



METAL WORK

Activity Plans

SKILLED**TRADES**^{BC}

Metal Work

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Youth Explore Trades Skills Learning Resources Development

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Metal Work

Introduction to Welding

Welding Beads courtesy of Malcolm from “migwelding: the DIY guide.” <http://www.mig-welding.co.uk>

Tools and Equipment

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angle grinder, bench grinder, drill press, hand drill, horizontal bandsaw, allen wrench, centre punch, combination square, dividers, file, file card, hacksaw, hammer, micrometer, pliers, screwdriver, scribe, tap and die, tin snips, vernier calipers, wrenches

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dremel (rotary tool), forge, foundry, milling machine, sandblaster, soldering pencil, hole saw, jeweller’s saw, letter stamps, number stamps, punch, rivets and rivet gun, ruler, side cutter, socket set, step drill, twist drill

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Spot welder – copyrighted free use

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About This Resource

In January 2016 a planning session took place in Vancouver, BC. It brought together educators who teach courses in metal work and fabrication. These courses expose students to fundamental metalworking skills needed for careers in the metalworking trades. The purpose of the planning session was to create a Manufacturing—Metal Work module for the Youth Explore Trades Skills course.

The Youth Explore Trades Skills resource project was tasked with the development of learning resources to support the BC Ministry of Education’s Youth Explore Trades Skills Program Guide.

During the planning session, educators felt the resources must meet a range of student and teacher needs. They designed each activity as a foundation lesson with extension activities for further growth of knowledge.

The resource introduces students to the fields of metalworking and manufacturing, and provides units in fabrication, welding, and machining. Each unit is built in self-contained modules that will equip both new and experienced teachers with easily navigable, ready-to-use lessons.

In order to align with the existing Youth Explore Trades Skills resources, the Metal Work modules follow the layout and design of the original Carpentry, Plumbing, Electrical, and Automotive modules.

Each activity can be used as a stand-alone resource or in sequence with the rest of the activities in the module. The modules can be used in conjunction with one another to create the foundations of the Explorations course. The planning team tried to create broad activities in order to allow teachers to match this resource to the tools and equipment that are available in their shop.

In this resource you will find:

- Detailed terminology related to the field of Metal Work & Manufacturing
- Detailed lists and descriptions of metal tools and equipment – both hand and power tools
- Detailed information regarding general shop safety
- Detailed lesson plans with activities, images, and video links. These activities fall under four main headings:
 - Introduction to Metal Work
 - Fabrication
 - Welding
 - Machining

All activities and lessons will be available in both PDF format and Word Doc.



Career Exploration—Metal Trades

Description

Students who are interested in investigating careers in the metal trades need to understand the pathways available to them. In this activity plan, students will learn about the various metal trades and the qualifications required throughout the process of becoming certified. Most metal trades involve a four level apprenticeship program. Each level consists of a block of hours of technical training and approximately 1500–1700 hours of on-the-job, practical training. To begin an apprenticeship, a person must become registered as an apprentice with a sponsor.

Foundation metal training gives students the opportunity to receive Level 1 technical training and practical skills. This may encourage an employer to register and hire the student as an apprentice. Some school districts in British Columbia offer partnership programs with post-secondary institutions that allow students to gain their foundation level of training while in high school. Students also need to understand the role that SkilledTradesBC plays in the apprenticeship process.

Once the apprentice has completed the necessary hours and training with an accredited institution, the apprentice becomes a journeyman.

Lesson Objective

The student will be able to:

- Understand the apprenticeship system and work-based training
- Identify the minimum educational requirements to get into the metal trades
- Know the educational strengths needed to succeed as a metal tradesperson
- Investigate apprenticeship opportunities within their school district
- Find post-secondary institutions that offer metal trades training within their region
- Understand SkilledTradesBC's role in the apprenticeship process
- Retrieve information about the metal trades through website navigation

Assumptions

- The student is interested in investigating a potential career in the metal trades.
- The student has access to a computer or tablet for this activity plan (recommended but not necessary).



Terminology

Apprentice: someone who works for a skilled or qualified person in order to learn a trade or profession.

Foundation program: provides the basic knowledge and skills needed for entry into a trade. It is typically taught in both the classroom and an in-school shop setting. You do not need an employer or sponsor to participate.

SkilledTradesBC: the organization responsible for leading and coordinating the skilled trades training and credentialing system for the province of BC. SkilledTradesBC provides strategic leadership, policy support, and customer services to help apprentices, employers, and industry. SkilledTradesBC sets program standards, maintains credential records, and issues the highly regarded Interprovincial Red Seal (IP) and BC Certificate of Qualification (CofQ) credentials.

Interprovincial Red Seal and BC Certificate of Qualification: through the Red Seal program, certified tradespeople can obtain a “Red Seal” endorsement on a BC Certificate of Qualification. The Red Seal allows qualified tradespeople to practise their trade in any province or territory in Canada where the trade is designated, without having to write further examinations. See www.red-seal.ca for additional information on the Red Seal Program. CofQ is only recognized in the province where it is obtained.

Training providers: if the training is to be counted toward an apprenticeship, institutions that offer technical training must be approved by SkilledTradesBC to become a SkilledTradesBC-Recognized Training Provider.

Work-based training: on-the-job training that requires specific learning outcomes.

Estimated Time

2–3 hours

Recommended Number of Students

20, based on the *BC Technology Educators’ Best Practices Guide*

Facilities

Computer lab with access to the Internet or class set of tablets. Teacher: Projector with computer and speakers, Internet access

Tools

Pen, pencil

Materials

Printed question sheet

Optional

If a class set of computers is not available, the teacher could lead a discussion about how to become a metal tradesperson using projector and computer/laptop to navigate through websites and explain them. This could also be an opportunity to go on a field trip to a local training provider and tour a training facility.

Resources

7 Steps to Success: SkilledTradesBC

<https://skilledtradesbc.ca/sponsor-employers>

SkilledTradesBC: Home Page

<https://skilledtradesbc.ca/>

WorkBC

<http://www.workbc.ca>

Career Trek BC

<http://www.careertrekbc.ca/>

Apprenticeship Basics: SkilledTradesBC

<https://skilledtradesbc.ca/about-the-trades>

Teacher-led Activity

Use a projector with computer to show the SkilledTradesBC website and explain the apprenticeship model.

1. Explain the apprenticeship process so students understand the apprenticeship model. See the Apprenticeship Basics link in the Resources section. The Red Seal Program is also explained on this page.

Please note: The SkilledTradesBC website is subject to change, so you may have to search the site to find the appropriate sections before the classroom demonstration.

2. Go to the Youth section and then choose Programs from the menu at the top right of the screen. This section explains the Youth Train in Trades and Youth Work in Trades programs.
3. Go to All Trades and select one of the manufacturing trades: Ironworker, Millwright, Metal Fabricator, Aircraft Structural Technician, Sheet Metal Worker, Tool & Die Maker, etc. View the information provided.

4. Go back to the Trades page and choose one profile from the Apprentice Program Listing at the bottom of the page. Download the Program Profile, which explains the apprenticeship pathway and educational requirements to complete that particular profile.
5. Go to All Trades and select one of the construction trades: Welder, Boilermaker, Industrial Mechanic (Millwright), Machinist, Metal Fabricator (Fitter), Motor Vehicle Body Repair, Steamfitter/Pipefitter. View the information provided.
6. Go back to the Trades page and choose one profile from the Apprentice Program Listing at the bottom of the page. Download the Program Profile, which explains the apprenticeship pathway and educational requirements to complete that particular profile.
7. From the menu at the top right on the SkilledTradesBC home page, choose Trade Training System and then Training Providers. This section shows all public and private training providers for trade programs.

Student Activity

Option 1: Class Set of Computers or Tablets Is Available

Students navigate through the WorkBC website and answer the questions found on the Metal Trades Exploration Activity sheet regarding the metal trades.

Option 2: Class Set of Computers or Tablets Is Not Available

The teacher uses a projector and laptop to navigate through websites and leads a discussion about how to become qualified in a chosen metal trade. Students complete the Metal Trades Exploration Activity sheet as the teacher moves through the sites. Once complete, have students draw a graphical representation of the apprenticeship process showing foundation-level training and the school and work portions of each level of training, culminating with the Red Seal qualification.

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

The student:

- Completes the answer sheet accurately
- Actively participates in the activity
- Actively participates in class discussion
- Actively participates in the optional extension activity

Metal Trades Exploration Activity

Find out some facts about the manufacturing and construction trades. Use the website www.workbc.ca

It's time to do some career exploration.

1. Select the Explore Careers & Industries tab on the main WorkBC page.
2. Select the Career Profiles in the dropdown menu.
3. Enter a manufacturing trade in the search box: Example: Welder and related Machine Operators. List your chosen occupation here:

-
- a. List six main **duties** of your chosen profile:

- b. List five facts about your chosen profile's **working conditions**:

- c. How many weeks in total will an apprentice spend getting his or her classroom educational training?

4. Answer the following questions concerned with demographic information:
- What is the median hourly wage of a full-time employee in the current workforce for your chosen profile?

 - What percentage of workers in the industry have full-time employment?

Find the **Employment Outlook**.

5. What is the expected change in the unemployment rate between 2014 and 2024?

6. Watch the video for your chosen profile (link is on the WorkBC page under Career Trek Videos). **Note: Some profiles do not include this portion.**
- How many hours of training are required to complete your certification, according to the video?

 - What are the typical working hours for your profile?

 - What five skills are required, according to the video?

7. Why are math skills important for your chosen profile?

8. What is a common general misconception about the job duties of your profile, according to the tradesperson interviewed in the video?
-

Optional Extension Activity

Go to www.mytelus.com and search for two contractors in your area. List them on this sheet.

Answer Key

(Sample: Welder)

3. a. Welders perform some or all of the following duties:

- read and interpret blueprints or welding process specifications
- operate manual or semi-automatic welding equipment to fuse metal segments using processes such as:
 - gas tungsten arc welding (GTAW)
 - gas metal arc welding (GMAW)
 - flux-cored arc welding (FCAW)
 - plasma arc welding (PAW)
 - shielded metal arc welding (SMAW)
 - oxy-acetylene welding (OAW)
 - resistance welding submerged arc welding (SAW)
 - operate manual or semi-automatic flame-cutting equipment as well as brazing and soldering equipment
 - operate brakes, shears, and other metal straightening and bending machines
 - repair worn parts of metal products by welding on extra layers

See more at: <https://www.workbc.ca/Jobs-Careers/Explore-Careers/Browse-Career-Profile/7237#section-duties>

b. Five facts about welders' working conditions could include:

- Most welders and related machine operators work 40 hours per week in factories and machine shops and on construction sites. Those working at mills, factories, and processing plants may work nights and weekends, or do shift work.
- Machine welders almost always work in controlled factory environments. Those working in manufacturing may work at sawmills, pulp and paper mills, or mines.
- The oil and gas industry hires welders to work on oil and gas rigs and pipelines. Welders and related machine operators who work in construction or in the oil and gas industry often work outdoors in various weather conditions.
- They may also be required to work from scaffolds or platforms.
- Other potential hazards to welders include exposure to fumes, intense light, and burns. Safety precautions must be taken to avoid injury.
- Welders in the construction industry often relocate to different job sites, sometimes in remote regions.
- Short periods of unemployment between projects are also common.

