (Figure 14), walls or bottom of holes as small as 0.250 inch. When necessary, a small penlight flashlight may be used to provide additional illumination.

To use this tool, insert it into a hole and look down at the top. A well-lighted full-sized image of the sidewall can be seen.

The sight pipe is made of crystal clear acrylic plastic, using both the optical and light-piping characteristics of this material. The enlarged head on the sight pipe collects natural light, and pipes it internally, illuminating the area to be viewed. The deep groove around the head makes it easy to use supplemental lighting such as a penlight, if needed.

Figure 13. Otoscope

Sight pipes can be used to inspect the surface finish of bores or sidewalls of cavities, intersections of small holes into larger bores, internal areas of castings for porosity or core placement, internal o-ring or snap-ring grooves, threads and the like.

Figure 14. Sight Pipe for Inspecting Holes

BORESCOPIES

Borescopes are miniature magnifying tubes which are used to inspect bottoms on sides of holes as small as 0.090 inch in diameter. Unlike the sight pipe, this tool contains an integral lighting system (Figure 15). Several fields of view are possible by altering the end of the tool.

Figure 15. Borescope for Inspecting Small Holes

PROBLEMS WITH LIGHTS

As previously mentioned, light bulbs quickly burn out if the power is left on high too long. It is a common problem, and while light bulbs themselves are not generally expensive, many of the newer bulbs cost \$5.00 to \$15.00 apiece. Whenever light sources are placed around working tools the possibility of breaking the bulbs or burning the hands is a very real safety hazard which must constantly be considered. In some cases, these light sources generate enough heat that they make hands perspire so that they cannot be successfully used for deburring. One of the major problems in most light sources is that they are not quickly focusable. If the part is stationary this does not represent a problem, but in most cases the part is not stationary; the part is held above tables and microscope platforms. A constant up-and-down motion brings the part in and out of the focus of the light beam. Also, as previously mentioned, it is very easy to obtain too much glare from some light sources.

PROBING

Although most burr related specifications at Bendix indicate that only visual means shall be used to verify the absence of burrs, in practice the touch sense is used. As an example, most individuals can detect a burr only 0.0005 inch high by drawing a fingernail over the burr-laden edge (Figure 16). Similarly, by using a wooden toothpick or similar probe it is possible to verify that a suspected burr exists or is absent. Because of the shadow effect generated by lights shining past radii, it is often difficult to determine if a black line at an edge is a burr or if it is a radius.

Figure 16. Detecting Burrs and Steps

Figure 17. Dental Pick

Figure 18. "Go" Gage Stopped Because of Burr

Fingernails and toothpicks are only some of the variety of items that can be used to determine tactilely if burrs exist. Dental picks (Figure 17) for example are excellent tools for this purpose as they have a very small diameter and have a bent end. Electronic probes can also be used. Size wires (gage wires) can successfully be used particularly in small gears to probe through the gear to the back edge. In some cases, a pipe cleaner is dragged over the edge, because any rough edges or rough burrs will tear pieces of cotton loose. These pieces of fuzz and lint become evident and indicate that the edge is not uniformly smooth.

Probing or the tactile approach in searching for burrs has three major problems:

- Probing can very easily scratch precision parts.
- Probing is very time consuming when done to the entire part, because many parts have many inches of edges.
- Probing itself is not foolproof, but it is an approach which can be used. It does not work except when probing in a direction 90 degrees to the burr.

In at least one case, an individual, using a fingernail to probe over edges, found that frequently scrapings from the fingernail were left on the edge. This was assumed to be the result of a sharp edge or burr. Actually it is possible to easily verify that fingernails drawn over any edge can leave fingernail scrapings. It is not necessarily the presence of a burr that leaves these particles on the part.

CLEANING

One of the most frequently overlooked aspects of locating burrs is the necessity of having a clean part to determine if burrs are

present. All too often, however, in the haste to move parts to the next operation parts are deburred as best as possible, cleaned and then submitted without a final scrutinization for burrs. On small features (miniature gears for example), it is impossible to tell if a particle at an edge is dirt or a burr still left at the edge unless the part is clean. It is absolutely essential that all parts must be cleaned when a final review is made for burrs.

USING GAGES TO DETECT BURRS

For a few parts gages have been designed to determine if burrs are present or if burrs of an excessive size are present. While this is not the normal case it can be done and has been done particularly for holes. An individual can use a "go" plug gage. This type of a tool is used to determine if a burr exists at either the entrance or exit side of holes. If this "go" gage fails to enter a hole it indicates that the hole is undersized or that a burr is thrown over into the hole interfering with this plug gage (Figure 18). Similarly, if the plug gage goes through the hole and not out the back side, the hole is slightly tapered, undersize, or a burr is thrown over into the hole interfering with the gage. These plug gages do not absolutely indicate that a burr is present but they are another weapon used in the war against burrs.

There are at least two problems with the use of gages when checking for burrs. The first problem is that burrs will wear or scratch these precision gages. This is not a practice normally condoned by those responsible for monitoring the size and quality of gages. The second problem is that in some cases the burrs may lock the gage in the part. Forcing the gage either through the hole or back out will not only scratch the gage but may also scratch the part.

BASIC APPROACHES FOR SPECIFIC FEATURES

Considering the comments which have been made in this chapter let's see how they can be used together. For example, we want to determine whether or not a hole has burrs left on it. First we can look at it through the microscope to determine if burrs are present. Secondly we could use a toothpick or pipe cleaner to determine if burrs are present. Also, plug gages are available as an indicator that something may be present in the hole.

On tapped holes we have a few more items to look for than we do on a plain hole. For example, we have to look at the crest of the threads to determine if they are burr free. (Figure 19) We have to look at the entrance to see if raised metal exists at the entrance. We have to look for a bent first thread. We have to look for a chip in the bottom of the threads and for dirt and chips in the roots of the thread. With a threaded hole for example, it is not possible to use a toothpick or any one of the items just mentioned to totally determine if the part is burr free. Here we have to use a combination of approaches. We can use probes at the surface, and we can use a threaded "go" gage to determine if burrs were causing interference. We have to use lights that look down on the bottom of the holes, and we have to have a clean part.

Figure 19. Burrs and Related Conditions on Thread Holes

ASSIGNMENT

1. Look at a blind threaded hole using a Nicholas illuminator, then with a gooseneck fiber optic light adjust the light intensity for better visibility.
2. Using a sample to be provided, deburr the part and verify that all edges are burr free using the concepts defined in this chapter.
3. Take a human hair, stretch it out taut then run your fingernail across the hair to show that it is easy to detect a burr only 0.003-inch high.
4. Take a piece of shim stock only 0.0005-inch thick, lay it flat on the table, hold it taut and run your fingernail across it to show that it is easy to detect even a 0.0005 inch high step.
5. Define the basic concepts for looking for burrs.
6. Practice using each of the eleven light sources discussed and evaluating within your own mind advantages and disadvantages of each of these light sources.
7. Using a piece of white ceramic as a workpiece look through the microscope at the ceramic to determine if edges are sharp or radiused. Use a white reflector at the base of the microscope. Repeat this procedure using a black reflector at the base of the microscope.
8. In a production situation in which you do not have a black reflector for the microscope, list the products you could use as a black reflector.

CHAPTER 3

TYPES OF DEBURRING TOOLS

There are basically 19 types of deburring tools and 59 subcategories of these tools in everyday use at Bendix. At the present time, there are 269 deburring tools listed in Tools Used For Hand Deburring.¹ As seen in Table 1, the deburring tools consist of knives, files, bur balls, scrapers, and a variety of other items.

This chapter concentrates on defining each of these categories of tools and illustrating or discussing the basic use of each one. It is important in completing this course to know each of these types of tools and not only the individual subcategories of them but to actually know what the individual tools themselves look like. As a result, you are actually expected to know what the 269 commonly used deburring tools are.

KNIVES

Triangular knives are typically used to cut or scrape burrs from straight edges. (Figure 1). Oval knives are normally used for hole edges or hard to reach areas. Specially shaped knives were designed for burrs on a specific part but are often useful in other situations. Scalpel blades are used for trimming flash from plastic. They are rarely successful, however, for metal burrs because of the metal's hardness.

FILES

More than 2700 different files in a variety of sizes can be purchased commercially. Swiss escapement, parallel machine, needle,

Table 1. Categories of Deburring Tools Used at Bendix

	Shown in Figure	Typical Code Number
Knives		
Triangular	1	48001706
Oval	1	48001767
Special Shapes	1	48002275
Scalpel Blades	1	14503246
Files		
Large	2	52509600
Minature	2	52510003
Round (rattail)	2	52508050
Half Round	2	52510060
Triangular	2	52510005
Curved or Bent	2	52511030
Bur Balls, Burs, Rotary Files		
Bur Balls	3	52620475
Burs	3	52620490
Rotary Files	3	52620140
Scrapers	5	14503202
Countersink Tools	6	50903106
Brushes		
Wheel	7	10207255
Cross Hole Deburring	7	10207225
End and Cup	7	50952050
Abrasive Filled Rubber Products		
Bullets	8	10604822
Cylinders	8	10604803
Flat Bars	8	10604688
Discs	8	10207200
Cups	8	10604823
Dental Bullets	8	10604819
Abrasive Filled Cotton Products		
Cylinders	9	10202224
Balls	9	10203109
Bars	9	10601520

Table 1 Continued. Categories of Deburring Tools Used
at Bendix

	Shown in Figure	Typical Code Number
Abrasive Filled Cork Products		
Ball Nose Cylinder	10	10201419
Bullet	10	10204816
Abrasive Paper Products		
Discs	11	10509706
Rolls	11	10400920
Sheets	11	10502856
Cord	11	10507016
Felt Bobs		
Discs	12	10207210
Bullets	12	10207220
Cylinders	12	10202246
Lapping Compounds	12	10650612
Mounted Points		
Balls	13	10200608
Discs	13	10203106
Cylinders	13	10200600
Cones	13	10201100
Special Shapes	13	10200607
Hand Stones		
Bars	14	10604036
Triangles	14	10601608
Cones	14	10604050
Points	14	10600502
Mandrels for Tools	15	48002589
Pin Vises		
Dog Nose	16	48002281
Collet	16	52103005
Motorized Tools		
Bench Motors	17	---
Air Motors	17	---
Dental Tools	17	---
Jitterbug Sanders	18	---
Belt Sanders	18	---
Reciprocating Files	18	---

Table 1 Continued. Categories of Deburring Tools Used at Bendix

	Shown in Figure	Typical Code Number
Miscellaneous Tools		
Swivel Blade Tools	19	50951700
Back Side Cutters	19	50951735
Special Design Tools	19	MS274851-002
Vacuum Probes	19	---

riffler, diemaker riffler, and die sinker riffler files can be found in a variety of miniature sizes. The files are rectangular, triangular, round, curved, or bent (Figure 2). Some are made from high speed steel; others are made from carbide or diamond particles plated onto a steel shank. Each of these can be used on any part, although it is easy to exceed 0.003 inch edge breaks when using many of these tools. Although the needle files come to almost a sharp point (0.030 inch), the narrowest rectangular file used at Bendix is 0.015 inch thick. Some triangular files, however, come to a knife-edge-like corner, which is thinner than 0.015 inch, and all can be quickly thinned if necessary.

BURS

Bur balls and related tools (Figure 3) also can be purchased in a variety of diameters, shapes, tooth coarseness, and materials (Figure 4). One company alone lists 1028 different burs and rotary files in its catalog. Although bur balls are the most used type of these tools, pointed cones and flame-like shapes also are in frequent use (Figure 4). For most miniature part uses, these tools are placed in pin vises and rotated by hand. All of these tools can be inserted in bench motors, air motors, or dental motors to provide faster action. These tools tend, however, to chatter or

Figure 1. Typical Deburring Knives

Figure 2. Typical Files

Figure 3. Typical Bur Balls and Related Burs Used at Bendix

Figure 4. Common Shapes of Burs

cut too deep unless very fine teeth are used. The smallest commercially available tool is a 0.004 inch ball. The smallest standard ball diameter is 0.020 inch. Several of these shapes will deburr the backside of holes which may be inaccessible by other means. These tools can be used on numerically controlled machines or other machines as well as manually.