See more at: <https://www.workbc.ca/Jobs-Careers/Explore-Careers/Browse-Career-Profile/7237#section-duties>

- c. Classroom training:
 - Welders do not need trade certification to work in BC. However, there are three levels of welding certification in BC.: levels C, B, and A. Each level requires 8 weeks of classroom training; a total of 24 weeks would be needed to earn all three levels.
 - Level C certification is a prerequisite for level B certification, which is a prerequisite for level A.
4. a. Median hourly wage will be \$26.40/hour
b. % of full-time employment = 51% of welders are employed full time
5. The unemployment rate will drop from 10.4% to 9.6%.
6. There is no video for welding on the WorkBC website.

(Sample: Machinist)

3. a. Machinists perform some or all of the following duties:
 - inspect machined parts and tooling in order to maintain quality control standards
 - work for machinery, equipment, motor vehicle, automotive parts, aircraft, and other metal products manufacturing companies and for machine shops
 - work in wood manufacturing and food processing plants, as well as in refineries
 - have an interest in mechanization
 - must have strong attention to detail and be able to communicate complicated technical ideas with precision and clarity
 - need to have good physical mobility, as well as be able to lift heavy objects and handle production pressures calmly

See more at: <https://www.workbc.ca/Jobs-Careers/Explore-Careers/Browse-Career-Profile/7231#sthash.E5PhfgBS.dpuf>

- read and interpret engineering drawings, blueprints, charts, and tables or study sample parts to determine machining operations to be performed, and plan best sequence of operations
- compute dimensions and tolerances; measure and lay out work pieces; set up, operate, and maintain a variety of machine tools, including computer numerically controlled (CNC) tools to perform precision machining operations such as sawing, turning, milling, boring, planing, drilling, precision grinding, and other operations
- fit and assemble machined parts and subassemblies using hand and power tools
- verify dimensions of products for accuracy and conformance to specifications using precision measuring instruments
- may set up and program machine tools for use by machining tool operators

See more at: <https://www.workbc.ca/Jobs-Careers/Explore-Careers/Browse-Career-Profile/7231#sthash.jCQaajHB.dpuf>

b. Five facts about a machinist's working conditions:

- Machinists and machining and tooling inspectors typically work 40 hours per week. However, some overtime may be required to meet production schedules. Some larger operations require shift work.
- Machinists and machining and tooling inspectors typically work indoors in machine shops or manufacturing plants.
- The working conditions can be noisy and dirty, and workers may also be exposed to unpleasant odours. Hazards include physical injuries due to possible machinery-related accidents, hearing damage from noise, and sickness caused by exposure to toxic lubricants or coolants. The increased use of enclosed, automated equipment has reduced the risk of such injuries and removed much of the noise and dirt created in traditional machine shops and plants. Safety procedures (from the WorkSafeBC Act) are strictly enforced to reduce potential injuries.
- Machinists and machining and tooling inspectors are required to stand for most of the work day.
- At times, these workers may also be required to lift moderately heavy objects, which may increase their risk of back injury. However, modern shops and factories now employ autoloaders and overhead cranes that reduce the need to lift heavy objects.

See more at: <https://www.workbc.ca/Jobs-Careers/Explore-Careers/Browse-Career-Profile/7231#sthash.jCQaajHB.dpuf>

c. Classroom training:

Four classroom training sessions of 5 weeks each, for a total of 20 weeks

4. a. The median hourly wage will be \$31.25/hour
b. % of full-time employment = 63% of employees are mostly full time
5. The unemployment rate will drop from 6.8% to 6.6%.

Video-related questions:

6. a. # of hours of training = 3–4 years
b. Working hours: 6:30 a.m.–3 p.m.
c. 5 skills required:
 - verbal and written communication
 - attention to detail
 - object-oriented
 - understand the operations of a variety of machine tools
 - read and interpret blue prints

7. Math skills are important so the employee is able to read and interpret blue prints and then use that information to machine parts.
8. Interviewee does not state any common misconceptions for his job.

Introduction to Tools and Equipment

Description

The goal of this activity plan is to highlight most of the wide variety of tools and equipment used in metal shops. The plan includes a lesson/demonstration with a PowerPoint presentation on all of the tools, and the student will complete tool and machine identification activities. The focus of the activity is broad, and it will be applicable in the majority of school sites.

Lesson Objectives

The student will be able to:

- Identify the tools and equipment in their own school metal shop
- Explain the function of the tools and equipment
- Discuss safety implications of each tool/machine
- Identify one or more operation that is possible with each machine/tool
- Recognize that tools/machines should always be used only for their intended purpose

Assumptions

- Students may not have had prior metal shop procedural and safety training
- Students have not seen all of the machines/tools in the shop under operation

Terminology

Hand/manual tool: a tool that is operated completely by human power using hands or feet.

Portable power tool: a handheld, portable tool operated through the use of electricity, air, or hydraulics.

Stationary machine: a large machine that is operated with electricity, air, or hydraulics, generally secured to the floor or a workbench.

Any other terminology related to the tools being introduced will be taught to the students as it is required during the lesson.

Estimated Time

1.5–2 hours

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*



Facilities

Secondary school metal shop, or equivalently equipped technology education shop

Students are generally unaware of the dangers in handling some tools for the first time, especially air- or electrically-operated tools. Therefore adequate space is a primary concern for safety.

Equipment/Machinery

All shop equipment/tools should be demonstrated in operation.

A data projector will be required for the PowerPoint presentations.

Tools

A wide variety of tools will be introduced that are used in the metal/machine shop. The names and functions of these tools will be identified through the activities in the plan.

Materials

Handouts of tool descriptions and images with most common names are attached.

Teacher-led Activity

Part 1: Hand Tools / Manually Operated Machines

1. Referring to the provided PowerPoint, outline all of the hand tools listed and if possible describe their potential uses or functions.
2. Have the students complete the provided tool identification activity throughout the presentation.

Part 2: Power/Air Tools & Machines/Equipment

1. Referring to the provided PowerPoint, outline all of the power/air tools and machines/equipment listed and if possible describe their potential uses or functions.
2. Have the students complete the provided tool identification activity throughout the presentation.

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

Students:

- accurately name the picture of the tool based on the presentation.
- accurately record the function/use of that tool based on instructor's presented information.

Optional Extension Activity

Students can be taken throughout the shop and into various tool storage facilities/cabinets and asked to identify individual tools and machines.

Student Activity: Hand Tools

Name:

Instructions

Based on the PowerPoint presentation that your teacher has just shown you, name the following tools and briefly describe their functions.

Figure	Tool Picture	Proper Name & Function/Use
1.		
2.		
3.		

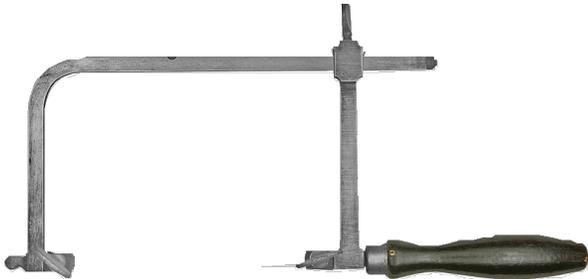
Figure	Tool Picture	Proper Name & Function/Use
4.		
5.		
6.		
7.		

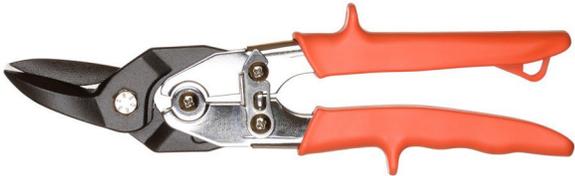
Figure	Tool Picture	Proper Name & Function/Use
8.		
9.		
10.		
11.		

Figure	Tool Picture	Proper Name & Function/Use
12.		
13.		
14.		
15.		

Figure	Tool Picture	Proper Name & Function/Use
16.		
17.		
18.		
19.		
20.		

Figure	Tool Picture	Proper Name & Function/Use
21.		
22.		
23.		
24.		

Figure	Tool Picture	Proper Name & Function/Use
25.		
26.		
27.		
28.		

Figure	Tool Picture	Proper Name & Function/Use
29.		
30.		
31.		

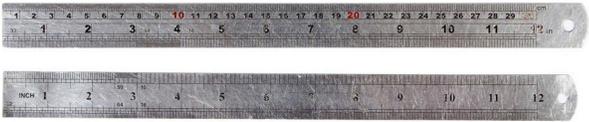
Figure	Tool Picture	Proper Name & Function/Use
32.		
33.		
34.		
35.		

Figure	Tool Picture	Proper Name & Function/Use
36.		
37.		
38.		
39.		

Figure	Tool Picture	Proper Name & Function/Use
40.		
41.		
42.		

Student Activity: Power Tools and Machines

Name: _____

Instructions

Based on the PowerPoint presentation that your teacher has just shown you, name the following power tools and machines and briefly describe their functions.

Figure	Power Tool/Machine Picture	Proper Name & Function/Use
1.		
2.		
3.		

Figure	Power Tool/Machine Picture	Proper Name & Function/Use
4.		
5.		
6.		
7.		

Figure	Power Tool/Machine Picture	Proper Name & Function/Use
8.		
9.		
10.		

Figure	Power Tool/Machine Picture	Proper Name & Function/Use
11.		
12.		
13.		

Figure	Power Tool/Machine Picture	Proper Name & Function/Use
14.		
15.		
16.		

Figure	Power Tool/Machine Picture	Proper Name & Function/Use
17.		
18.		
19.		
20.		

Figure	Power Tool/Machine Picture	Proper Name & Function/Use
21.		
22.		
23.		
24.		

Answer Key

Student Activity—Hand Tools

Tool Picture	Proper Name & Function/Use
Figure 1	HACKSAW
Figure 2	SQUARING FOOT SHEAR
Figure 3	DIVIDERS
Figure 4	BEVERLY SHEAR
Figure 5	ENGLISH WHEEL
Figure 6	COMBINATION SQUARE
Figure 7	JEWELLER'S SAW
Figure 8	AVIATION SNIPS
Figure 9	HAMMERS
Figure 10	COMBINATION ROLLER
Figure 11	MICROMETER
Figure 12	LETTER STAMPS
Figure 13	HOLE SAW
Figure 14	SCRIBER
Figure 15	CENTRE PUNCH
Figure 16	STEP DRILL
Figure 17	ALLEN WRENCH
Figure 18	STRIKER
Figure 19	TAP & DIE
Figure 20	TINSNIPS
Figure 21	SLIP ROLLER
Figure 22	EMERY CLOTH
Figure 23	RIVETS & RIVET GUN
Figure 24	BAR FOLDER
Figure 25	FILES
Figure 26	VERNIER CALIPERS
Figure 27	TWIST DRILLS
Figure 28	WRENCHES
Figure 29	PIPE BENDER
Figure 30	SOCKET SET
Figure 31	CHISELS
Figure 32	PLIERS
Figure 33	REAMERS
Figure 34	RULER
Figure 35	PUNCHES

Tool Picture	Proper Name & Function/Use
Figure 36	SCREWDRIVERS
Figure 37	SIDE CUTTERS
Figure 38	ROPER WHITNEY PUNCH
Figure 39	DI-ACRO BENDER
Figure 40	BOX & PAN BRAKE
Figure 41	NUMBER STAMPS
Figure 42	FILE CARD

Student Activity—Power Tools and Machines

Power Tool/ Machine Picture	Proper Name & Function/Use
Figure 1	BUFFER
Figure 2	AIR RIVETER
Figure 3	OXYACETYLENE TORCH
Figure 4	ANGLE GRINDER
Figure 5	ARC WELDER
Figure 6	COLD SAW
Figure 7	HAND DRILL
Figure 8	VERTICAL BANDSAW
Figure 9	SOLDERING PENCIL
Figure 10	TIG WELDER
Figure 11	LATHE
Figure 12	MIG WELDER
Figure 13	IMPACT DRIVER
Figure 14	DRILL PRESS
Figure 15	HORIZONTAL BANDSAW
Figure 16	MILLING MACHINE
Figure 17	FOUNDRY
Figure 18	ABRASIVE SAW
Figure 19	DREMEL (ROTARY TOOL)
Figure 20	SANDBLASTER
Figure 21	BENCH GRINDER
Figure 22	SPOT WELDER
Figure 23	FORGE
Figure 24	PLASMA CUTTER

General Metal Shop Safety

Description

The purpose of this activity is to introduce students to the metal shop environment while giving a brief description of tools, equipment, processes, and safety procedures. Safety is stressed at all times in a working shop environment, and students are made aware of what safety equipment and procedures are to be followed.

This activity plan has two parts:

1. Teacher-led shop tour
2. Student-completed shop map and question sheet

Lesson Objectives

- Familiarize students with the metal shop
- Review emergency procedures and how they relate to the metal shop environment
- Introduce students to new tools and equipment
- Inform students about use and location of all emergency equipment in the shop, including fire extinguishers, power shut-off buttons, fire blankets, first aid kits, emergency exits, and eyewash stations

Assumptions

The student should:

- Be attentive and participatory
- Recognize that appropriate attitudes are the best insurance for safety

The teacher should:

- Be a certified technology education/industrial education teacher
- Be familiar with the metal shop where this activity plan is being applied
- Have experience with all aspects of the given metal shop, including machines, tools, and potential processes
- Be able to introduce individual tool safety when demonstrating tool use
- Be familiar with the individual school emergency preparedness plans and how to implement them appropriately in the metal shop environment



Terminology

Emergency exit: a marked exit door used when leaving a building during an emergency

Eyewash station: a safety device designed to rinse away debris, particulate, or chemicals from the eye.

Fire blanket: a blanket made of fire-retardant material that is placed over the fire to extinguish it.

Fire extinguisher: a portable safety device designed to extinguish a fire through the release of extinguishing material. There are several different types of extinguishers, each specific to the type of fire: Class A = wood, trash, and paper; Class B = liquid; Class C = electrical.

First aid kit: a container with bandages, gloves, cleaning solutions, and other first aid materials.

Power shut-off button (emergency stop): a bright red switch that shuts off power to all equipment and outlets in the shop.

SDS: Safety Data Sheet, also known as *MSDS* (Material Safety Data Sheet). Provides detailed information on the composition, safe handling and storage, and first aid measures for products.

- WHMIS: Workplace Hazardous Material Information System

Estimated Time

30–90 minutes

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Metal shop facility

Tools

- Whiteboard
- Overhead projector
- Computer/laptop

Materials

- Blank shop map: prepare a handout and attach to the activity handout
- Pencil
- Blank paper
- Ruler

Textbook and a relevant safety chapter could be mentioned to supplement the lesson.

Resources

“HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

“BC Technology Education Association Best Practices Guide”

<http://www.bctea.org/best-practice-guide/>

Assessment

Please note: Answers to the question sheet and shop map activity are specific to each shop. A general key is provided; however, the instructor may want to add additional answers. A general assessment guideline is provided below.

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

Shop Map Activity

- Student actively participated in the tour and discussions.
- Overall map is neat and organized.
- Symbols and labels are clear.
- Map includes ALL necessary safety equipment locations.
- All fixed pieces of equipment are included and in the correct location.

Question Sheet

- All questions are answered in full.
- Explanations of procedures are clear and correct.
- Student can clearly articulate where safety equipment is located.

Optional Extension Activity

Tool mapping: Have students take pictures of tools and equipment and create a labelled document of the shop.

Teacher-Led Activity

Conduct a shop tour introducing all equipment, tools, and appropriate safety measures, including WHMIS/SDS. Delivery is up to the individual teacher, as not all shops are the same. The information provided in this lesson is general in nature and should be expanded upon by the instructor.

Student Activities:

Shop Map and Safety Questions

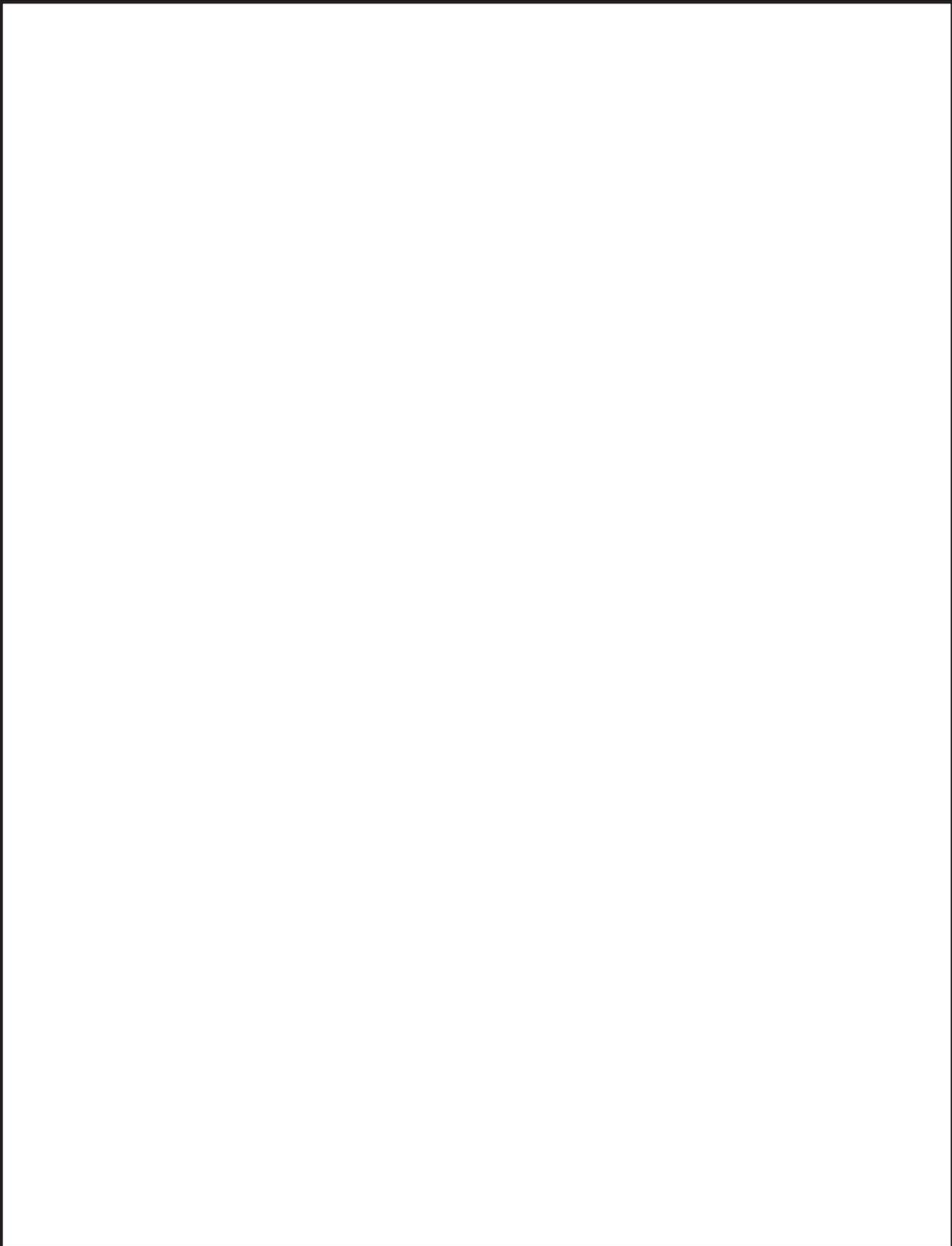
Shop Map Instructions

Use the attached blank template to complete a map of your shop based on what you learned during the shop tour. Include all safety notations and tool and equipment labels.

1. With a pencil and ruler, sketch a birds-eye view of your metal shop classroom.
2. Using symbols of your choice, indicate the following on your map:
 - All fire extinguishers
 - All emergency exits
 - All emergency power shut-off buttons
 - First aid kit
 - Eyewash station
 - Fire blanket
 - Chemical shower
 - Flammables cabinet
 - SDS binder
 - Any other specialized emergency safety equipment
3. Next draw the following on your map. Simple squares would work well and are easy to draw.
 - All work tables
 - Tool cabinets
 - Material storage
 - Parts and equipment storage locations
4. Draw all of the fixed tools and equipment on your map. You may want to use a symbol or a colour-coded legend for this section. Use the following list as a guide to locate the tools in your shop:
 - Abrasive saw
 - Arc welder
 - Bar folder
 - Bead roller
 - Bench grinder
 - Beverly shear

- Box and pan brake
 - Buffing wheel
 - Cold saw
 - Combination roller
 - Di-acro bender
 - Drill press
 - English wheel
 - Forge/foundry
 - Hossfeld bender
 - Horizontal band saw
 - Lathe
 - MIG welder
 - Milling machine
 - Oxyacetylene torch
 - Pipe bender
 - Plasma cutter
 - Sand blaster
 - Slip roller
 - Spot welder
 - Squaring foot shear
 - TIG welder
 - Vertical band saw
5. Review your map for any other important details or specialized equipment. Some things to include would be waste disposal containers and sinks.