SCRAPERS

Several scrapers are available commercially for removing burrs. A simple paint scraper (Figure 5) is used on larger parts but is not generally small enough to use on miniature parts. In addition, maintaining small edge breaks is difficult with these tools.

COUNTERSINK TOOLS

The Bendix coded tool catalog lists more than 100 countersink tools (Figure 6). These come in at least three basic geometries. Most drills and reamers also are often used to remove burrs in the same manner as countersink tools. These tools also are typically rotated by hand rather than in a machine to prevent excessive edge break.

BRUSHES

Fifteen miniature brushes are in common use on miniature parts. These brushes include the small diameter wheel-like brushes, end brushes, cup brushes, and cross hole deburring brushes (Figure 7). Brass fiber brushes will discolor steel parts, and all brushes can eventually pick up enough oil or grease to leave black marks on stainless steel parts. At speeds of 20,000 rpm, nylon brushes

Figure 5. Scrapers Used for Deburring

Figure 6. Typical Countersink Tools Used for Deburring

Figure 7. Typical Brushes Used for Deburring

Figure 8. Typical Abrasive Filled Rubber Products Used for Deburring

will melt and leave a nylon film on parts. Few small diameter brushes can be purchased as standard items, but most brush manufacturers will make any brush that a company wishes. End brushes are useful for removing splattered metal drops left by electrical discharge machining or welding processes.

ABRASIVE FILLED RUBBER PRODUCTS

For deburring small parts, bullet-shaped rubber tools (Figure 8) are widely used. They can be purchased in four different levels of aggressiveness. The degree of aggressiveness is determined by the size and number of silicon carbide particles molded into the rubber. To facilitate identification, the degree of aggressiveness is indicated by color. For example, brown indicates a medium aggressiveness, dark green indicates coarse, red designates fine, and light green indicates extra fine for one manufacturer. Products produced by other manufacturers have different color codes.

If these products are used on lathes or mills, the particles that are worn off may score or scratch machine ways. If blown into chuck jaws or collets, these particles will indent subsequent parts.

ABRASIVE FILLED COTTON PRODUCTS

When there is a requirement for more aggressive cutting than is provided by abrasive filled rubber, a normal choice would be abrasive filled cotton or muslin (Figure 9). By varying abrasive size and the type of bonding agent, it is possible to produce smooth radii and fast burr removal. This is a widely used tool in the aircraft industry for the reasons mentioned.

Figure 9. Abrasive Filled Muslin Tools Used for Deburring

ABRASIVE FILLED CORK PRODUCTS

Cork particles and abrasive particles bonded together with special glues or resins are also used for fast cutting with smooth radiusing (Figure 10).

Figure 10. Abrasive Filled Cork Tools Used for Deburring

ABRASIVE PAPER PRODUCTS

A variety of sandpaper-like products are used on the miniature parts (Figure 11). The miniature discs have adhesive backs for holding them to mandrels. The smallest commercially available disc size is 0.5 inch diameter. Smaller sizes have been punched out with dies made at Bendix.

FELT BOBS

Occasionally, specially formed felt shapes (Figure 12) are used with a diamond lapping compound to remove burrs. Usually, the abrasive-filled rubber products will deburr faster without generating too large a radius.

Figure 11. Typical Abrasive Paper Products Used for Deburring

Figure 12. Typical Felt Bobs and Lapping Compound Used for Deburring and Polishing

LAPPING COMPOUNDS

Lapping compounds are used to provide smooth, lustrous surfaces. While they are not typically used for removing burrs, they will remove small burrs and produce smooth radii. They are easily used on flat surfaces and in holes.

MOUNTED POINTS

Miniature grinding wheels, known as mounted points (Figure 13), are used for edge finishing in many companies, but these commercial tools are too abrasive for many miniature part applications. The mounted points used in the dental industry are, however, widely used for the miniature parts. Mounted points, too, come in a seemingly endless quantity of sizes, shapes, and materials. The diamond coated tools used in the dental industry quickly break edges in hard-to-reach areas without chatter.

HAND STONES

A wide variety of abrasive hand-held stones also are in use for removing burrs and improving finishes (Figure 14).

MANDRELS

Many of the tools shown in Figures 1 through 10 require a special mandrel (Figure 15) to hold them.

Figure 13. Typical Miniature Mounted Points

Figure 14. Typical Abrasive Hand Stones Used for Deburring

Figure 15. Mandrels Used to Hold Miniature Tools

Figure 16. Pin Vises

PIN VISES

A variety of pin vises (Figure 16) are used to hold parts and tools for deburring. Some of these have brass collets or jaws to prevent indenting the part while it is grasped. In addition to those that locate on the outside diameter of parts, four are available for grasping inner diameters. When necessary, these can be machined to hold smaller diameters or special shapes.

MOTORIZED TOOLS

More than 500 motorized tools for deburring can be purchased. For example, one company offers 15 different dental tool motors. Motors powered with belt drives, integral electric motors, flexible shaft drives, or air powered motors can be obtained. Some operate at 2000 rpm and others operate at 400,000 rpm. An estimated 50 different designs of these tools are used by Bendix (Figures 17 and 18). Although each of these products can be used successfully with no training, it is necessary to lubricate some of the dental tools several times a day. In most applications, the motors that operate at 20,000 rpm or slower are designed to remove burrs by applying a measurable force to the part, while faster ones require only a light touch.

MISCELLANEOUS TOOLS

For noncritical parts, several swivel-bladed tools are available (Figure 19). Some tools are designed to remove burrs from the bottom side of holes when that side is inaccessible by normal means. Roughly 20 tools have been designed to deburr a special feature on a specific part. Whenever conventional tools will not remove

Figure 17. Motorized Deburring Tools

Figure 18. Jitterbug Sander and Reciprocating File

a burr, the process engineer should be requested to design a special tool or to purchase some of the non-standard burr tools (Figure 19).

On a few parts, chips and loosely attached burrs are difficult to remove because of their location (in deep holes, for example). Sometimes a vacuum probe and vacuum producing motor will remove these particles.

The tools just shown and described are typical of those used at Bendix and at many other companies. There are a variety of other tools, however, that do not fit as neatly into the system of categorizing tools as the ones shown. It is possible today to buy an estimated 3000 different hand deburring tools. In reality the number of tools which can be used for deburring probably approaches 5000 in addition to all the drills and reamers which are also used. The items shown in this chapter however, form the bulk of those which are commonly used in most companies and Bendix in particular for removing burrs. Later chapters will describe in more depth into the capability, limitations, and the size and shape availability of many of these tools.

SOURCES OF ADDITIONAL INFORMATION

1. L. K. Gillespie, TOOLS USED FOR HAND DEBURRING, Bendix Kansas City, report BDX-613-2111R, May, 1979.
2. A GUIDE TO DEBURRING, DEFLASHING, AND TRIMMING EQUIPMENT, SUPPLIES AND SERVICES, SME Bibliography Series Report, 1976.
3. SUPPORT STORES MATERIAL CATALOG, Books 1 and 2, Bendix Kansas City Division, November 1, 1978.

ASSIGNMENT

1. Make a list of the 19 major catagories of deburring tools.
2. Using the photographs supplied, identify the types of deburring tools shown in the photographs.
3. Approximately how many deburring tools does Bendix Kansas City use?
4. What category does sandpaper come under?
5. What would you call a miniature grinding wheel?
6. Are files commonly used on miniature parts?
7. What one consideration must you make when holding parts?
8. List one miscellaneous type of tool not described in this chapter.

CHAPTER 4

KNIVES AND THEIR USE

USING DEBURRING KNIVES

There are two basic approaches to using knives. They can be used as fist tools or as finger tools. Fist tools, scrapers, large knives, and many large tools are used with the power being supplied by the whole hand and arm. An example is a paint scraper where the fist is clutched around the tool holding it tightly and applying a great deal of pressure. Figure 1 illustrates the fist position. While this is used on very large parts, it is not a successful approach on miniature parts or precision parts because it does not permit feeling the burrs. On precision parts, the finger is used as a tactile indicator of the actual condition. In the fist position, the knife essentially is scraping through and past the edge being deburred. Considerable momentum is developed and it is difficult to stop or control the amount of edge break applied to a part. Using the fist position to pull a knife through the part can cause cuts on the thumb, gouges on the part, or cuts to the hand holding the part. This is an awkward use of a precision tool, a tool that is in itself inherently dangerous; that is, the knife is designed to cut and will do just that to the hand or the part.

The fist position, of course, is widely used on very large parts in which delicate action is not required. Figure 2, for example, illustrates some of the tools which are commonly used in a fist position.

This chapter deals primarily with the use of knives in the finger position. Figure 3 illustrates one of the two approaches to the finger position. In this case, the knife is held with two fingers

Figure 1. Fist Position of Knife Usage

Figure 2. Tools Commonly Used in a Fist Position

Figure 3. Overhand or Pencil Finger Position of Knife Usage

Figure 4. Underhand Finger Position of Knife Usage

and the thumb, almost like holding a pencil. This is called the pencil position. The second position is the underhand position (Figure 4).

In the pencil position (Figure 3), the knife can be rotated to accommodate changes in intersecting planes on the part. The middle finger can be used as a surface feeling probe. By using this method under a microscope, a small burr can be removed as easily as writing with a pencil.

In the underhand position (Figure 4), the knife can also be rotated for easy burr removal. In this position, the ring and small fingers can be used as a surface support. The index finger can be used as a surface feeling probe. This is a particularly useful approach for deburring holes. This approach permits rotating the tool around the contour, providing uniform force against the edge.

In deburring, both the underhand and the finger positions are widely used for deburring. While it takes a certain amount of practice to develop skill, in just a matter of a few minutes it is possible to evolve a general appreciation for handling knives in this manner. In addition to greater safety for the part, these approaches minimize the danger of cutting oneself or losing control near the edge of a part. Precision deburring requires precision movements and skill. Using these approaches is not greatly different from the free flowing writing in handwriting. Smooth even strokes around the contour of the parts are required for precision and minimum fatigue.

TYPES OF DEBURRING KNIVES

Deburring knives come in a variety of shapes and sizes. Each shape has been developed to do a specific job, but many shapes and sizes can be used on many different parts. The actual use of these knives

will vary slightly from each person. Some individuals will find that the tool is particularly adaptable to a left-handed worker while others will find that same tool works equally well for right-handed workers in certain applications. Personal preference plays a major role in the use of tools, just as it does in the brush of a painter. There is no attempt to force individuals to adapt to a specific style. The worker needs to practice and observe those around him.

The deburring knives come in four basic shapes: triangular, oval, sharp scalpel blades, and special shapes. The special shapes would include such tools as the flat point or chisel type of tool, a scraper, angle hooked tools which look very similar to golf clubs, tools with a cone shaped end, and related special design knives. There are numerous sizes and shapes available in each category as shown in some later illustrations in this chapter.

As implied by its name, the triangular knife has three cutting edges (Figure 5). These knives can be ground either concave or convex. Concave or hollow ground knives have a very sharp edge but they dull quicker and are more likely to chip (Figure 6). Convex ground tools (Figure 7) have a more rigid body on each edge, and as a result can last longer. In addition, they can be reground much faster with existing equipment than the concave tools. Both convex and concave ground tools are used at Bendix. In many cases, within the same tool storage bin, both types of tools can be found. Whether one gets convex or concave ground tools depends upon whether they were ground at Bendix or by an outside vendor.

All knives, including the triangular ones, can be used in the pencil or underhand position. The use of these knives with the fingers enables the user to rotate the knife to suit the edge or corner to be deburred. Typically, a triangular knife is used on a straight edge about 1 inch long. In contrast, the oval knives are used in

Figure 5. Triangular Knife Cutting Edges

Figure 6. Concave Grind on Triangular Knife
(Concavity Exaggerated for Clarity)

Figure 7. Convex Grind on Triangular Knife

Figure 8. Oval Knife

round holes. These distinctions, while generally true, are not always followed in practice and should be used only as general guidelines.

The oval knife (Figure 8) has a cylindrical body and a flat surface ground at an angle which gives the working edge an oval shape. While they are principally designed for removing burrs in holes, they are often used both to chisel out burrs and to reach difficult areas. Figure 9 shows a variety of oval knife sizes.

The angle hooked knife (Figure 10) has two cutting edges at 90 degrees to the shank. This allows the user to remove the edge burrs along a slotted groove (Figure 11). This tool will fit into most slots to remove edges, and sometimes it can be used to remove burrs from both edges of the slot at the same time. Special angle hook knives are designed to clean out and deburr threads or to scrape along a single edge. Figure 12 illustrates some of the variety of angle hook knives used at Bendix.

The chisel or flat pointed knife is generally a cylinder shaped tool with a flat ground on each side leaving a flat sharp edge much like a sharpened screwdriver (Figure 13). The chisel is used as a knife and is not used with pounding motion but rather a gentle pushing motion to scrape loose burrs. A typical application would be to clean out chips in the bottom of a blind tapped hole. Figure 14 illustrates some of the variety of sizes available in this type of tool.

As implied by its name, scrapers are designed as tools to be drawn or pulled over the workpiece as opposed to being pushed into the workpiece. One of the popular scrapers in use is called a Red Devil, one manufacturer's name for its paint scraper. This scraper is used for larger edges, typically a part which is 5 to 10 inches in diameter. Figure 15 illustrates the use of one of these scrapers.

Figure 9. Oval Knife Sizes Available at Bendix

Figure 10. Angle Hooked Knife

Figure 11. Use of Angle Hooked Knife to Deburr a Slot

Figure 12. Angle Hooked Knives

Figure 13. Chisel Edge Knife

Small scrapers have also been designed for use in areas when other tools do not work satisfactorily.

The cone end tool is often used to clean out and deburr threads. This tool has a double cone back-to-back with a flat surface ground to the center line (Figure 16). This enables the tool to remove burrs from hard to reach areas such as blind holes. This is also used if a slot is cut into the wall of a tube (Figure 11). This can deburr most of the inside edges. Some individuals prefer this tool to an angle hook tool for deburring threads or tapped holes, particularly for the larger sizes (1/4 inch diameter, for example).

Figure 14. Other Chisel Edge Knives

Figure 15. Paint Scraper Used for Deburring Large Parts

Figure 16. Cone End Tool

Scalpels (a surgeon's scalpel or a hobby sharp bladed knife) are used almost exclusively in removing flash from plastic molded parts. Because of its thinness this type of knife is not well suited for removing chips or burrs from metal (Figure 17).

Knives cost from \$3 to \$60 each. The oval knives, which are the easiest to make, are the least expensive. In many cases, if the order quantities are high enough, the cost of these tools is only \$2 to \$3 a tool. The triangular knives require more grinding, and for this reason are more expensive. The angle hook knives cost \$10 to \$20 each, because they require considerable machining. Chisels cost from \$3 to \$10, and commercial scrapers cost \$1 to \$2 apiece. Any special design tool becomes expensive when small quantities must be ordered.

When performing deburring on a daily basis, it is essential to have the proper tools on hand when they are needed. For this reason, most individuals doing deburring will have 20 to 50 knives, with a variety of different sizes and shapes, in their toolbox at any one time. There is a natural tendency to use some tools too long, allowing the tools to become dull before they are returned for regrinding. Dull tools require considerably more strength to use for deburring and do not work as well as sharp tools. For this reason, whenever tools are dull they need to be returned to the tool crib and exchanged for new tools.

Before using a deburring knife, the user should investigate the edge under a microscope. It is too easy to grind deburring knives so that the edges are ragged or chipped. In some cases, these tools are reground, 1000 at a time, and it is easy for those doing the grinding to overlook those which are improperly ground. Improperly ground tools will not last. In some cases, when looking at newly ground tools, one will find a burr on the tool. It is important in this situation to identify this problem to the

Figure 17. Scalpel Blades Used for Deburring

Figure 18. Knives Generate Burrs

supervisor so that he can correct the situation. Deburring knives which have burrs on them will not successfully deburr parts.

Table 1 lists the characteristics of knives currently being used at Bendix.

KNIVES MAKE BURRS

While knives are widely used for deburring, it should be noted that while removing a burr they typically make two more small burrs (Figure 18). Even these small burrs are objectionable on many parts. As a result, one must either scrape (as opposed to cut) off these small burrs or use abrasive filled rubber products, brushes, or related tools to remove these knife-made burrs.

RELATION BETWEEN THE KNIFE AND PART

In the chapter on microscopes, it was noted that the worker does not hold the part down on the microscope base or table (Figure 19). It is important for both part quality and personal safety to hold the part above a solid surface (Figure 20). If necessary, wrists or arms may rest on the table top.

When using the table to support the part, any sudden lunge with the hand holding the knife will gouge the part or cut the other hand. By holding the part in the air, the grasping hand easily and quickly responds to sudden motions by the knife wielding hand. Abrupt changes in burr sizes or location can easily cause minute lunges.

As indicated previously, knives are inherently dangerous. They are designed to cut. In normal use, deburring knives do not present a safety problem. Any time a knife is used in a fist

Table 1. Characteristics of Bendix Deburring Knives

Bendix Code Number	Tool Type	Shank Diameter (Inch)	Working End Diameter (Inch)
48001702	Triangular	3/16	0.187
48001703	Triangular	1/4	0.250
48001705	Triangular	5/32	0.156
48001706	Triangular	1/8	0.125
48001707	Triangular	1/8	0.062
48001709	Triangular	1/4	0.250
48001710	Triangular	3/16	0.187
48002265	Triangular	1/4	0.156
48002271	Triangular	3/16	0.075
48002274	Triangular	0.156	0.037
48001738	Oval	1/8	0.060
48001767	Oval	1/4	0.100
48001768	Oval	1/4	0.100
48002266	Oval	1/4	0.093
48002268	Oval	1/4	0.156
48002272	Oval	1/8	0.125
48002286	Oval	3/16	0.096
48002287	Oval	1/4	0.156
48003065	Oval		0.020
48000127	Angle Hooked		0.063
48001507	Angle Hooked	1/4	0.031
48002269	Angle Hooked	1/4	0.100
48002270	Angle Hooked	1/4	0.200
48002276	Angle Hooked	1/4	0.005
48002279	Angle Hooked	1/4	0.096
48002280	Angle Hooked	1/8	0.062
48002290	Angle Hooked	1/8	0.091
48002996	Angle Hooked	1/8	0.062
48002997	Angle Hooked	1/8	0.062
48002998	Angle Hooked	1/8	0.062
48100067	Angle Hooked	1/8	0.062
48002273	Cone End	1/4	0.100
48001712	Chisel	1/8	0.096
48001747	Chisel	1/8	0.065
48002275	Chisel	1/8	0.030
48002277	Chisel	1/8	0.310
48002278	Chisel	1/8	0.125*
48003027	Chisel		0.062
48003034	Chisel	5/32	0.084

Table 1 Continued. Characteristics of Bendix Deburring Knives

Bendix Code Number	Tool Type	Shank Diameter (Inch)	Working End Diameter (Inch)
14503245	Scalpel Blade		
14503246	Scalpel Blade		
14503249	Scalpel Blade		
Scraper Style Knives			
48000732	Altered Pillar File	1/4	0.200
48000733	Altered Pillar File	1/4	0.200
48002916	For Gear Forms	1/4	0.062
48002284	Special Shape		0.150
48002285	Wax Carver	1/8	0.125

*End of chisel is in shape of "T".

position, however, the possibility is ever present for cutting oneself or injuring those close by. For this reason, knives should not be used in the fist position except in special circumstances. In no case should knives be used for anything except their intended purpose.

Figure 19. For Personal Safety and Part
Quality DO NOT Hold Part
Against Solid Surface

Figure 20. Correct Way to Hold Part While Hand Deburring

ASSIGNMENT

1. Practice using each of the knife holding positions.
2. Using knives only, deburr at least one of the parts provided.

CHAPTER 5

MOTORIZED TOOLS AND THEIR APPLICATION

There are five basic categories of motorized tools:

- Bench motors,
- Air motors,
- Flexible shaft motors,
- Portable sanders, and
- Reciprocating files.

Most individuals performing deburring will use a bench motor, an air motor, and in many cases, a flexible shaft motor on an almost daily basis. The advantage of motorized tools is that they are much faster than hand motions alone. In many cases, a motorized tool will speed deburring by a factor of two, three, and even up to five times the normal rate. There are some 500 different motorized tools used in the U.S. for deburring, deflashing, and polishing applications. This chapter will deal with those in common use on miniature parts.

BENCH MOTORS

There are at least three kinds of bench motors in common deburring use at Bendix. These include the belt driven motor with the three jaw chuck, the belt driven motor with a series of collets, and a direct drive with a three-jaw chuck (Figure 1).

The advantage of three jaw chucks is they will easily accept any shank size available. The motors which have collets on them require that you select the proper collet, remove the collet from the

Figure 1. Bench Motors Used at Bendix

motor and replace it with the correct size collet. This requires considerable time to use two or three different rotary tools in deburring. The collet type motor, however, has one advantage in that the collet normally will not damage precision parts if used carefully.

The belt driven motors which are available require the operator to use different pulleys on the motor to obtain different speeds. While this is not difficult, it will slow down some operations slightly. Small pulleys on the tool spindle will result in high speeds. Using the large diameter pulley on the same spindle will slow down the motor.

The direct drive motor which is available has a maximum speed of 3100 rpm. The belt driven motors have approximately the same maximum speed. Table 1 provides a general comparison of the various motors and their speeds typically used at Bendix. It should be noted that purchase motors with significantly different speed ranges and capabilities are also available.

The bench motors are reasonably heavy units, designed to be placed on a bench and left there. Typically, these tools are used to hold small brushes for brushing after the large burrs have been removed. In some cases, they can be used to hold felt bobs, or rubber filled abrasive products. They may be used also to hold the part while it is being deburred. In this type of usage, however, it is important not to tighten the chuck too much, because it will damage the part either by squeezing it out of shape or by indenting and leaving marks on the part. In typical usage, the part is held to the brush in the motor and rotate the part until all of it has been brushed (Figure 2).

AIR MOTORS

Bendix uses two basic types of air motors. The conventional industrial air motor in most common use accepts a 1/8 inch diameter collet and uses air pressures of 50 to 80 pounds a square inch (Figure 3). These air motors run at 50,000 rpm. Such high speeds motors require filtered air with a small amount of oil in the air. Typically, small, abrasive-filled rubber products or small sanding devices and even dental stones are put in the small air motors. These tools are then handled much like a small pencil. Only light pressure is used under normal circumstances. In some situations when using a low speed motor or low speeds on these motors, considerable pressure must be exerted to grind off the burrs.

Table 1. Characteristics of Deburring Motors Used At Bendix

<u>MOTOR</u>	<u>COLLET/CHUCK</u>	<u>POWER SOURCE</u>	<u>SPEED RANGE</u>	<u>SAFETY</u>	<u>TYPICAL COST</u>
BENCH MOTOR					
1. Direct Drive	Jacobs Chuck	Elect.	0 - 3100 RPM	Chuck Key	\$350
2. Precision Belt	Jacobs Chuck	Elect.	800 - 3600 RPM	Chuck Key	850
3. Belt	Collet	Elect.	800 - 3600 RPM		350
AIR MOTOR					
Industrial	1/8" Collet	Air (80 PSI)	0 - 50,000	Do Not Use Brushes	140
Dental	Collets	Air (40 PSI)	0 - 6,000	Do Not Use Brushes	350
Flexible Shaft	Collets or Chuck	Elect.	0 - 14,000	Do Not Use Brushes	200
Hand Held Sanders	----	Elect. or Air			150
Reciprocating Files	----	Air/Elect.	0 - 14,000		350

Figure 2. Typical Bench Motor Use

Figure 3. Industrial Hand Held Air Motors Used for Deburring

One of the most popular deburring tools at Bendix is the dental air motor (Figure 4). These are motors actually used by dentists while working on teeth. They have a number of significant advantages. The major advantage is that they are very small. The second advantage is that a number of different styles of heads are available for use with these air motors. These heads permit the use of a variety of shank sizes and shapes. In addition, these tools are very light, they are very precision, and a number of tools are available for use with them. It is important in using these tools to recognize and to verify that the pressure driving them is no more than 40 pounds per square inch. High pressures will burn up the motor in 1 minute or less. These motors have both forward and reverse directions and an adjustable speed control which will provide any speed up to 6000 rpm (motors with speeds up to 400,000 rpm are commercially available).