Shop map



General Shop Safety Questions

1. How many emergency shut-off buttons are there in the shop?

2. Where is the flammable storage cabinet located? Give two examples of products that may be stored in it.

3. In case of an earthquake where should you take cover in the metal shop?

4. What are three kinds of approved eye protection in the metal shop?

5. Where should oil-soaked rags/towels be placed when you are done using them? Why?

6. Why is it important to notify the instructor when an accident or injury has occurred?

7. Why is it important to have a clean and organized shop environment? Explain.

8. Explain why, when operating any piece of equipment, it is extremely important to not be under the influence of alcohol or drugs.

9. In case of a fire what is the first step you should take?

10. What is the purpose of a fire blanket? When should it be used?

General Shop Safety Questions Answer Key

1. How many emergency shut-off buttons are there in the shop?
Site-specific
2. Where is the flammable storage cabinet located? Give two examples of products that may be stored in it.
Site-specific. Two examples: paint thinner, stains, paint
3. In case of an earthquake where should you take cover in the metal shop?
Site-specific
4. What are three kinds of approved eye protection in the metal shop?
Face shield, goggles, welding mask
5. Where should oil-soaked rags/towels be placed when you are done using them? Why?
Should be placed in sealed fire bins, to ensure spontaneous combustion does not occur.
6. Why is it important to notify the instructor when an accident or injury has occurred?
To ensure that the hazard can be removed quickly and the students can receive appropriate medical attention if needed.
7. Why is it important to have a clean and organized shop environment? Explain.
It is important to have a well-organized shop environment, as it helps in the prevention of accidents and injuries. When materials and equipment are stored appropriately it provides a more efficient work environment.
8. Explain why, when operating any piece of equipment, it is extremely important to not be under the influence of alcohol or drugs.
Being under the influence of alcohol or drugs can impede a student's judgment, and could cause significant injuries to the operator and others in the shop.
9. In case of a fire what is the first step you should take?
Turn off the power and evacuate the building in the safest, most direct way.
10. What is the purpose of a fire blanket? When should it be used?
The purpose of a fire blanket is to extinguish flames on a person. It should be used when a student has caught fire as a result of working in the shop environment.

Metal Shop Measurement Foundations

Description

This activity plan provides a basis for instruction of foundational measurement standards and procedures. It includes the use of imperial and metric measurement tools needed to work in the metal trades.

Lesson Objectives

The student will be able to:

- Work with both measurement systems used in metal trades in Canada
- Demonstrate an essential understanding of proficient measurement tool use
- Name and operate all basic measurement tools covered

Assumptions

The teacher should:

- Be able to explain both the metric and SAE measurement systems
- Be able to identify and explain precision measurement tool use

The student should:

- Understand numbers systems
- Have a basic understanding of what a unit of measurement is
- Have experience using the metric system

Terminology

Decimal inch: an SAE measurement that is a part of a whole inch represented as a decimal value.

Fractional inch: an SAE measurement that is a part of a whole inch represented as a fraction.

Measurement: assigning a number to represent a length or amount of something based on a standardized system of units.

Measuring tape: a flexible ruler with linear measurement markings attached to a spring mechanism housed in a case. These may be in imperial or metric units or both.

Metric: a system of measurement based on a decimal standard, the global standard in measurement. Also known as the *International System of Units*, abbreviated as *SI*.



Micrometer: a gauge that measures small distances/thicknesses between its two faces, one of which is adjusted by a fine screw thread.

Ruler: a linear device that has graduations based on either the metric or SAE system intended for measuring distance.

Ruler graduations: the fixed interval markings along a ruler that represent a progressive increase in length measurement.

SAE: an acronym for the *Society of Automotive Engineers*, generally synonymous with the US standard for the traditional “imperial” measurement system.

Unit: a standard quantity in a specific system of measurement.

Vernier caliper: a precision measurement device that uses a caliper structure to measure fine measurements along a Vernier scale.

Estimated Time

1.5–2 hours

Recommended Number of Students:

20, based on the *BC Technology Educators’ Best Practices Guide*

Facilities

Secondary school metal shop or equivalently equipped technology education shop

Tools

- Whiteboard
- Overhead or data projector
- Computer
- Rulers
- Tape measures
- Micrometers
- Vernier calipers

Materials

- Worksheets
- For optional activity: samples to measure (variety of sizes and shapes of general materials)
- Writing implement

Resources

Apprenticeship and Workplace Math 10 online: Open School BC, Open Course Resource.
<http://ocr.openschool.bc.ca/course/view.php?id=23>

Teacher-led Activities

1. Teacher will introduce each of the four main measurement tools:
 - a. Ruler
 - b. Tape measure
 - c. Micrometer
 - d. Vernier caliper
2. Teacher will demonstrate the use and accurate reading of each tool.

Student Activities

Each of these activities should take no more than 30 minutes.

Activity 1: Measuring in Metric Using a Measuring Tape

This is adapted from Open School BC's Apprenticeship & Workplace Math 10 Module 1 Section 1 Assignment Part 1: Measuring in Metric.

Activity 2: Measuring in SAE/Imperial

This is adapted from Open School BC's Apprenticeship & Workplace Math 10 Module 1 Section 2 Assignment Part 1: Imperial Units of Length.

Activity 3: Vernier Calipers and Micrometers

This is adapted from Open School BC's Apprenticeship & Workplace Math 10 Module 2 Section 1 Lesson B: Measuring Diameters

Activity 4: Measuring Diameter

This is adapted from Open School BC's Apprenticeship & Workplace Math 10 Module 2 Section 1 Assignment Part 2: Measuring Circumference and Diameter.

Optional Extension Activity

Have a variety of material blanks (common samples) and have students work through individual measurement stations. Each station would have a different measurement tool to use and a requirement to use both measurement systems throughout the activity.

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

- All worksheet questions are answered correctly and completely.

Student Activity 1: Measuring in Metric Using a Measuring Tape

Instructions

For this assignment, you will need a tape measure that shows millimetres, centimetres, and metres. You will also need two partners.

Procedure

- Step 1:** Measure your and your partners' heights to the nearest millimetre. Record your measured heights in the appropriate column of the table below.
- Step 2:** Measure your and your partners' heights to the nearest tenth of a centimetre. Record your measured heights in the appropriate column of the table below.
- Step 3:** Measure your and your partners' heights to the nearest thousandth of a metre. Record your measured heights in the appropriate column of the table below.

	Height		
	(mm)	(cm)	(m)
You			
Partner 1			
Partner 2			

Have a look at your completed table. Do you notice any patterns? Answer the following questions based on the patterns you see. You may use the measurements you recorded as examples in your explanations.

1. Explain how you would change a measurement from millimetres to centimetres and give an example.

Example:

2. Explain how you would change a measurement from metres to centimetres and give an example.

Example:

3. Explain how you would change a measurement from millimetres to metres and give an example.

Example:

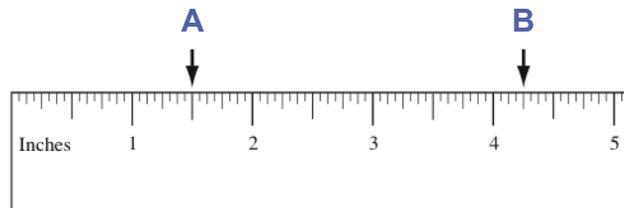
Student Activity 2: Measuring in SAE/Imperial

Instructions

Please show all your work.

1. Name two objects about one inch in length.

2.



- a. At what measures on the ruler are points A and B?

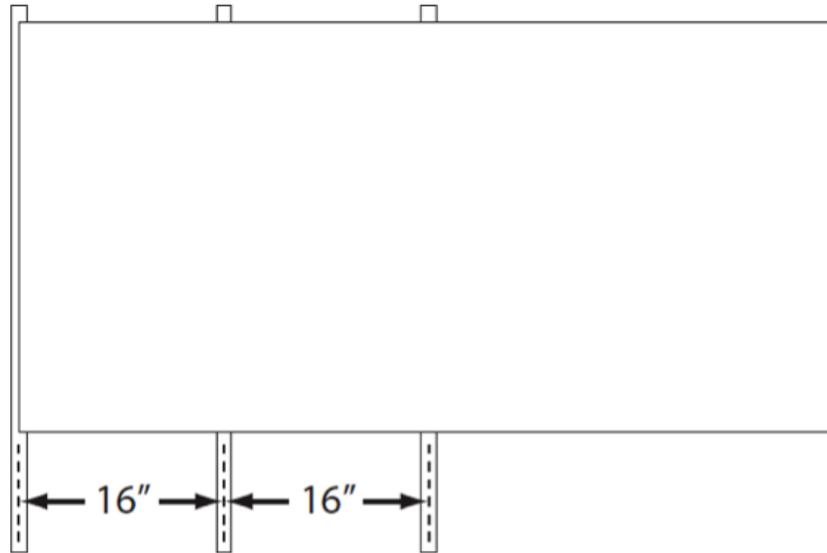
A: _____

B: _____

- b. How far apart are A and B?

3. Nidal lives one block from his school. Nidal paced off the distance and estimates the distance to be 215 yd. What is this distance in feet?

4. The centre lines of vertical framing studs are commonly 16" apart. How many studs would be required to fasten an 8' length of sheathing? Ignore the width of the studs themselves.
(**Hint:** The left edge of the sheet falls along the centre line of the first stud.)



5. A 2×6 is $1\frac{1}{2}$ " in thick. How high would a stack of ten 2×6 's be?
Express your answer in feet and inches.

6. One circuit of the running track at Jon's school is 440 yd. What fraction of a mile is that distance?

7. Norman, who lives in Fort St. John, is planning to visit his friend in Seattle. He will be travelling through Blaine, Washington. The distance from Fort St. John to Blaine is 1221 km. The distance from Blaine to Seattle is 109 mi. To the nearest kilometre, how far is it from Fort St. John to Seattle?

8. Monique was asked to quickly estimate the dimensions, in inches, of the cell phone shown below.

She estimates the cell phone measures approximately $5\frac{1}{2}$ " by $2\frac{1}{2}$ ".



a. How do you think Monique arrived at this estimate?

- b. Do you think that Monique's estimate was a good one? Why or why not?

- c. What are the actual dimensions, in inches, of the phone? Round your answers to one decimal place. (Hint: Use the conversion rate of 2.54 cm per inch.)

- d. Briefly describe a strategy you could use to quickly estimate the conversion between centimetres and inches.