There are three different heads for these motors, and additional heads can be purchased. These heads take three different shape tools. For example, one head will accept a 3/32 inch diameter straight shank tool. Another will take a 1/16 inch diameter straight shank tool. The third one will take a 3/32 inch diameter shank tool which has a groove and flat at the end of it. By removing the heads, a 3/32 inch shank tool can be inserted into the handpiece itself (Figure 5).

While these dental tools will not accept many of the large industrial rotary deburring tools available at Bendix, they will accept a large number of dental tools. These dental tools include rubber dental points, rubber dental cups, rotary files, rotary burs, and rotary dental stones (Figure 6). As in the case of conventional industrial air motors, these tools require very light pressures for normal deburring. Heavy pressures will tend to break down the bearings and collet bushings.

Figure 4. Dental Air Motor

Figure 5. Heads and Shanks Used With Dental Air Motor

FLEXIBLE SHAFT MOTOR

Flexible shaft motors (Figure 7) are widely used for deburring miniature and even larger parts. These motors have variable speeds that permit the use of up to 10 different hand pieces (Figure 8). Some of the hand pieces available have 3 jaw chucks on them. Others have collets, and a few have sets of collets which can be inserted in them. The most common available hand pieces have 3/32 inch diameter straight shanks or 3/32 inch diameter shanks with a flat and a groove cut in the end. As in the case of the dental air motors, these will accept all of the dental tools and many of the commercial cutting tools. The advantage of these tools is that they are in many cases sturdier or more useful in industrial applications than the lighter dental tools.

HAND HELD SANDERS

A number of handheld sanders (Figure 9) are available at Bendix although these are not commonly used on miniature parts. A typical use for the handheld sanders is on sheet metal parts or parts 5 to 10 inches in diameter or larger. Commercially, at least 100 variations of these sanders are available at a relatively low cost. The advantage of these tools as in the case of any rotary tool is that they are much faster than hand motions alone. Rotary sanders, orbital or jitterbug, as well as belt sanders are commercially available. Belt sanders are available with belts only 1/4 inch wide.

RECIPROCATING FILES

Figure 10 illustrates a reciprocating file which is available for use at Bendix. These tools use a variety of miniature files or

Figure 6. Dental Tools Used in Dental Air Motor

Figure 7. Flexible Shaft Motor and Handpiece

sanding products to provide a back and forth motion in hard-to-reach areas. These tools are not widely used for miniature parts, although miniature files only 0.014 inch thick are available for use with them. The principal application would be used on dies, molds, sheet metal, and larger sized parts.

SAFETY CONSIDERATIONS

Rotary motors of any kind present some form of safety hazard. The fact that they are rotating implies that the possibility for throwing things exists and the possibility exists for individuals to come in contact with the rotary portion of the motor. The following specific problems are included:

Figure 8. Handpieces Used With Flexible Shaft Motor (Photograph Courtesy Foredom Electric Company)

Figure 9. One Type of Hand Held Sander Used for Deburring

Figure 10. Reciprocating File Used for Deburring Hand-Size and Larger Parts

- On three-jaw chucks, forgetting to leave the chuck key in the chuck will cause it to be thrown out when the motor begins. Even though these chuck keys are very small, they develop tremendous force when thrown from the motor. They are safety hazards which must not be allowed to occur. REMOVE ALL CHUCK KEYS BEFORE STARTING THE MOTOR.
- As mentioned before, typical use of bench motors is for brush deburring. These brushes will grab clothing and wrap the clothing around the tool in the motor. For this reason, it is important to not allow clothing to come in close contact with the end of the chuck or the tool.
- In all cases, eye glasses should be worn around rotating machinery and even the innocent looking handheld motorized tools.
- All motorized tools should have a cover over the area of the tool and any exposed edges which would scrape or grab clothing, hands, or fingers.
- It is particularly important on air motors to not use small diameter-shaped tools which extend a large distance from the chuck. For example, do not use miniature brushes in high speed motors. At high speeds, brushes will bend, grab shirt sleeves, and scrape knuckles. In addition, the possibility of such tools flying off of the spindle is very real and the possibility of fibers being thrown off from the brush is also very real and ever present.

ASSIGNMENT

1. Practice using each of the motorized tools described in this chapter.
2. Verify the pressures available for air motors, and learn how to change air pressure settings.

CHAPTER 6

USE AND CARE OF THE MICROSCOPE

A prime requisite for deburring precision miniature parts is a good microscope with which to view the part while deburring. Figures 1 through 4 illustrate some of the microscopes now in use for deburring precision miniature parts at Bendix. While other microscopes are available, these four types are more common. While there are obvious differences between these microscopes, they all operate basically the same. The first two are known as stereo zoom microscopes; stereo implying there are two eyepieces with which to view the part. This provides greater depth of field than is possible with a single eyepiece. The zoom implies that the level of magnification is adjustable. The latter two figures illustrate microscopes which have adjustable magnification levels. These two microscopes have three or four different magnification levels that can be dialed into the microscope. The first two microscopes have an infinite variety of magnification levels.

DEFINITIONS

Figure 5 illustrates some microscope definitions. The eyepieces are the removable objects used to view the workpiece. Eye shields are protective devices or shields to prevent light from interfering with the view. The power body is a removable portion of the microscope in which all the lens and focusing devices are attached. The eyepiece tubes are round channels for the eyepieces. While the eyepieces themselves may be removed, the

Figure 1. Stereozoom Microscope
Used for Deburring

Figure 2. Stereozoom Microscope (Enlarged)

Figure 3. Stereo Microscope With Coaxial Lighting and Click-Stop Magnification Levels

Figure 4. Operating Stereo Microscope With Coaxial Lighting and Three Magnification Levels

Figure 5. Microscope Definitions (Courtesy, American Optical)

eyepiece tubes are permanently attached. On most microscopes there are focusing knobs on both sides of the microscope which are used to move the power body up and down on the stand. The zoom magnification knob adjusts the amount of magnification of the part. The working height is the amount of free area beneath the auxillary lens and above the stage plate surface. This represents the available space to place the object or the tools for deburring. Note that the microscope shown also has a trans-illuminating base to provide light shining upward past the part. While this feature is available on many microscopes, it is not commonly used on those for deburring precision miniature parts. It is an accessory which can be added as the need arises.

It should be noted that there are two primary replaceable lenses in most microscopes. The eyepieces have lenses in each of them. The amount of magnification on these lenses is marked on the eyepiece. The auxillary lens on the bottom side of the power body also increases or changes the level of magnification available. It is possible to change either the magnification on eyepieces or the auxillary lens for greater magnification or for greater depth of field.

FOCUSING

Initially, it is important to focus the microscope correctly.

- Place a flat surface specimen in the center of the stage plate.
- Illuminate the specimen.

Figure 6. High Magnification
Reduces Depth of Field
and Area Viewed

- Using the focusing knob, raise the power body of the microscope above focus, if necessary, then lower the body to bring the object into sharp focus.

This technique reduces the tendency of the eye to accommodate and minimizes eye fatigue. Adjust the eyepieces laterally to accommodate your eyes. The proper technique is to first move the gear-linked eyepiece tubes apart then move them together as quickly as possible until the two fields of view become one.

NOTE: If eyeglasses are worn in normal activities, then they should be worn during the set up and usage of the microscope.

Initially focus the microscope using the following procedure.

- Set the calibrated zoom magnification knob (on operator's right) to highest power; either 2.5X or 3X, depending upon the model being used.
- With the left eye closed, look through the right eyepiece. Using a focusing knob, lower the body of the microscope until the flat object is in sharp focus.
- Next, set the magnification knob to the lowest power; either 0.7X or 1.0X, depending upon the model being used.
- Without disturbing the focusing knob and using the left eye only, look through the left eyepiece. Turn the focusing sleeve on the left eyepiece tube counterclockwise until the object is out of focus. Still using the left eye only, turn the sleeve clockwise until sharp focus is obtained.

NOTE: In performing this step, make certain that the eyepieces are seated against the eyepiece tubes or the eyepiece shields.

- The microscope should now be adjusted correctly for comfortable viewing with both eyes. The operator can set the instrument at any magnification within the range of the zoom power body without having to refocus.

MAGNIFICATION

In using a microscope to view miniature parts and hard to see features, a question which naturally arises is "What magnification should I use?" or "What magnification level is best?" There is not a simple answer to either of these questions. For most uses, 7X to 10X magnification is easiest on the eye and generally adequate for most deburring. Many individuals can see better at 10X magnification than they can at 30X.

While the magnification of the eyepieces is clearly marked on the eyepiece, the value shown there does not reflect the actual magnification of a part. To illustrate this, there are basically three lenses in a microscope, the eyepiece lens, lenses in the center of the body of the microscope, and the auxillary lens at the bottom of the power body. The total magnification is a magnification level of each of these multiplied by themselves. Restating this as a formula:

Total magnification = eyepiece magnification x body magnification x auxillary magnification.

As an example, under normal circumstances the eyepiece magnification will be 10X. Assume that the zoom setting is .7 on the zoom magnification knob at the right of the microscope and that no auxiliary lens is screwed into the bottom of the power body. In this case, the total magnification would be $10 \times 0.7 \times 1.0$, or 7X magnification. You will note that in this particular instance, since there is no lens at the bottom of the power body, you are neither magnifying at this point nor are you reducing it. Thus, if there is no lens then the magnification of the lens is 1.0. It is not changing the magnification level.

For the second example, assume that for a 15-power eyepiece, the zoom magnification knob is set at 2 and that an auxiliary lens of 1.5 is attached to the bottom of the power body. The total magnification under these conditions is $15 \times 2 \times 1.5$. The total magnification when viewing the part is then 45 power. In other words, the features viewed through this lens system would be 45 times their actual size. While most eyepieces available on the microscopes are 10X magnification, 20X magnification eyepieces are available within the plant and other magnification level can be purchased if necessary. Typically, you do not use an auxiliary lens, because the highest magnification level required on typical Bendix parts is 30X magnification. Generally, you will be instructed to use no more than 20 power magnification. Since the microscopes with 10X eyepieces and the zoom levels of .7 to 3 will accommodate up to 30 power magnification, there is obviously no need to use an auxiliary lens.

It is common for many individuals using a microscope to look at the zoom magnification knob and say that they are using a magnification level of 0.7, 2, 3 or whatever number they see there. This is, of course, incorrect. The magnification level they are using is the number on the magnification knob times the eyepiece power

times the auxillary lens power. Thus, under normal circumstances, 2 on the magnification knob actually indicates 20 power magnification.

One of the problems with using high magnification is that the more magnification that is used, the smaller the depth of field (Figure 6). Just like a camera or telescope, at very high magnification levels, only a small area is actually within view or within focus at that level. Regardless of the microscope used, high magnification means only a small area of the part can be seen. A smaller lateral area as well as a smaller vertical area are in view.

In the definition section of this chapter, working height was mentioned. It was stated there that working height is the amount of open area underneath the power body which is available for placing hands, parts, and tools. Generally, this is fixed by the design of the microscope. If necessary, the working height can be increased with an extension sleeve such as shown in Figure 7. While Bendix does not normally use extension sleeves, they are available.

USING THE MICROSCOPE

Before using the microscope, it is also important to adjust the tension on the vertical slide according to the following method.

- Tension on the focusing mechanism may be regulated to suit personal preference. To increase tension, hold one knob firmly and turn the opposite knob clockwise. An alternate method of increasing tension is to twist both knobs simultaneously in a clockwise direction. To reduce tension, turn knobs counterclockwise.