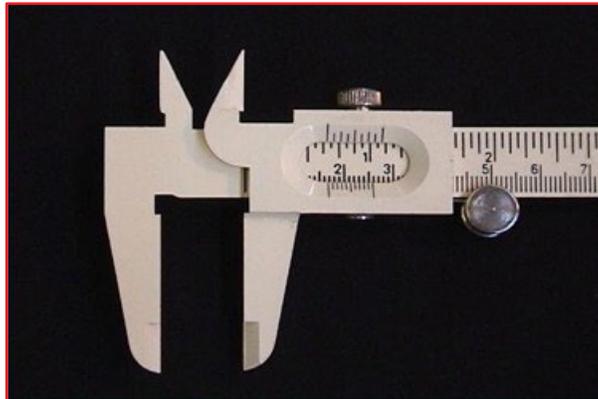
Student Activity 3: Vernier Calipers and Micrometers

Rulers, metre sticks, and measuring tapes can give measurements to the nearest millimetre, or to the nearest 0.1 cm. Other measuring instruments can more accurately measure to the nearest tenth of a millimetre, or 0.01 cm, or even to the nearest one-thousandth of a millimetre, or 0.001 mm, depending on their scales.

The two measuring instruments you will learn about here are the caliper and the micrometer.

Vernier Calipers

A Vernier caliper is an instrument used for making accurate linear measurements. It was invented by a French engineer named Pierre Vernier in 1613. It is a common tool used in laboratories and other industries that require precise measurements. Manufacturing of aircraft, buses, and scientific instruments are a few examples of industries in which precision measurements are essential.



Vernier Calipers

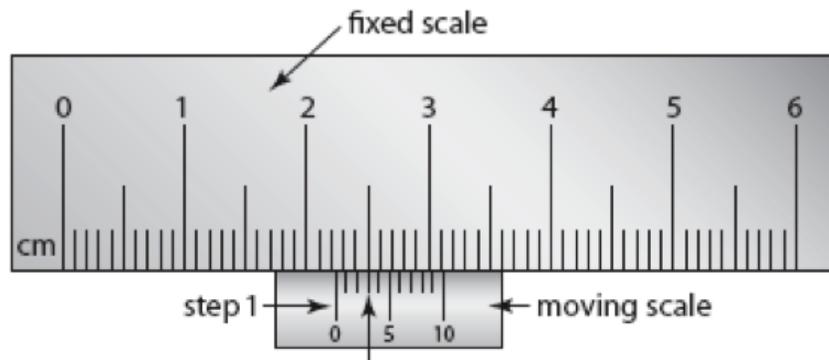
A Vernier caliper (often called a *Vernier* or *caliper*) is a convenient tool to use when measuring the length of a small object or the outer or inner diameter of a round object like a pipe or hole. A Vernier caliper can measure accurately to 0.01 cm, or 0.1 mm.

Reading a Vernier caliper is not difficult. Once the jaws of the Vernier are in place, the scales are set and the reading can be made.

There are two scales used for measuring with calipers: SI (metric) and imperial. These two scales can sometimes be found on the same caliper, one on the top and one on the bottom. When using each scale, the procedure for determining each measurement is slightly different. Only SI calipers will be discussed here.

Reading SI or Metric Calipers

When measuring with a metric caliper, the final measurement will usually be in centimetres (cm). There are three steps needed to read these Vernier calipers. Each step is done independently and then the values are all added together.



Reading SI or Metric Calipers

In this example, the movable scale is on the bottom of the fixed scale. (It can also be on the top.) The numbers at the top of the fixed scale are in centimetres. Notice that there are tick marks on the fixed scale between the numbers. These are in millimetres or tenths of a centimetre. Therefore, there are 10 ticks between the numbers. There are also 10 tick marks on the movable scale.

Step 1: Locate the “0” on the movable or sliding scale. Now you need to determine where the “0” is.

In this example, the zero is between 2 and 3 cm, so we know our reading will be at least 2 cm. This is our first part of the reading and can be recorded as follows:

2. _____ cm

Our goal is to fill in the two blanks to finish the reading.

Step 2: Now you must determine the next blank, which represents the tenths of a centimetre. To do this, look carefully at the tick marks between 2 and 3 centimetres on the fixed scale. You can see that the zero line has gone past the second tick but has not yet reached the third tick. So we write down a “2” for the next blank. So our reading now looks like this:

2.2 _____ cm

Step 3: You will use the ticks on the moving scale for the final reading. Notice that one of the ticks on the moving scale lines up or matches best with a tick mark directly above it on the fixed scale. In this example, the arrow shows that the third tick matches up most closely with the line on the fixed scale. Thus, the value for the third blank must be a 3, and our reading would be:

2.23 cm

Note: It doesn't matter which line is matched on the fixed scale as we read from the movable scale.

Some sites that might help you are the following:

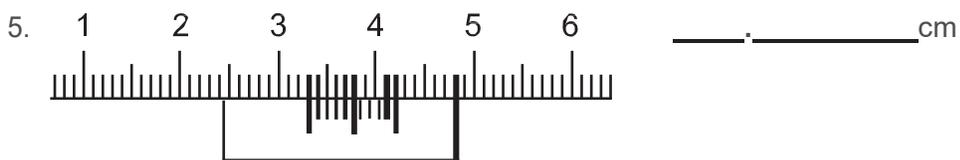
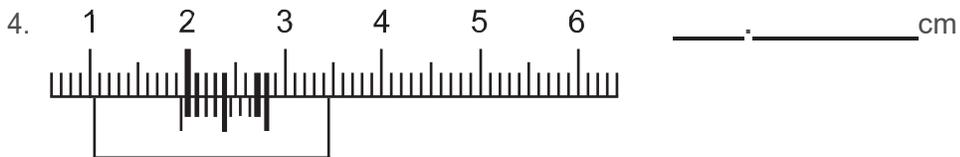
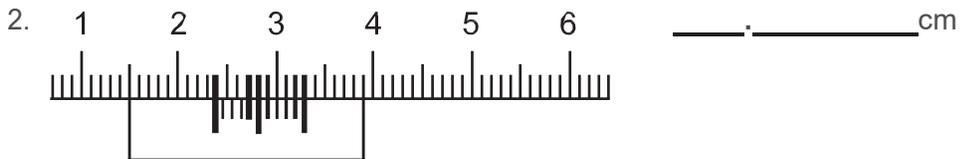
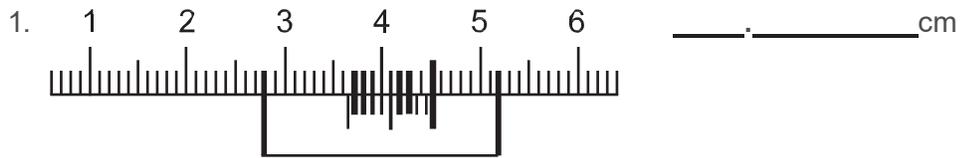
<http://www.physics.smu.edu/~scalise/apparatus/caliper/>

<http://www.upscale.utoronto.ca/PVB/Harrison/Vernier/Vernier.html>

<http://hyperphysics.phy-astr.gsu.edu/hbase/class/phscilab/vernier.html>

Vernier Calipers Practice

Now try these caliper readings and write down their measurements.

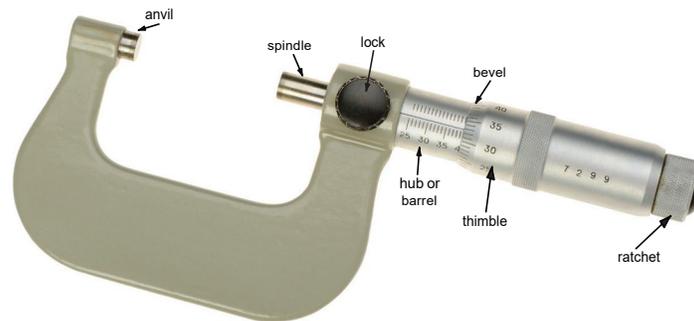


Micrometers

Micrometers are another tool that can be used to precisely measure small lengths. In fact, micrometers can make even smaller and more precise measurements than a Vernier caliper can! Micrometers are often used to measure things like the thickness of round or flat items, engine parts, and items being made in a machine shop. While Vernier calipers can measure accurately to the nearest tenth of a millimetre (0.1 mm), a micrometer can measure to the nearest hundredth of a millimetre (0.01 mm).

The illustration shows the standard design of a micrometer. The areas that we will concentrate on are the sleeve (or barrel) and the thimble. The thimble is the moving scale on a micrometer.

In an imperial micrometer (top photo), as the jaws open and the space between the anvil and the spindle gets larger, the thimble turns and goes further down the sleeve. The parts in an SI or metric micrometer (bottom photo) are all the same, but the scales are different.



Micrometer—Photo by Galushko Sergey © 2010

This photo shows an enlargement of the sleeve and thimble of the SI or metric micrometer. This is the type of photo or diagram that you will be reading the measurements from.

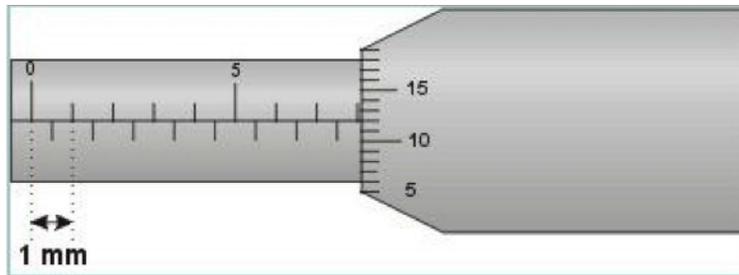


Metric micrometer's sleeve and thimble

Reading SI or Metric Micrometers

When an object is placed in the jaws of a micrometer between the anvil and the spindle, the thimble is turned in order to make both the anvil and the spindle touch the object. As the thimble is turned, it moves to the left (in the diagram below) and the length of the spindle decreases.

To read any length, first look at the top of the spindle reading. This scale is in millimetres. Simply count from the zero to where the thimble cuts across the spindle. In this example, the thimble crosses the spindle just past 8 mm.

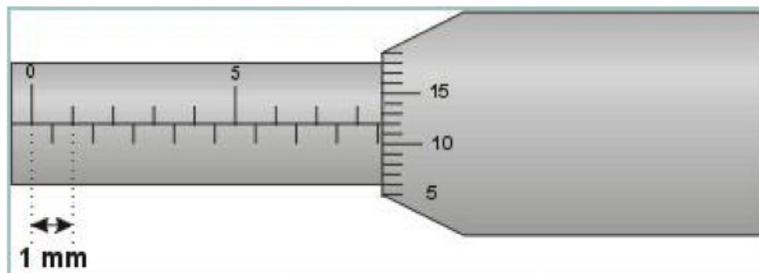


Next read the thimble on the micrometer. The thimble reading is made where the line from the spindle crosses the thimble. In this diagram, the thimble reads 12. However, this is NOT 12 mm but 0.12 mm. Now the readings are added together to get the final reading:

$$8 \text{ mm} + 0.12 \text{ mm} = 8.12 \text{ mm}$$

Notice that there are also divisions on the bottom of the scale in the barrel. These are half-millimetre divisions; they come into play when the thimble is partially turned between whole millimetre marks, as shown in the micrometer below:

While the top of the scale on the spindle is still showing 8 mm, there is a tick mark now showing on the bottom of the scale before the thimble. If this is the situation, you must add 0.5 mm to the top reading before reading the thimble. So this reading would be:



$$8 \text{ mm} + 0.5 \text{ mm} + 0.12 \text{ mm} = 8.62 \text{ mm}$$

When measuring with a Vernier caliper, there might be some room for error depending on which lines match the best. With the micrometer, however, there is only one right answer. Therefore, micrometers are much more precise and accurate than Vernier caliper are.

A site that might help you is the following:

Introduction to Metal Work: Measurement

Reading SI or Metric Micrometers (uses javascript so may not work on all devices)

<http://www.upscale.utoronto.ca/PVB/Harrison/Micrometer/Flash/MicSimulation.html>

Virtual Micrometer—Thousandth of Inch Simulator

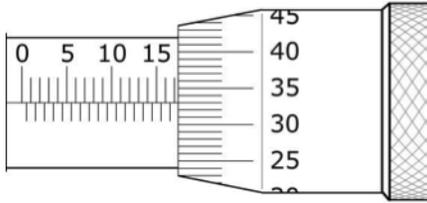
<http://www.stefanelli.eng.br/en/virtual-micrometer-thousandth-inch-simulator/>

Apps are available. Search for “micrometer simulation”.

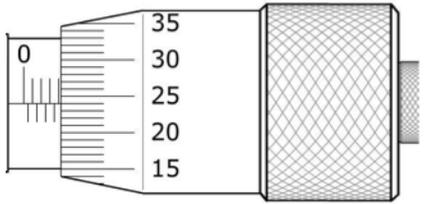
Now read these micrometers and write down their measurements.

Micrometers Practice

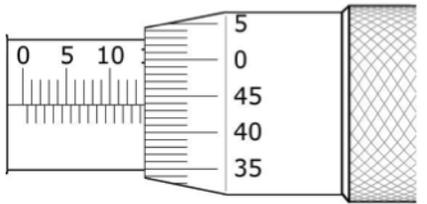
1.



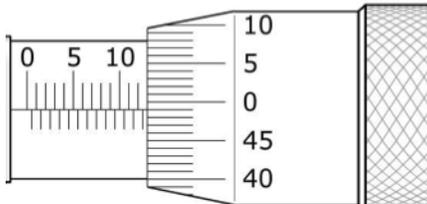
2.



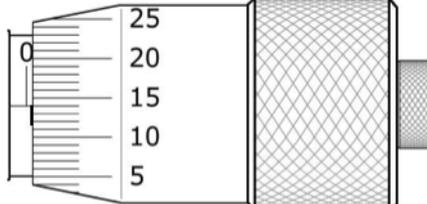
3.



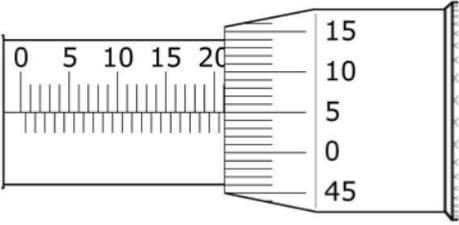
4.



5.



6.



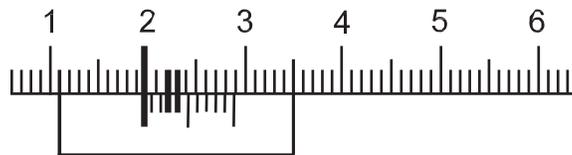
Student Activity 4: Reading Vernier Calipers and Micrometers

Instructions

Please show all your work.

- Describe a situation where you might use a Vernier caliper. Explain why you would use this measurement tool in the situation you described.

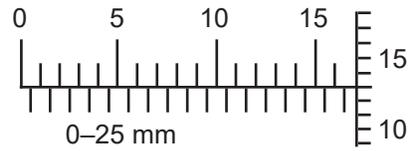
- Read the following Vernier caliper measurement. The Vernier caliper is calibrated in metric units.



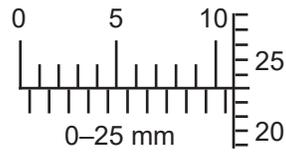
- Read the following Vernier caliper measurement. The Vernier caliper is calibrated in metric units.



3. a. Read the following micrometer measurement. The micrometer is calibrated in metric units.



- b. Read the following micrometer measurement. The micrometer is calibrated in metric units.



Assessment Guidelines

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

- All assignments are completed correctly.

Answer Key

Student Activity 1: Measuring in Metric Using a Measuring Tape

	Height		
	(mm)	(cm)	(m)
You	1645	164.5	1.645
Partner 1	1702	170.2	1.702
Partner 2	1817	181.7	1.817

1. To change millimeters to centimetres, divide the measurement in centimetres by 10. For example,

$$1645 \text{ mm} = \left(\frac{1645}{10} \right) \text{ cm}$$

$$= 164.5 \text{ cm}$$

2. To change a measurement from metres to centimetres, multiply by 100. For example,

$$1.645 \text{ m} = (1.645 \times 100) \text{ cm}$$

$$= 164.5 \text{ cm}$$

3. To change a measurement from millimeters to metres, divide by 1000. For example,

$$1645 \text{ mm} = \left(\frac{1645}{1000} \right) \text{ m}$$

$$= 1.645 \text{ m}$$

Student Activity 2: Measuring in SAE/Imperial

1. Answers will vary. Some examples are the width of your thumb, the width of a postage stamp, and the width of the control key on a computer keyboard.
2. a. A: $1\frac{1}{2}$

$$\text{B: } 4\frac{1}{4}$$

$$\text{b. } 4\frac{1}{4}'' - 1\frac{1}{2}'' = \frac{17}{4}'' - \frac{3}{2}'' \text{ The points are } 2\frac{3}{4}'' \text{ apart.}$$

$$= \frac{17}{4}'' - \frac{6}{4}''$$

$$= \frac{11}{4}''$$

$$= 2\frac{3}{4}''$$

3. Let x = the distance in feet.

$$\frac{x}{215 \text{ yd}} = \frac{1 \text{ ft}}{3 \text{ yd}}$$

$$x = \frac{(1 \text{ ft})(215 \text{ yd})}{3 \text{ yd}}$$

$$x = 645 \text{ ft}$$

The distance between Nidal's home and school is approximately 645 ft.

4. Student may include a diagram to support their solution or as an alternative to calculating it mathematically. The solution by calculation is shown below.

$$8 \text{ ft} = 8 \times 12 \text{ in}$$

$$= 96 \text{ in}$$

$$\frac{96 \text{ in}}{16 \text{ in}} = 6$$

There are 6 studs after the first.

There are 7 studs behind the sheet.

5. $10 \times 1\frac{1}{2} \text{ in} = 15 \text{ in}$ The stack would be 1 ft 3 in high.
 $= 12 \text{ in} + 3 \text{ in}$
 $= 1 \text{ ft } 3 \text{ in}$

6. $1 \text{ mi} = 1760 \text{ yd}$

Let x = the distance in miles

$$\frac{x}{440 \text{ yd}} = \frac{1 \text{ ml}}{1760 \text{ yd}}$$

$$x(1760 \text{ yd}) = (1 \text{ ml})(440 \text{ yd})$$

$$x = \frac{440}{1760} \text{ ml}$$

$$x = \frac{1}{4} \text{ ml}$$

So, 440 yd is one quarter of a mile.

7. First find the distance from Blaine to Seattle.
 Convert 109 mi to kilometres.

$$1 \text{ mi} = 1.6 \text{ km}$$

$$109 \text{ mi} = (109 \times 1.6) \text{ km}$$

$$= 174.4 \text{ km}$$

$$\approx 175 \text{ km}$$

Now find the total distance from Fort St John to Seattle.

$$\begin{aligned}\text{Total distance} &= (\text{Fort St. John to Blaine}) + (\text{Blaine to Seattle}) \\ &= 1221 \text{ km} + 175 \text{ km} \\ &= 1396 \text{ km}\end{aligned}$$

The approximate distance from Fort St. John to Seattle is 1396 km.

8. a. Answers will vary. Monique rounded the measurements to the nearest centimetre and then divided by 2.
- b. Answers will vary. Monique rounded the measurements to the nearest centimetre and then divided by 2.

Do you think that Monique's estimate was a good one? Why or why not? (1 mark)

Answers will vary. Student should express a reasonable explanation for their choice. Two sample responses are provided below.

Yes, Monique's estimate was a good one. There are 2.54 cm in an inch. Monique rounded the dimensions up, so she rounded the conversion factor down to 2, which is an easy number to divide by.

No, Monique's estimate was not a very good one. There are 2.54 cm in an inch. Monique should have rounded the conversion factor up to 3 before dividing. Then her estimate would have been about $3\frac{2}{3}$ in by 2 in.

- c. 1 in = 2.54 cm
We can solve this by dividing by the conversion factor.

$$\begin{aligned}10.9 \text{ cm} &= \left(\frac{10.9}{2.54}\right) \text{ in} \\ &= 4.3 \text{ in}\end{aligned}$$

$$\begin{aligned}5.8 \text{ cm} &= \left(\frac{5.8}{2.54}\right) \text{ in} \\ &= 2.3 \text{ in}\end{aligned}$$

The cell phone measures 4.3 in by 2.3 in.

- d. Answers will vary. Student may repeat the strategy that Monique used, or describe one of their own. As long as their explanation is clear and logical, they should receive the mark.

Student Activity 3: Vernier Calipers and Micrometers

Vernier Calipers Practice

1. 3.64 cm
2. 2.37 cm
3. 4.76 cm
4. 1.93 cm
5. 3.32 cm

Micrometers Practice

1. 17.33
2. 4.24
3. 13.94
4. 12.99
5. 0.64
6. 21.05

Student Activity 4: Reading Vernier Calipers and Micrometers

1. Answers will vary. Some situations include: measuring the inside or outside diameter of a pipe, measuring the opening of a piece of pottery so you can make a lid that fits properly, measuring the small parts of engines. The students' explanation will vary, but may include one or more of the following points:
 - a Vernier calliper provides a more precise measurement than a ruler or tape measure
 - a Vernier calliper has two sets of jaws and so can easily measure the inside diameter and the outside diameter of an object
 - when measuring the diameter of a circular object, the calliper will “grab-on” to the widest part, so you know you're measuring the diameter (whereas you would be guessing where the diameter was if you used a ruler)
2. a. 1.98 cm
b. 3.34 cm
3. a. 16.63 mm
b. 10.73 mm

Metallurgy: The Science of Metals

Description

This activity plan provides basic information on metallurgy, which is the science of understanding the physical properties of metals. Metals can be divided into three categories: non-ferrous, ferrous and precious/pure. The purpose of this plan is to explore metals and give students a foundational understanding of what metals are made of and how they are classified.