Figure 7. Extension Sleeve for Increasing Working Height

In using the microscope, it is important for personal comfort to use good posture. When using the microscope, the back should be straight, you should look through the eyepieces without bending the neck, and one must work at such a height that you do not have to bend over either to look through the microscope or deburr the parts (Figure 8). At first, some neck and back fatigue will occur because you are not familiar or do not take the time to properly adjust the microscope to your own needs. With proper set up, however, fatigue will quickly go away. Figure 9 shows the use of riser blocks to adjust the microscope for very tall individuals. Figure 10 illustrates the use of microscope bases tipped at an angle for more comfortable viewing; also, the wider base provides greater stability to hold microscope platform. In addition, this particular base provides a number of convenient pockets for temporarily storing tools or some of the very miniature parts.

You will note that most of the microscopes in common usage have a Nicholas illuminator. This illuminator can be placed in the microscope stand at either of two locations (twin port in Figure 5). These two locations provide adequate positioning of the light for normal deburring. For those situations in which it is not totally acceptable in these positions, it is possible to place the microscope light in front of the microscope as shown in Figure 11. In addition, the microscope light can be placed off the microscope as shown in Figure 12. While the Nicholas illuminator is shown in the last two photographs, it is also possible to put a cool fluorescent light on the microscope which will move with the power body (Figure 13). The advantage of a light moving with the power body is that in most cases, the light will permanently illuminate the area being deburred. A disadvantage of the lights mounted off the microscope is that when the microscope body is adjusted upward, the light is still focused at the lower position.

It is possible to insert special scales within the eyepiece of the microscope. Figure 14, for example, illustrates scales which have small radii inscribed on them. These radii will provide an indication of the actual amount of edge break to be put on parts. Note, however, since the microscope power is adjustable, that the proper magnification must be set on the microscope to know what radii each of these small radiuses indicate. As an example, the scales available at Bendix have small arcs representing 0.003, 0.005, 0.007 and 0.009 inch radii when a microscope is set at 30 power magnification. Other scales are available commercially or can be designed to suit specific application.

CARE AND CLEANING

Always use the plastic dust cover provided when the microscope is not in use. Eyepieces should always be kept in the microscope to

Improper

Proper

Figure 8. Proper and Improper Microscope Posture

Figure 9. Riser Block Used to Adjust Microscope Height

Figure 10. Microscope Tipped for More Comfortable Viewing

Figure 11. Nicholas Illuminator
on Power Body

Figure 12. Nicholas Illuminator
Mounted on Separate
Stand

Figure 13. Fluorescent Illuminator
Attached to the Power
Body

Figure 14. Eyepiece Disc With
Radii Inscribed to
Measure Edge Break

prevent dust from collecting within the eyepiece tube of the body. When cleaning the microscope, do not attempt to disassemble the power body. The lens system within the body was carefully cleaned and aligned at the factory.

Dust on the eyepiece lens is seen as specks which will rotate with the eyepiece when it is turned. If the viewing field does not appear clear, carefully inspect the lower lens of the power body. Subtle loss of contrast and definition due to dust or a slight smear on these lenses can be avoided with routine inspection and cleaning. If any optical surface becomes badly coated with dust or dirt, all such loose dust or dirt should be blown off with a syringe or dusted with a camels hair brush before attempting to wipe the surface clean.

Optical surfaces should be cleaned with a lint free, soft, linen cloth, lens paper, or a cotton-tip moistened with distilled water, xylene or alcohol. It is very important to avoid the use of excessive solvent. Cloth, lens tissue, and cotton-tips should be just moistened with solvent and not wet enough for the solvent to run down in around the lens with the resultant danger of loosening cement on interior surfaces. Always promptly wipe the surface dry using a circular motion before allowing it to air dry.

Glass surfaces should never be touched with the fingers because they will leave a greasy smear and frequently corrosive perspiration. Do not clean optical parts unnecessarily.

If you have problems seeing through your microscope, tell your supervisor. Every four months, microscopes are checked and repaired as necessary. It is important for the supervisor to know which microscopes need this service.

MICROSCOPES WITH COAXIAL ILLUMINATION

Figures 3 and 4 illustrate microscopes which have light passing through the lens system. This lighting is known as coaxial illumination (Figure 15). Coaxial, in this case, implying that it is coincident with the viewing light rays. The microscopes shown in Figures 3 and 4 do not have zoom lenses. They have either three or four adjustable magnification levels. As an example, on the microscopes shown in Figure 3, the adjustable levels are 3.1, 5, 8, 12.6, and 20. When using 10X eyepieces and a 200 mm auxiliary lens at the bottom of the power body, then magnification levels are 3.1, 5, 8, 12.6, and 20 power magnification.

There are three principal advantages to these microscopes. The first advantage is that the light is always shining on the part and requires no adjustment of the light as the part or the power body are moved. The second advantage is that the working focal length of the microscope (that is, the distance from the auxiliary lens to the point in focus) can be easily adjusted. As an example, with a 100 mm objective lens or auxiliary lens, the focus is 4 inches below the objective or auxiliary lens (Figure 16). The use of a 400 mm objective lens extends the focus to 16 inches from the bottom of the power body. These lenses are easily interchangeable and readily available. The third advantage of these microscopes is that they employ more expensive optical systems than some other microscopes. In many cases, users feel that parts are in clear view or more easily viewed than with less expensive microscopes. It should be noted, however, that even the microscopes shown in Figures 1 and 2 can have adaptors added to them which provide coaxial illumination and permit changing the focal length of the microscope.

Note that in Figures 3 and 4, the microscopes are extended some distance from the vertical post. This is an advantage in that

Figure 15. Coaxial Illumination (Photograph Courtesy of Bausch & Lomb)

Figure 16. Focal Point As a Function of Auxillary Lens Size

Figure 17. Different Viewing Positions Are Available With Some Microscopes

Figure 18. Teaching Microscope Which Allows Two Individuals to Observe the Same View

very large parts may be deburred under these microscopes. It is also a disadvantage, because any vibration to the table is magnified by these arms. Thus, for proper utilization of any microscope extended on an arm or boom (such as shown in Figures 3 and 4), it is essential that vibrations be eliminated at least during the time the part is being viewed through a microscope.

As a final note, when lights are used with these microscopes, it is important to use only the amount of power or the amount of light actually required. When many of these microscopes lights are turned to their maximum power, the microscope bulbs will only last a few hours. In one case, at full power the microscope light will only last 40 hours. When turned to its lowest level, which is normally adequate for general viewing, it will last up to 500 hours.

MISCELLANEOUS OBSERVATIONS

Figures 1 and 2 illustrate the most common arrangement of microscopes for deburring at Bendix. It is possible to turn the power body 180 degrees to the position shown in Figure 17. This is easily accomplished by turning one or two locking levers and rotating the power body.

Figure 18 illustrates one of several arrangements possible for two-person viewing of the same object. This allows both student and teacher or worker and observer, to view exactly the same object. This is a major advantage when trying to show others the minute problem areas which are easily overlooked.

A variety of eyepiece shields can be used with most microscopes. Some are hard rubber-like items which eliminate stray lighting. Some felt-like "doughnuts" bond to the eyepiece top lens to

Soft Flat Eyepiece Shields

Eyepiece Shields Which Remove Stray Light

Figure 19. Some of the Eyepiece Shields Available for Microscope Use

prevent scratching of the lens by eyeglasses. Some soft rubber shields are also available.

While the shields shown in Figure 19 eliminate some stray light and help "guide" eyes to proper viewing, the flat covers shown in Figure 1 may be more beneficial in the long run. Among other advantages they eliminate irritation around the eyes by contact with the shields.

SOURCES OF ADDITIONAL INFORMATION

For additional information on microscopes, the following references may be useful.

1. AO Stereostar/Zoom Stereoscopic Microscope Reference Manual, American Optical, Scientific Instrument Division, Buffalo, New York, 1975, Brochure No. 560-101, dated 11/76.
2. AO Stereostar/Zoom Steroscopic Microscope, American Optical Corporation, Scientific Instrument Division, Buffalo, New York, Publication No. SB560-5/76.
3. Stereo Zoom 7 Microscope Instructions, Bausch & Lomb, Scientific Instrument Division, Rochester, New York, Publication No. 312701-465ND.
4. Bausch & Lomb Stereo Zoom 7 Coaxial Illuminator, Bausch & Lomb, Scientific Instrument Division, Rochester, New York, Publication No. 31-2368, 0870, CH.
5. Zeiss OPMI 9 Operation Microscope, Carl Zeiss, West Germany, Brochure No. 30-315-E.
6. The Particle Atlas, Ann Arbor Science Publishers Incorporated, Ann Arbor, Michigan, Pages 10-21.

ASSIGNMENT

1. Define the various pieces of a microscope.
2. With your supervisor's assistance, set up and focus the microscope as discussed in this lesson.
3. Define the differences between the microscopes discussed in this lesson.
4. With the setting now on your microscope, write down the magnification level one would view parts at.
5. How does one adjust the tension on the vertical slide?
6. With the supervisor's assistance, demonstrate proper cleaning of a microscope.

CHAPTER 7

BASIC DEBURRING NEEDS

Deburring is performed at many levels of difficulty and completeness. For example, final deburring, in-process deburring, rough deburring, or finished deburring are mentioned. Each of these words mean something different. In order to communicate effectively among all of those involved with deburring, it is important to use the same definitions.

ROUGH DEBURRING

Often engineers or supervisors use the term 'rough deburring.' The implication of this term is that additional deburring will be done later and that precision requirements probably do not have to be maintained for this type of deburring. An example of rough deburring would be a situation where a general machinist is machining a part and has to remove heavy burrs in order to measure the part and determine if the machine set-up is adequate. The machinist will use the words 'rough deburring' to indicate the fact that he is only removing burrs to the extent that he can measure parts. The edges he deburrs may have to be finished deburred at a later time. There will be occasions when production workers will also be asked to rough deburr some features of a part. When this is the case, it is important to determine exactly what the individual who makes the request means when he says 'rough deburr.'

IN-PROCESS DEBURRING

On many parts it is necessary to deburr a part at three or four different operations during the sequence of manufacture. For example, after a hole is drilled, it needs to be deburred in order for the part to fit in the next fixture to be further machined. This type of deburring is called 'in-process' deburring. 'In-process' in this case implies that the part still requires additional manufacture before it is ready for the final deburring and submission to Inspection. In-process deburring does not mean rough deburring. In-process deburring quite often requires the same level of quality, precision, and small edge breaks that the final deburring requires. In-process deburring must specify exactly what edges and how much edge break or radius is required. A later chapter will define the words actually used on the traveler. In all cases, in-process deburring must indicate what areas to deburr and what the edge qualities are expected to be.

FINISH DEBURRING

Finish deburring applies if the part is finished from a machining standpoint and requires only to be deburred and cleaned before submission to Inspection.

FINAL DEBURRING

Typically, the term of 'final deburring' indicates that the part is ready to be submitted to Inspection after a last deburring operation. Final deburring implies that all edges are burr free when this operation is completed. In many cases, paperwork associated with the parts will indicate specific edges which are

to be deburred and other edges which are expected to be looked at to verify that burrs do not exist on them. The final deburring operation is the last operation before inspection. As such, it is the most crucial; it is the operation which typically requires the longest time to complete. When parts leave the final deburring operation, they must be burr free.

CODE NUMBERS FOR DEBURRING OPERATIONS

Frequently rather than saying final deburr or in-process deburr, code numbers associated with these operations we used. A code number of Z901, for example, indicates that this is an in-process deburring operation and that additional deburring will be required at a later date. A code number of Z902 indicates that this is a final deburring operation, and that no future deburring will be required on this part. These code numbers are often used interchangeably with the words 'in-process' or 'final deburr.'

TERMINOLOGY USED IN MACHINING OPERATIONS

Many machining operations require some deburring. Frequently the words 'deburr on machine cycle' or 'deburr on machine' are included in the machining operation. 'Deburr on machine cycle' indicates that while the automatic machine is producing a part, the machine operator is expected to remove the burrs from the last part produced. While the edges may not be smoothly blended, the machine operator is expected to produce a part free of burrs produced at that operation. Burrs produced in earlier operations may still be left on the parts.

'Deburr on machine' tells the machine operator that while the part is still clamped in the machine, it must be deburred. This note generally appears on manual lathe operations in which the machine does not automatically produce the next part.

ASSIGNMENT

1. Define in your own words what rough deburring means.
2. Define in your own words what final deburring means.
3. What does a Z902 imply?

CHAPTER 8

REVIEW OF DECIMAL NUMBERS

There are many levels of accuracy associated with the deburring operations found on various parts. So many in fact, that to perform at the various levels of accuracy, a basic understanding of decimal numbers is a must. The following figure illustrates the mathematical notation associated with each individual decimal place to the right of the decimal point.

Although a different name is assigned to each decimal place to the right of the decimal point, thousandths and ten thousandths are the two terms which are used to specify edge breaks in manufacturing. Before we begin a review of thousandths and ten thousandths, ask yourself if you know what one thousandth or one ten thousandth really is.

An ordinary piece of paper is approximately three thousandths of an inch thick. A human hair, likewise, is approximately three thousandths of an inch thick. Take either a piece of paper or a human hair, imagine splitting its thickness three times, then each individual piece of paper and hair, would be a fairly accurate representation of one thousandth of an inch (Figure 1).

What about one ten thousandth of an inch? How much is that? Let's repeat the paper and human hair example cited above with only one change. Instead of splitting the thickness of the paper and human hair three times, split each thirty times, and each individual piece of paper and hair would be equal to one ten thousandth of an inch (Figure 2).

WRITTEN AND SPOKEN TERMINOLOGY

Following, are some examples of decimal numbers and how they would be communicated orally in a manufacturing environment.

<u>Number</u>	<u>Spoken</u>
0.001	One Thousandth
0.002	Two Thousandths
0.004	Four Thousandths
0.0002	Two Ten Thousandths
0.0003	Three Ten Thousandths
0.0009	Nine Ten Thousandths
0.009	Nine Thousandths
0.010	Ten Thousandths
0.0015	One and A Half Thousandths
0.0021	Two and One Tenth Thousandths or Two Thousandths and One Tenth
0.0064	Six Thousandths and Four Tenth Thousandths

Figure 1. An Example of One Thousandth of an Inch

Figure 2. An Example of One Ten-Thousandth of an Inch

Note that in the case of 0.0021 and 0.0064 that when we say XX thousandths and Y 'tenths' we are implying 'Y' tenths of a thousandths rather than tenths of an inch. If, however, one said only 'one tenth' it would imply to some individuals one-tenth of an inch and to others one ten-thousandth. An alternative method of saying a number like 0.0021 would be to say "two-point one thousandths." One would then know that you were saying 2.1 thousandths or 0.0021.

ASSIGNMENT

Look at the following exercise and fill in either the missing decimal number or the "spoken" equivalent.

	<u>Number</u>	<u>Spoken</u>
1.	0.003	_____
2.	_____	Six Thousandths
3.	_____	Eleven Thousandths
4.	0.0002	_____
5.	0.0015	_____
6.	_____	Two point Three Ten Thousandths
7.	_____	Five point Six Ten Thousandths
8.	0.008	_____
9.	0.0102	_____
10.	_____	Four Ten Thousandths

CHAPTER 9

DEBURRING HOLES

A common feature that must be deburred is a hole. As an example, in normal deburring the following types of conditions must be deburred.

- Large through hole
- Small through holes
- Small through holes with a 0.0002 inch tolerance
- Small through holes with 8 microinch finish
- Small through holes with a 0.003 inch maximum radius
- Small blind holes
- Intersecting holes
- Holes intersecting slots
- Holes having counter bores.

While we have not defined what constitutes small or large, it is obvious that a different approach must be used for a very large hole, for example a 6-inch-diameter hole, than would be used on a small hole. These are typical holes sizes found on precision miniature parts:

- One inch or larger diameter,
- 0.250 inch diameter,
- 0.062 inch diameter,
- 0.025 inch diameter, or
- 0.010 inch diameter.

BASIC APPROACHES FOR HOLES

Assume for a moment you must deburr a part having no close tolerances, no close finishes, and no edge breaks. The part has a 0.25 inch diameter hole going entirely through the part, and the part is flat. The following is a normal approach for deburring the hole in this situation:

- a. Sand or stone the flat surface;
- b. Use a bur ball or countersink to provide a small radius or break around the edges of the hole;
- c. Use an abrasive filled rubber bullet to provide a smooth blend at the hole entrance and exit;
- d. Blow-off the loose particles and chips which are now on the hole;
- e. Clean the part;
- f. Scrutinize the hole to assure that the burrs were removed; and
- g. Repeat steps a through f as required.

The deburring of this hole is begun by sanding or stoning the surface. As shown in Figure 1, after the hole is drilled there is either a burr or a hump of raised metal at the entrance and exit of the hole. Sanding or stoning the surface removes the large

Figure 1. Raised Metal Produced by Drilling

Figure 2. Abrasive Disc Used to Remove Raised Metal on Holes

amounts of metal at these locations. Stone or sand using only your hands, sandpaper and hand stones, or you may choose to use an abrasive disc mounted in a motor. (Figure 2)

The bur ball or the countersink tool provides a small amount of edge break. This is necessary in order for the part not to cut the mating part. The abrasive filled rubber product provides a smooth blend to the small burr left by the bur ball or the countersink tool (Figure 3). Any time sandpaper or abrasive filled products are used, a considerable amount of debris is left by the tools. It is more easily removed by blowing it off with a small blast of air. This does not remove the total amount of residue, however. Typically, the part is dipped in a small can of Freon or soapy water and, the moisture is blown off again. At this time, after it's clean and believed burr free, you must scrutinize the part to verify that, in fact, it is burr free. If you fail to scrutinize the part after you clean it, you run the risk of overlooking a small particle. It only takes one small particle on one portion of one edge of a single part to cause a failure in subsequent assemblies or a reject by inspection. Probably, 20 percent of the time after deburring holes and other features and after cleaning, you will find that the burr or raised metal has not been totally removed and you must repeat steps a through g.

Assume a different situation. A part has no close tolerances, no close finish, or no precision edge break to maintain. The part has a hole 3 inches in diameter running entirely through the part and once again it is a flat part. In this case, a reasonable approach to deburring this type of hole is given in the following listing:

Figure 3. Bur Balls and Countersink Tools Produce Small Burrs

Figure 4. Part Having a 0.020 Inch Diameter Hole

- a. Sand or stone the surface;
- b. Use a burr knife or a hand-held stone to chamfer the edge;
- c. Use abrasive paper or a power brush to blend the edge to provide a smooth radius;
- d. Blow-off the loose particles;
- e. Clean in a liquid if necessary;
- f. Scrutinize for burrs of raised metal;
- g. Repeat steps a through f as required.

For this situation the only major differences are in steps b and c. On a large hole, it can be to maneuver a knife, scraper, or even a hand stone to scrape-around the edges, removing the heavy burr. Similarly, on a large hole it is easy to use abrasive paper (the correct nomenclature for sandpaper-like products) or even our miniature power brushes.

In the first example, the use of a burr knife or scraper was not discussed. Typically you will find that rotary burs or bur balls provide one of the easiest and quickest ways to remove burrs. Some individuals, however, on small holes (even on very miniature holes) prefer to use a small knife in place of a bur ball or countersink tool. Either approach is acceptable, and there are advantages to both. For the individual new to deburring, the bur ball or countersink is one of the easiest tools to use.

Now assume a third condition. A part has a 0.020 plus or minus 0.0002 inch diameter tolerance; it has a 0.003 maximum edge break radius. The hole goes entirely through a flat part.

At this point it is important to recognize how small a 0.020 diameter hole is. As shown in Figure 4, a 0.020 diameter hole is the size of a miniature lead pencil and much smaller than a conventional wooden pencil lead. It is also important to again

acknowledge what close tolerances imply. In this case, there is a 0.0002 inch diameter tolerance. As indicated in an earlier chapter, a tolerance of this size is only 1/15th the thickness of a human hair. It is very easy to increase the diameter beyond this tolerance if you are not careful. The 0.003 inch maximum break is also very difficult to maintain. Essentially, you must make sure that the part is burr free and at the same time it cannot have more than the thickness of a hair, chamfer, or radius at the edges (Figure 5).

A reasonable approach to deburring this very small hole is given:

- a. Stone or sand the surface of the workpiece;
- b. Gently use a small bur ball;
- c. Use a toothpick or if allowed a small reamer;
- d. Use an abrasive filled rubber dental point;
- e. Clean the part;
- f. Scrutinize for burrs; and
- g. If allowed, use a "go" gage.

Note in this instance there was added the use of a reamer, a toothpick, and an abrasive filled miniature rubber point. Any time a bur ball is used it generates two burrs. The bur ball removes one large burr and produces two smaller ones (Figure 3). A reamer run through the hole will remove the small burr inside the hole (Figure 6). In many cases a toothpick will also do the job with less possibility of damage to the hole. The inexperienced person using the reamer is very likely to enlarge the hole beyond the allowable tolerance, and at the very least scratch the precision hole surfaces. The toothpick will not do this under normal conditions. The toothpick is soft enough that it will deform before

Figure 5. Edge Having a 0.003
Inch Chamfer

Figure 6. A Reamer Will Remove Burrs
Thrown Into a Hole

it enlarges the hole size. In such situations, it is always advisable to ask the supervisor if it is allowable to use a reamer to remove the burr down in the hole. The reason for using the miniature dental points is that they represent the smallest soft tool available for providing a smooth radius in the holes. Figure 7, for example, illustrates the quality of the hole after the use of one of these dental bullets. As previously indicated it is easy to have a burr in a hole and not see it. If a "go" gage is allowable (once again a supervisor will indicate the size of "go" gage which should be used in the hole) use it to indicate whether or not a burr is present.

Figure 7. Edges of a Small Hole After Using a Dental Abrasive Filled Rubber Bullet

Figure 8. Edges on a Counterbored Hole

Once again it is possible to use a miniature burr knife in place of the rotary burr tool to remove the heavy burr. Some individuals will use a knife on every hole. For extremely small holes, a knife raises the possibility of scratching the interior surface of the hole. In addition to the approach just listed is one basic approach which is logical and frequently adequate, but it is not the only way to deburr these holes. Each individual develops their own technique based on these approaches.

APPROACHES FOR COUNTERBORED HOLES

At this point assume a hole which has a counterbore at one end (Figure 8). On the counterbored hole, there are three surfaces which must be deburred, and one of them is relatively difficult to reach. In this situation, provided the hole is large enough, you could:

- a. Stone the flat surfaces;
- b. Use a countersink or bur ball on the three round surfaces;
- c. Use a knife if necessary, particularly down in the bottom of the counterbore;
- d. Use an abrasive filled rubber bullet, a special counterbore tool, or a reamer;
- e. Clean the part;
- f. Scrutinize; and
- g. Repeat steps a through f as necessary.

Note that the hole at the bottom of the counterbore (edge number 2) is the most difficult area to deburr, particularly if the counterbore is very shallow. In some cases, a reamer is necessary. In other cases, a specially designed counterbore tool will work. In

still other cases sandpaper can be used to reach the difficult diameter. Again, on very small holes, you may want to use a wooden toothpick to provide the necessary radius, to move the burrs, and to verify that burrs are absent.

APPROACHES FOR INTERSECTING HOLES

Consider now the intersecting holes shown in Figure 9. Note that the intersection of any two holes presents a three dimensional surface (Figure 10). Because of this, deburring and providing a consistent edge break may be very difficult. There is a typical approach for deburring intersecting holes:

- a. Stone the flat surface of the hole;
- b. Use a deburring knife for the hole intersection;
- c. Use an abrasive filled rubber bullet or miniature dental bullet;
- d. Clean the part;
- e. Scrutinize the part;
- f. Repeat steps a through e as required.

In the case of intersecting holes, bur balls will not provide a uniform break around the intersections. For this reason, burr knives are used almost without exception for this type of situation. In a few cases, such as shown in Figure 11, the intersections are so far away from the surfaces and in such small holes that it is impossible to reach them with a burr knife or any other deburring tool. In this type of situation, mechanized processes must be used and will be discussed in a subsequent paragraph. Whenever this type of situation occurs, contact the supervisor to determine if the mechanized process would be preferable for the

Figure 9. Two Intersecting Holes

Figure 10. Three Dimensional Configuration of Hole Intersections

intersections. In some cases rather than abrasive filled products, you may want to use a sandpaper-like product at the hole intersection. If the holes are large enough (for example, one-half of an inch in diameter or larger) then the abrasive paper products may work very well for smoothing out the intersection after the knife has been used.