Students will learn the categories of metals, properties and characteristics. Material Identification will help them to quickly identify metals and their various shapes.

It is suggested to complete this activity prior to Materials Identification.

Lesson Objectives

The student will be able to:

- Understand the basics of the field of metallurgy
- Discuss the similarities and differences between the categories of metals
- Identify processes for metals
- Discuss the properties of metals
- Identify common metals found in the metal shop

Assumptions

The teacher should:

- understand the basics of material science
- understand the properties of metal
- understand how metals are classified

Terminology

Alloy: a mixture of metals/elements that creates new metals with different characteristics

Aluminum: a metallic element that is silvery/blue in colour, lightweight and easy to fabricate

Base material/element:

Brass: a yellow alloy that is made with copper and zinc

Bronze: a yellow/brown alloy that is made with copper and tin

Carbon: a naturally occurring non-metal element used in metals



Copper: a naturally occurring red/brown metal that is ductile and conducts heat well

Element: a substance that cannot be broken down any further. Composed of atoms that contain the same atomic number

Ferrous: a metal that contains iron as its base material

Gold: a precious metal that is yellow in colour, resistant to chemicals and very malleable

Iron: a heavy type of metal, used in the production of steel

Lead: a soft, malleable grey element

Metallurgy: a branch of science and technology concerned with the properties of metals, their production and purification

Molecule: a group of two or more atoms that link together

Nickel: a silvery white metal, hard and resistant to corrosion

Non-ferrous: a non-magnetic metal that does not contain iron as its base material

Pewter: an alloy composed of 90% tin and a mix of copper and antimony

Precious: a highly valued object or substance. In this lesson, used to describe valuable metals like gold and silver

Properties: in relation to metal, characteristics and descriptions to help identify materials

Pure: a material containing only one element

Silver: shiny, grey metal that is an excellent conductor and is resistant to corrosion

Stainless steel: an alloy that contains chromium to ensure the metal is resistant to corrosion

Steel: an iron-based alloy that is very hard and strong. Used heavily in manufacturing

Tin: a soft, very shiny metal used in the production of alloys; strong resistance to corrosion; non-toxic

Zinc: a base metal used in the production of alloys, known for its resistance to corrosion

Estimated Time

30–90 minutes

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Metal shop or classroom environment

Tools

- Computer and projector
- PowerPoint presentation

Materials

- Pieces of a variety of metals for visual and tactile examples
- Notes printed from the PowerPoint presentation as a handout for students

Resources

- *Modern Metalworking*, textbook by John R. Walker, copyright 2004, Goodheart-Wilcox Company Inc.

Teacher-led Activity

Using the PowerPoint presentation on metals, present the background information on the science behind metals, known as metallurgy.

Have a class discussion that includes the following topics:

- Discuss the similarities and differences between the categories of metals
- Identify processes for metals
- Discuss the properties of metals
- Identify common metals found in the metal shop

Evaluation

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Students are actively engaged in class discussion.

Metal Trades Materials Identification

Description

There is a variety of different metals used in the metal trades and throughout school metal shops. This activity plan provides instruction for the foundational knowledge of material identification in the metal trades. It includes the common processes and procedures used to identify and categorize individual samples based on specific criteria. Students will gain experience identifying and differentiating common metal types.

Lesson Objectives

The student will be able to:

- Identify samples of material
- Accurately categorize materials as ferrous and non-ferrous
- Identify the characteristics of common metals in the machine and welding shops

Assumptions

The teacher should:

- Have experience differentiating different ferrous and non-ferrous materials
- Have an understanding of the various processes used to identify metals

The student should:

- Know that there are several metal types used in the metal shop
- Have a basic understanding of what a metal is

Terminology

Alloy: a mixture of metals and/or elements that creates characteristics different from those of the component materials.

Cold rolled: steel that is processed below its recrystallization temperature. Usually higher carbon, harder, and more accurately sized than hot rolled steel.

Ductile: a material that will deform under tension (pulling force).

Ferrous: a metal contains iron and is often magnetic.

Fusible: capable of being fused, especially by heat.

Hardness: a metal's ability to resist deformation or indentation.



Hot rolled: steel that is processed above its recrystallization temperature. Usually lower carbon, softer, and more economical than cold rolled steel.

Magnetic: whether or not the metal is attracted to a magnet.

Malleable: a material that will deform under compression.

Metal: a material that is usually hard, shiny, malleable, fusible, and ductile, with good heat and electrical conductivity.

Non-ferrous: a metal that doesn't contain iron and is not magnetic.

Relative weight: weight of a sample compared to other metals.

Estimated Time

1–1.5 hours

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Secondary school metal shop or equivalently equipped technology education shop

Tools

- Whiteboard
- Overhead or data projector
- Computer

Materials

- Worksheets
- Samples of materials to identify
- Writing implement

Resources

BCIT Technology Teacher Education Program course notes/worksheets

Modern Metalworking, textbook by John R. Walker

Teacher-Led Activities

1. Describe and define *metal*.
2. Explain the difference between ferrous and non-ferrous metals, using examples either online or physical.

3. Outline the main criteria for determining the characteristics of different metals:
 - a. Magnetic/non-magnetic – whether or not a magnet attracts the metal.
 - b. Ferrous/non-ferrous – this is often determined through the test for magnetism, except with stainless steel, which is an alloy of steel that isn't magnetic.
 - c. Colour/appearance – a visual physical characteristic that helps determine the metal type. Hot rolled has black carbon coating while cold rolled is uncoated.
 - d. Relative weight – weight of a sample as compared to other metals.
4. Explain the additional tests, some of which aren't always possible or feasible in every shop:
 - a. Spark testing – using a grinder to test metal based on spark colour, frequency, length, and overall appearance
 - b. Hardness testing – it would be rare for a school shop to have a hardness tester (i.e., Rockwell scale tester). However, hardness would also be a possible determinant.
 - c. Comparative tests in malleability, and ductility could be performed in class.
5. Get students started on the identification activity.

Student Activity

1. Students will move from station to station with a worksheet to identify metals based on properties and characteristics.
2. Stations will be set up with all of the common metal types found in the shop:
 - a. Hot rolled mild steel
 - b. Cold rolled mild steel
 - c. Tool steel
 - d. Cast iron (less common)
 - e. Stainless steel
 - f. Aluminum
 - g. Copper
 - h. Brass
 - i. Bronze (less common)
3. Students will fill out the worksheet based on the observations of four to six properties.

Assessment

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Worksheet completion: worksheet is complete and neatly filled out.
- Observations: all tests were completed accurately and data was noted.
- Summary: information was accurate and complete.

Optional Extension Activity

Students could analyze several different carbon steel samples, including mild steel, tool steel, wrought iron, and cast iron, and use a grinder to do a spark test on the samples.

Students could refer to the chart at the link below to determine the carbon content in the samples and the corresponding category of the iron-based sample:

<http://www.weldingwire.com/Images/Interior/documentlibrary/metal%20id.pdf>

Student Activity: Identifying Metal Samples Name(s):

Instructions

You and your partner(s) must move station to station and identify the characteristics of the metal sample at each station based on the common tests. Your teacher may also instruct you to conduct the optional tests.

After completing your observations, summarize your data gathered on each sample. Please ensure that you are summarizing in full sentences.

Station ID # _

Observations (What can you see?)

Common Tests	
Magnetic/non-magnetic	
Ferrous/non-ferrous	
Colour/appearance	
Relative weight	
Optional Tests	
Spark testing	
Hardness testing	

Summary (What metal is it and why?)

Station ID # _

Observations (What can you see?)

Common Tests	
Magnetic/non-magnetic	
Ferrous/non-ferrous	
Colour/appearance	
Relative weight	
Optional Tests	
Spark testing	
Hardness testing	

Summary (What metal is it and why?)

Station ID # _

Observations (What can you see?)

Common Tests	
Magnetic/non-magnetic	
Ferrous/non-ferrous	
Colour/appearance	
Relative weight	
Optional Tests	
Spark testing	
Hardness testing	

Summary (What metal is it and why?)

Metal Stock Identification

Description

Metal is produced in many different types, shapes, and forms. This activity plan provides examples of stock forms that might be found in a metal shop. Many of these shapes are common to all shops, while others are less frequently available. Almost all of the stock forms used in a metal shop are available in steel, and most are also available in other non-ferrous metals. Students will gain experience identifying different stocks and classifying them appropriately.

Lesson Objectives

The student will be able to:

- Identify stock types visually
- Use the proper names for stock types
- Properly identify stock by shape and dimensions
- Categorize the stock by metal type

Assumptions

The teacher should:

- Have experience differentiating stock types by shape, size, and type of metal
- Ensure that the metal shop is supplied with many types of stock for this activity

The student should:

- Have experience determining metal type
- Have a basic understanding that material comes in different shapes and sizes
- Have the ability to measure and determine dimensions of materials

Terminology

Dimensions: measurements of width, depth, length, thickness, or wall thickness.

DOM: structural tubing that is different from pipe.

Ferrous: a metal that contains iron and is often magnetic.

Galvanized: steel that is coated, usually in zinc, to prevent oxidation/rust.

Gauge: thickness measurement of sheet stock.

Grade: a term for the quality of the material. Often refers to hardness or strength.



Metal: a solid material that is hard, fusible, and workable and usually conducts heat and electricity.

Metal stock: material in the specific shape, size, and length in which it comes from the supplier.

Non-ferrous: a metal that doesn't contain iron and is not magnetic.

Schedule 40/80: pipe wall thickness.

Web: thickness of angle/I beam.

Estimated Time

1–1.5 hours

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Secondary school metal shop or equivalently equipped technology education shop

Tools

- Whiteboard
- Overhead or data projector
- Computer
- Micrometer
- Vernier caliper
- Sheet metal gauge
- Scale

Materials

- Worksheets
- Samples of stock types to identify
- Writing implement

Resources

Metal Supermarkets website: <http://metalsupermarkets.com/>

Modern Metalworking, textbook by John R. Walker

Teacher-led Activity

1. Describe and define metal stock.
2. Explain that stock comes in many different shapes, sizes, and metal types.
3. Outline the main characteristics by which metal stock is categorized:
 - a. Metal type – the type of metal (e.g., aluminum, stainless steel, brass)
 - b. Material shape – the shape that the metal is formed in (e.g., tubing, pipe, sheet); also considering whether the material is solid or hollow. Explain the difference between tube, pipe, hollow bar, and between drill rod, shafting and round bar.
 - c. Grade – the quality of the material; most school shops use the lowest grade for their supply.
 - d. Dimensional size – the size of the material; sometimes multiple dimensions, including width, thickness, wall thickness, and length
4. Get students started on the stock type identification activity.