AREAS OF CONCERN ON HOLES

When deburring holes there are four major considerations which must be made:

- a. Do not change the hole size;
- b. Do not exceed the allowable edge break;
- c. Do not damage precision surface finishes; and
- d. Do not change the thickness around the hole.

In a typical deburring operation, you do not affect the hole size because you are working at the edges rather than in the diameters of the hole. Edge breaks are critical on many components. There are probably 100 different components which require edge breaks such as 0.003 inch maximum break. These are very difficult to maintain for an individual not familiar with precision deburring. That is one of the major reasons that this training course was assembled, to provide you with the knowledge and the abilities to produce such precision edge breaks. While it may not be totally obvious at this time why certain requirements are needed, it is necessary to point out that parts will be scrapped and long production delays occur if these edge breaks are exceeded.

Surface finishes in holes and on surfaces adjacent to holes are one of the most frequent types of problems faced on miniature parts. Figure 12 for example illustrates a part having precision surface

Figure 11. Hole Intersections Are Not Accessible With Deburring Tools

finishes on the flat surface as well as within the hole. If you use too coarse of an abrasive paper product, or use a knife indiscriminately and scratch the surface, then the parts will be rejected and many cases cannot be reworked satisfactorily. Later chapters will discuss what the surface finish numbers imply and what the surfaces really must look like after deburring. If at this point you have any questions about surface finish on the actual part, it is important to ask your supervisor whether your approach will damage such finishes.

MECHANIZED PROCESSES FOR HOLES

Tables 1 through 4 present some basic capabilities and limitations of mechanized processes for deburring holes. As seen there, each process has a unique set of limitations. No process can work on all sizes of holes, on all edge break call-outs, or on all surface finish requirements. Each deburring process affects many features of a part. Consequently, hand deburring is actually the most economical and the easiest solution for deburring some holes. When you face situations, however, that are extremely difficult, or take more than two or three minutes a hole to complete, then

Figure 12. Part Having Precision Finishes in Hole

Table 1. Codes Used in Table 2
for Deburring Processes

Code	Deburring Process
A	Vibratory
B	Barrel Tumbling
C	Spindle Finishing
D	Centrifugal Barrel Finishing
E	Abrasive Jet
F	Sanding
G	Brushing
H	Hand
I	Abrasive Flow
J	Mechanized Mechanical
K	Thermal Energy
L	Chemical
M	Electropolish
N	Electropolish
O	Ultrasonic
P	Torch or Flame Melting
Q	Water Jet
R	Electrochemical Vibratory
S	Electrochemical Brush
T	Chemical Vibratory
U	Liquid Hone
V	Chlorine Gas
W	Magnetic Loose Abrasive
X	Plasma

Table 2. Typical Processes for the Precision Deburring of Intersecting Holes

Maximum Edge Break (inch)	Allowable Diameter Change*			
	Hole Diameter Change (inch)			
	0.00005	0.0001	0.001	0.005
0.0001	-**	-	-	-
0.001	-	-	-	-
0.002	K,M	K,M	K,M	K,M
0.005	K,M	H,J,K,M	H-K,M	D,H-N, T,V-X
0.010	H,K,M	H,J,K,M	H-K,M	D,H-N, T,V-X

*Refer to Table 1 for definitions of deburring-process code letters. Information in this table pertains to stainless steel workpieces having a surface-finish requirement of 32 microinches or better, and holes 0.5 inch in diameter, or smaller; it is based on the complete removal of burrs having an initial thickness of 0.003 inch and an initial height of 0.003 inch.

**Dashes indicate that no process will produce the desired result for the specified burr size, surface finish, and material.

Table 3. Basic Capabilities of Deburring Processes--Feature Size*

Deburring Process	Typical Working Range Feature Size (Inch)					
	0.001	0.010	0.100	1.00	10.00	100.00
ABRASIVE						
Abrasive Jet	_____		_____			
Loose Abrasive Barrel			_____			
Centrifugal Barrel		_____				
Vibratory			_____			
Sanding (Edges Only)				_____		
MECHANICAL						
Mechanized			_____			
Hand		_____				
Brushing			_____			
CHEMICAL						
Chemical	_____					
ELECTROCHEMICAL						
Electrochemical		_____				
Electropolish	_____					

*Feature size indicates the size of holes, slots, and related features that can be deburred by a process without special effort.

Table 4. Basic Capabilities of Deburring Processes--Surface Finish*

Deburring Process	Typical Working Range, Surface Finish (μ in.)			
	(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 μ in. 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.

the supervisor should be asked if perhaps a mechanized process might not be a more economical approach for deburring those features. In later sections of this training guide, we will discuss mechanized processes, how they work and what the real capabilities are in more detail.

ASSIGNMENT

1. Deburr the holes in the flat plates provided. Produce no more than a 0.005 inch edge break at the entrance and exit to these holes.
2. Deburr the intersecting holes in the samples provided. Provide no more than a 0.010 inch edge break on these intersections.
3. Deburr the counterbored holes on the samples provided. Provide no more than a 0.005 inch maximum break on any of these edges.
4. In your own words describe the areas of concern one has when deburring holes.
5. Describe the differences one might have in deburring a one inch diameter hole from the deburring of a 0.020 inch diameter hole.

CHAPTER 10

DEBURRING THREADED FEATURES

Deburring threads represents one of the most difficult problems faced on miniature parts. There are several portions of the thread which must be burr-free. Threads themselves come in a variety of part geometries and in a variety of sizes. The very miniature threads are extremely difficult to hold without damaging. Threads represent some unique problems, not only for deburring but for the assembly of parts. If threads are not burr-free, a burr can shear off and interfere with many of the precision mechanisms. This chapter will discuss threaded holes and threaded shafts. It will begin by discussing the deburring of threaded holes.

TYPES OF BURRS FOUND ON THREADS

There are five basic types of burrs or configurations that must be removed when deburring threads:

- Raised metal on the top surface,
- Burrs on the crest of threads,
- Burr or chip at the bottom of a blind hole,
- Chips or oil in roots of threads, and
- A bent first thread.

Figure 1 illustrates the first of the listed conditions. In that illustration there is a small hump of metal which is commonly referred to as "raised metal" on the top surface of the hole. In many cases, this small swell of metal is almost invisible

Figure 1. Raised Metal At Threaded Hole Entrance

Figure 2. Raised Metal Prevents Proper Assembly

until you become accustomed to looking for it. This is not permitted because it causes mating parts to stand above their normal flat surface (Figure 2). This raised metal must be removed to provide a uniformly flat surface or a depressed area at the hole entrance (Figure 3). Bendix standards, in fact, demand that all threaded holes have a chamfer equal in diameter to the largest diameter of the thread (Figure 4).

Figure 5 illustrates the example of a large burr or chip at the bottom of a blind tapped hole. In many instances, this chip would not affect the function of the hole. In many other instances, however, since mating screws are inserted and removed many times and these screws are of varying lengths, it is possible for the chip to break loose and ultimately fall out into the assembly. For this reason, it is important to do everything possible to remove such chips. This is a very difficult task. As shown in this illustration, the chips are on the side wall and in a deep hole it is almost impossible to reach them without specially designed tools.

Figure 6 illustrates burrs commonly found on the crest of threads. In this instance, there are burrs on both sides of the crest at the top. These burrs must be removed and some radius provided on the crest of the thread. Figure 7 illustrates chips and loose particles in the bottom or root of the thread. These must be removed before inspection. In many cases, chips, dirt and oil mask loose particles or burrs in these areas.

Figure 8 illustrates a bent first thread. In this instance, the metal is literally pushed into the root section of the thread. In some cases this would not affect the function. In others, because of the nature of the mating parts, the metal would be torn loose and again would fall into the assembly. Figure 9

Figure 3. Allowable Conditions At Threaded Hole Entrance

Figure 4. All Threaded Holes Must Have a Chamfer of Approximately the Indicated Size

Figure 5. Chip or Burr At Bottom of Blind Hole

Figure 6. Burrs on Thread Crests

Figure 7. Chips and Loose Particles in Thread Roots

Figure 8. Bent First Thread

Figure 9. Bent Fin on First Thread

Figure 10. Cross Section of Thread Produced By a Cutting Tap

illustrates another example of the same type of bent first thread. In this instance the bent thread is a very small flap of metal. In this particular illustration, the total diameter of the screw is smaller than a pencil lead. In fact, the total diameter is roughly the size of six human hairs put side by side. Note that while Figures 8 and 9 are of screws rather than holes, the same damaged first thread occurs on holes. If there is any chance that the first thread will be bent or deflected in assembly, the flexible part must be cut out.

Close inspection of threads produced at Bendix will indicate that there are basically two forms of threads. The first thread represented by Figure 6 has a truncated triangle shape as shown in Figure 10. These threads are produced by a tap which actually cuts metal out of a hole. Figure 11 illustrates the crest configuration of threads produced by cold forming taps. These threads have a U-shaped pocket at the top of the crest and the ends of the U are often very ragged. Figure 12 illustrates the idealized shape of these cold formed threads as shown in many publications including Bendix Drawing 9900000.

Figure 13 actually illustrates the nature of many of these cold formed threads and some materials better than the idealized figure that is shown. Figure 11 illustrates the type of idealized thread which can be produced with careful attention by the machinist producing the thread. In this instance, the U at the top of the crest is actually closed shut and there is a small black spot just below the crest. This black spot is actually a hollow area which runs just underneath the crest and around the thread.

Threads must be burr free. As just indicated, a burr is left on the crests of all threads whether produced by tapping or cold forming. On external threads, these fine burrs can be easily removed from most parts by sanding, tumbling, or brushing (Figure 14).

Figure 11. Cross Section of Thread Produced By a Cold Forming or Express Style Tap

Figure 12. Idealized Shape of Cold Formed Thread

Figure 13. Example of Configuration of Some Cold Formed Miniature Threads

Figure 14. Expected Quality of Thread Crests on Precision Miniature Parts

Although internal threads are more difficult to debur, they too can appear as burr free external threads, particularly in the larger thread sizes. On the smaller threads, such as the 1.0, 0.8, and 0.6 mm threads, it is important to ensure that retapping or using thread gages to "clean" threads does not affect thread size.

When viewed with the naked eye, the crest burrs cannot be seen on a 0-80 UNF thread (Figure 15). They are only obvious when viewed at 10-20X magnification. The answer is not clearcut as to whether such small burrs actually create problems in assembly, but it is important to realize that a small metal fragment, like one of these hairlike thread crest burrs, can keep an electrical contact from closing and thus cause a failure. Larger metal fragments or burrs can cause the close fitting components to jam. Although the probability of such events is small, considering the many times that some parts are assembled, disassembled, and tested, the actual possibility is real for many situations.

On the 0-80 UNF and smaller threads, it is generally not possible to achieve the same levels of internal burr-free crests as for larger sizes. Consequently, inspection departments are less demanding on these minute features. The mating external threads can be "clean" and are expected to be so. The fact that one of the two threaded components has entirely burr-free crests, that gages have been threaded into the internal threads, and that a significant effort has been made to remove all loose particles significantly reduces the possibility of burr-related problems.

It is more difficult to remove burrs from cold formed threads and threads in aluminum. In threads as rough as those in Figure 13, it is important to use crosshole deburring brushes to remove all loose particles.

Figure 15. Miniature Threaded Part

Figure 16. Cross Hole Deburring Brushes

In fact, all internal threads should be brushed to remove loose particles.

General inspection practice is to inspect almost all threaded features produced in the miniature machining department under 7X magnification (up to 20X magnification is used on some components). Similarly, parts having very close tolerances (± 0.002 inch) or whose features are very small (0.040 inch) are typically inspected under magnification for burrs. Conversely, threads whose diameter is 3 or 4 inches will seldom be inspected under microscopes unless a specific concern is raised. Such a policy on use of scopes may seem inconsistent, but it should be noted that minute crest burrs represent a larger problem to the small precision parts than to larger or less critical parts.

Neither Drawing 9900000 nor Drawing SS331834 requires that the lead in or lead out thread (referred to as the "incomplete thread" or "blunt start" in national thread standards) be partially removed, except for Acme style threads. As previously indicated, however, in practice, it is essential to remove enough of these thread ends to ensure that this thin thread portion cannot be bent over or otherwise damaged. Inspection practice is to reject any threads in which this thin fin is bent or in any way damaged. Both specifications, however, require leading edges of external threads to be chamfered, which minimizes some of the "fin."

Drawings 9900000 and SS331834 require that all threaded holes be chamfered. If they are not chamfered, a small swell of metal occurs at the hole entrance and exit. Those performing the drilling and tapping are responsible for chamfering the holes. Although those performing deburring may have to occasionally perform such chamfering, the absence of such chamfers should be noted to supervision.

BASIC DEBURRING APPROACH FOR THREADED HOLES

Assume that there is a threaded hole which has no close tolerances or close edge breaks. The hole is one inch in diameter and it is through a flat part. The following is a typical deburring approach:

- A. Stone and sand the top flat surface,
- B. Use a knife to cut away any bent portion of the first thread,
- C. Use a knife or bur ball to provide a chamfer or to enlarge a chamfer,
- D. Using a wheel-like brush radius the hole entrance,
- E. Use a crosshole deburring brush to clean out the threads,
- F. Clean the part,
- G. Scrutinize, and
- H. Repeat A thru G as required.

As in the case of all holes it is easiest to stone or sand the flat surface to remove raised metal. The only successful method of removing bent first threads is by actually cutting them out with a knife. The amount of material which can be removed varies. Typically, all of the thread which is bent or which may be easily bent is cut away. As previously mentioned, all threaded holes must have a chamfer of approximately the size shown in Figure 4. In some instances, the machinist will have to apply a chamfer to the part before it comes to deburring. In other instances, the chamfer will be absent or possibly not as large as required. For this reason, many individuals commonly will use a bur ball to provide the proper chamfer. This is a very fast operation, and the amount of chamfer can be easily controlled by the size of the bur ball and the amount of pressure applied.

On miniature parts, it is a requirement of deburring that all threaded holes have a crosshole deburring brush passed through them. Figure 16 illustrates some of the deburring brushes and their minute sizes. These brushes are inserted into the thread and turned by hand. In most cases, the production traveler will indicate the brush which should be used. If too large a brush is used in the hole, the small fibers in the brush will break loose and become wedged in the bottom of the threaded hole. On through holes this may not present a problem, but on a blind hole it may be more difficult to remove a small wire fiber than the burrs which are in the hole. In some cases, a nylon brush rather than a stainless steel wire brush is available for this purpose.

To provide a smooth entrance to a large diameter hole, a wheel-like brush is passed back and forth over the hole surface to blend the surface. In most cases it will be necessary to use an abrasive filled nylon brush although stainless steel and brass brushes may also be used for this purpose. As in the case of all holes, they must be cleaned to verify, in fact, that all burrs have been removed.

On some large threads, it is desirable and permissible to use a cutting tap to remove large burrs. Because threaded holes have two levels of thread quality, it is important that the supervisor or the engineer specify on the traveler which tap should be used if one is permissible.

Assume a situation where a number 4-40 thread (0.097 diameter) required deburring. In this case, the thread is in a blind hole. Note that a number 4-40 thread is approximately the same diameter as a normal writing wooden pencil (Figure 17). The following sequence would probably be used to deburr inside the hole.

Figure 17. Relative Size of a 4-40 Thread

Figure 18. Typical Tool Used to Dig Chips From Bottom of Threaded Holes

- A. Stone or power sand the flat surface.
- B. Use a countersink or bur ball.
- C. Use a knife to remove a bent first thread.
- D. Use a knife to wipe away any burrs produced by the bur ball or countersink tool.
- E. Use a reamer to remove burrs on crests.
- F. Use a crosshole deburring brush.
- G. Use a "go" gage.
- H. Dig out any chips in the bottom of the threaded hole.
- I. Ultrasonic clean the hole.
- J. If necessary, use a small hole flushing unit to clean the hole.
- K. Scrutinize the hole using gooseneck fiber optic on coaxial light.
- L. Repeat steps A through K as required.

Note that in this instance a knife was used to remove the burrs produced by the bur ball. Also note that a "go" gage was called out to verify that burrs were adequately removed from the crest of threads. The tool used for digging out the chip from the bottom of the thread was not specified. Figure 18 illustrates one example of such a tool, and Figure 19 illustrates how the tool is used. The only successful way of cleaning small threads is to use an ultrasonic cleaner which will be described in more detail in a later volume. A device is available which uses small hypodermic needles to flush small holes (Figure 20). While this is a slow process, it is necessary in some cases to remove all chips. In a few cases, a threaded hole may be entirely packed with wire-like chips. These chips may have to be removed with tweezers or a small knife, before beginning any of the other methods.

Figure 19. Uses of Tool Used to Dig Out Chips

It is extremely easy to miss burrs in blind threaded holes. Small holes in particular make it difficult for light to penetrate to see what is inside the hole. The gooseneck lamp or the coaxial lighting available in some microscopes are the only ways to see in small blind holes.

In a third assumed condition, a blind hole is to be deburred which has a 0.024-inch diameter thread. In addition, we must not provide any more than a 0.003 inch chamfer. The following is a typical approach for such a situation.

- A. Stone or sand the top surface.
- B. Gently use a bur ball or knife to chamfer the hole.
- C. Use a crosshole deburr brush.
- D. Use a rubber filled abrasive dental point to provide a smooth radius at the hole entrance.
- E. Dig out chips from bottom of hole.
- F. Clean the part.
- G. Scrutinize.
- H. Repeat A thru G as required.

In this case, the hole is one-third the diameter of the one described earlier. Figure 21 illustrates this size hole compared to the conventional pencil lead. As seen there, this hole is extremely small. It is the type of hole that can be easily overlooked, since such small holes quite often are not threaded. In this case, the fact has been emphasized that care must be taken not to exceed a 0.003 maximum edge break on such a feature. The hole must have some small chamfer, but the requirement here is that the chamfer be very small.

Figure 20. Small Hole Flushing Unit

It is permissible in a few instances to use a small reamer in the hole to remove burrs on crests. Table 1 lists some recommended reamer sizes. In the case of the last example, the threads are so extremely small that it is very easy for a reamer to remove too much material and thus scrap the part. For this reason, if a reamer is not specified on the production traveler, the individual performing the deburring should ask a supervisor if it is allowable and which size may be used. Again, on miniature holes, it may be necessary to use a "go" gage to verify that the hole is burr-free enough that it will not cause a mating part to stick.

There is a deburring problem caused by using crosshole deburring brushes. Note in Figure 16 that brush fibers do not extend all the way to the end of the brush. There is a small length of the

Figure 21. Relative Size of 0.6 mm Thread

Figure 22. Threads Which Were Centrifugally Barrel Tumbled

Table 1. Recommended Reamers and Brushes for Class 2A Threaded Holes

Thread Size	Maximum Allowable Minor Diameter (Inch)	Recommended Maximum Reamer Size (Inch)	Recommended Reamer Number	Recommended Brush	Recommended Flat Bottom Drill
0.6 mm	0.0198	0.0193	50100800	10207239	--
0.8 mm	0.0263	0.0258	50310760	10207238	--
1.0 mm	0.0327	0.0322	50311065	10207238	50101903
1.2 mm	0.0406	0.0401	50311346	10207226	--
0-80	0.0514	0.0509	50311871	10207226	50104050
2-56	0.0737	0.0732	50313020	10207227	50106-13
4-40	0.0939	0.0934	50314018	10207237	50108520

brush which has no fibers. On very, very shallow holes, the depth of the hole may not be any deeper than this nonfiber area of the brush. As a result, the crosshole deburring brush may not be beneficial. The crosshole deburring brushes wear very quickly. As they wear they develop a tapered portion of the fiber area. The tapered portion of the fiber area does not successfully and adequately remove material from the lower portion of the threads. As a result, do not use worn crosshole deburring brushes because they are not successfully cleaning out the threads.

POTENTIAL PROBLEM AREAS IN THREADED HOLES

As previously mentioned, it is easy, on miniature threads, to change their size out of the allowable tolerance while deburring. This is particularly true when using small reamers. It is also true when using "go" gages. The frequent insertion of any tool, such as a "go" gage in the threads, wears threads to the extent that they will no longer be functional in the assembly.

The second potential area, often overlooked, is that even the very miniature threads require that the first thread be removed if it is bent or very flimsy. Despite the fact that these threads are very small, this is an essential requirement.

Because of the small size of the miniature threads, it is not possible in many cases to get the desired thread quality. Careful attention, however, to each of the items discussed in this chapter will provide the necessary background and approaches to meet the needs of these miniature threads.

BASIC DEBURRING APPROACHES FOR THREADED SHAFTS

Bendix produces many threaded shafts or screws. These features are found on a variety of components in addition to the commercially purchased screws. The threaded shafts are much easier to deburr and to handle than threaded holes. It is generally easily seen whether the crests, the roots, and the first threads have been adequately removed. In addition, by the use of brushes, it is possible to develop a small radius at the crest of all the threads. A method of deburring a number 4-40 thread is given in the following example:

- A. Cut away any bent first threads,
- B. Brush the thread,
- C. Clean the thread,
- D. Scrutinize, and
- E. Repeat steps A thru D as required.

This basic approach is used for most threads regardless of their size. Again on very miniature threads, extensive brushing with the wrong brush can conceal the change threads beyond the allowable limits. This is not the normal case, however. It is also possible to use a mechanized deburring process such as barrel tumbling to deburr threads. Figure 22, for example, illustrates the quality of such threads which have been barrel tumbled. Barrel tumbling and mechanized processes for threads will be discussed in a later chapter.

POTENTIAL PROBLEM AREAS FOR MALE THREADS

There are three principal concerns when deburring male threads. It is very easy, when using knives on threads, to scratch them

such that they may not be acceptable. A second concern is that if too vigorous a brushing is used, the crest will have too large a radius or break on it. The third basic concern is that too much brushing can change the dimension of the threads such that they are also not acceptable. Note that the majority of these problems will not occur on most parts. On the extremely miniature parts, however, the possibility of such damage is real.

MECHANIZED DEBURRING PROCESSES FOR THREADS

Table 2 illustrates the mechanized processes which can be used for deburring threads. At this point the actual capabilities of the processes will not be discussed because we have not yet discussed how they work. Basically, however, mechanized processes are used on all threaded shafts and on the hard to reach intersections of threaded features. As an example, Figure 23 illustrates the intersection of two threads. Some related problem areas are with intersections of threads with holes, threads with slots, and threads with any other hard-to-reach areas. When a part has threads intersecting, with these types of features, he or she should ask the supervisor if perhaps a mechanized process might not be faster. As an example, electrochemical deburring can deburr the intersection of two threads in one minute or less (Figure 24), while conventional hand methods require 10 to 15 minutes and still do not provide the necessary quality. There are, however, a number of situations in which the mechanized processes cannot maintain the desired quality.

Table 2. Mechanized Processes Used for Deburring
Miniature Threads*

Process	Internal Threads	External Threads	Intersecting Threads
Barrel Tumbling	--	x	--
Vibratory Deburring	--	x	--
Centrifugal Barrel	--	x	--
Miniature Abrasive Jet	--	x	x
Electrochemical	--	x	x

*A dash implies the process cannot normally provide adequate deburring.

Figure 23. Intersecting Threads

Figure 24. Intersecting Threads After 30 Second Electrochemical Deburring and Brushing

ASSIGNMENT

1. Deburr the threaded shafts provided.
2. Deburr the threaded holes on the samples provided.
3. Using a conventional microscope, deburr a blind threaded hole until you are satisfied it is acceptable. Then inspect this threaded hole using a microscope having coaxial lighting.
4. Define the areas of the thread which must be burr-free.
5. Describe the reasons threaded shafts are easier to deburr than threaded holes.
6. What one tool is used in all threaded holes in miniature parts?

BDX-613-2400

A TRAINING MANUAL FOR PRECISION HAND DEBURRING,
PART 1, L. K. Gillespie, May 1980

Part 1 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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