Student Activity

1. Students will move from station to station with a worksheet to identify material stock based on their characteristics.
2. Stations will be set up with many of the common stock types from the shop, including samples that are:
 - a. Multiple different metal types
 - b. Hollow, solid, and sheet
 - c. Various shapes and sizes
 - d. Common and rare
 - e. Different grade levels
3. Students will fill out the worksheet based on their observations of the five characteristics above.

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

- Worksheet completion: worksheet is complete and neatly filled out.
- Observations: all tests were completed accurately and data was noted.
- Summary: information was accurate and complete.

Student Metal Stock Information Sheet

Use the following information to complete the Identifying Metal Stock activity.

Metal Types

1. Hot rolled steel
2. Cold rolled steel
3. Tool steel
4. Alloy steel
5. Stainless steel
6. Aluminium
7. Copper
8. Brass
9. Bronze
10. Galvanized (usually sheet stock)

Stock Shapes

Consider if the stock is hollow, solid, or sheet (Figure 1).

Grade

Most school shops use utility grade for all material, except when building specialty projects requiring specific steel alloys, tool steel, or aluminum alloys.

Dimensions

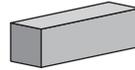
Stock may be measured in a variety of dimensions, including width, thickness, wall thickness, and length. Pipe is measured by the inside diameter. Sometimes there will be two different widths (one could be called depth), as in the case of tubing, angle iron, and channel. Weight is important as it helps identify and price most metals, particularly precious metals. Web thickness is important in angle, channel and I-beam. There are also some very specific dimensions that are used with some sheet materials, like expanded metal or tread plate, which you will have to ask your teacher to help you with.



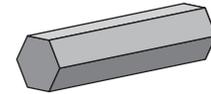
Round bar



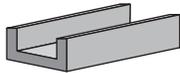
Rectangular bar



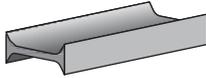
Square bar



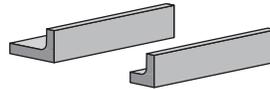
Hexagonal bar



Channel



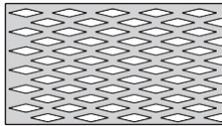
I-beam



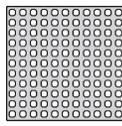
Angle iron



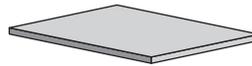
Sheet



Expanded metal



Perforated sheet



Plate



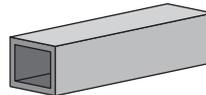
Tread plate



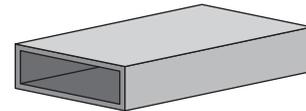
Pipe



Round tube



Square tube



Rectangular tube



Hollow bar



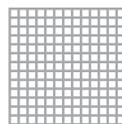
Shafting



Drill rod



Precision ground stock



Mesh sheet

Figure 1—Stock Shapes

Student Activity: Identifying Metal Stock Name(s):

Instructions

You and your partner(s) must move from station to station and identify the stock form characteristics of the metal sample at each station based on the categories in the Student Metal Stock Information Sheet.

After completing your observations, summarize your data gathered on each sample. Please ensure that you are summarizing in full sentences.

Station ID # _____

Observations (What can you see?)

Common Characteristics	
Metal type	
Hollow/solid/sheet	
Stock shape	
Grade	
Dimensions	

Summary (What metal is it and why?)

Station ID # _____

Observations (What can you see?)

Common Characteristics	
Metal type	
Hollow/solid/sheet	
Stock shape	
Grade	
Dimensions	

Summary (What metal is it and why?)

Station ID # _____

Observations (What can you see?)

Common Characteristics	
Metal type	
Hollow/solid/sheet	
Stock shape	
Grade	
Dimensions	

Summary (What metal is it and why?)

Introduction to Sheet Metal Fabrication

Description

Sheet metal fabrication is a very broad subject area and uses many tools, machines and joining processes. Sheet metal workers fabricate, assemble, alter and install a variety of sheet metal products. Typical jobs performed by a sheet metal worker include HVAC (Heating, Ventilation and Air Conditioning) ductwork, industrial sheet metal work and residential sheet metal work as well as aviation construction. Sheet metal smiths also work on stainless steel hospital and kitchen equipment, industrial exhaust systems and roofing and flashing (copper, aluminum, stainless steel and galvanized iron).

This Activity Plan is designed to introduce students to the various types of sheet metal as well as common introductory fabrication processes, such as measurement, layout, riveting and folding. More experienced students will also be introduced to more advanced options like brazing. The Activity Plan is flexible and allows for modification to suit individual student needs.

Lesson Objectives

The student will be able to:

- Briefly describe what is generally meant by the term *sheet metal*
- Correctly identify common sheet metal types and describe their characteristics and properties
- Name basic fabrication equipment and list some of the operations done with them
- Complete basic fabrication processes using common sheet metal tools and equipment

Assumptions

The teacher will:

- Be a certified technology education/industrial education teacher
- Be familiar with the metal shop that this activity plan is being produced in
- Have experience with all aspects of the given metal shop, including machines, tools and processes

The student will:

- Have an understanding of metallurgy, shapes and forms of metals
- Understand basic principles and methods of layout
- Be attentive and participatory
- Recognize that appropriate attitudes are the best insurance for safety
- Safely work in the metal shop



Terminology

Aluminum: a metallic element that is used as an alloying agent for a group of alloys.

Aviation snips: a hand tool designed to cut sheet metal into intricate designs. Can be used to cut compound curves. Red = left cutting; Green = right cutting; Yellow = universal, able to cut in any direction.

Bar folder: a sheet metal machine that is used to create straight bends in sheet metal.

Bead roller: a hand roller designed to add raised, curved decorative hems to sheet metal.

Beverly shear: a small hand-operated piece of equipment that has two blades that when passed against each other shear the metal.

Box and pan brake: a sheet metal machine that is used to create bends, hems and boxes in sheet metal.

Brass: an alloy metal consisting of a mixture of copper and zinc. Gold/yellow in colour.

Brazing: a process in which two metals are joined using a non-ferrous filler rod that is melted at temperatures over 450°C (840°F).

Centre punch: a tapered piece of metal that is used to create an indent in metal to centre the drill bit while drilling.

Cold rolled steel: steel that has been rolled into its finished shape after it has been cooled. After this process is complete it is put through a pickling solution or dilute acid to remove the iron oxide coating.

Combination roller: a machine used to perform burring, crimping, wire edging and other forming techniques on sheet metal.

Copper: a metallic element, orange in colour. Commonly used in art metal, electrical work and as an alloying agent.

Emery cloth: an abrasive cloth used to remove material and smooth surfaces.

English wheel: a hand-operated tool that enables the formation of compound curves from flat sheets of metal.

Expanded sheet metal: sheets made by cutting slits into regular metal sheets and stretching them out to create numerous openings in a diamond pattern. Expanded sheets are lighter, stronger and less expensive than regular flat sheets. They also allow for the free passing of liquids, light and sound.

Ferrous: a metal containing high levels of iron.

File: a hand tool designed to shape and smooth metal. Available in a variety of shapes and sizes to fit different projects. Made of hardened steel with varying textures to remove large or very minimal amounts of material.

Galvanized steel: a steel sheet that is dipped in a zinc coating to protect it.

Gauge: the thickness of the sheet metal measured with a thickness gauge.

Hammer: a tool designed to give a heavy blow to an object. Made with a variety of different head materials for specific purposes.

Hem: a border made by folding over the edge of a piece of sheet metal to increase strength, prevent exposure of a sharp edge and increase the product's durability.

Hot rolled steel: steel that is formed into its finished shape while red hot. It is identified by its black oxide coating that is formed during the rolling process.

Letter and number stamps: hardened steel bars with letters and numbers. Used to permanently label metal projects.

Non-ferrous: metals that contain little to no iron.

Oxyacetylene welding: welding torches that use a combination of oxygen and acetylene to produce a flame hot enough to join metal together using a filler metal.

Rivet: a non-threaded fastener used to join metal pieces together that do not need to come apart.

Roper Whitney punch: a hand tool used to punch holes in sheet metal stock.

Ruler: a precision measurement tool that is a length of steel with marks at regular intervals.

Scribe: a long, pointed piece of hardened steel that is used to mark layout lines on metal.

Sheet metal: a term used to describe a variety of thin rolled metal sheet stock.

Slip roller: hand-driven equipment that contains three hardened steel rollers: a drive roller, a gripping roller and a radius roller.

Spot welder: a resistance welding technique.

Squaring foot shear: a foot-controlled machine used to cut sheet metal stock.

Stainless steel: an alloyed steel designed to have greatly increased corrosion resistance compared to carbon/alloy steel. Common alloying ingredients include chromium (usually at least 11%), nickel and molybdenum.

Tin snips: a hand tool designed to cut out layouts on sheet metal. Also called *hand shears*.

Welding: the process by which two or more metals are joined together by heating the metals to the point where they fuse together.

Estimated Time

1–2 hours

Recommended Number of Students

20, based on the *BC Technology Education Association Best Practices Guide*

Facilities

Metal shop facility with all necessary tools, materials and equipment

Tools and Equipment

Personal protective equipment

Hand Tools

- Aviation snips
- Centre punch
- Emery cloth
- Coarse and smooth files
- Gauge
- Peening hammer
- Letter/number stamps
- Rivets & rivet gun
- Roper Whitney punch
- Ruler
- Scribe
- Tin snips

Stationary Equipment

- Bar folder
- Bead roller
- Beverley shear
- Box and pan brake
- Combination roller
- English wheel
- Oxyacetylene welder
- Slip roller
- Spot welder
- Squaring foot shear

Materials

Multiple samples of the various sheet metals you plan to introduce during the course for identification and demonstration purposes. This may include aluminum, copper, brass, galvanized sheet metal, cold rolled steel, aluminum and hot rolled steel. It is suggested that teachers demonstrate the procedures using materials that will be found in their individual shop as well as equipment that is specific to their shop.

Resources

Box and pan brake

<http://www.bing.com/videos/search?q=how+to+use+a+box+and+pan+brake&view=detail&mid=0B5F895025F7C74515AE0B5F895025F7C74515AE&FORM=VIRE>

Roper Whitney punch

<http://www.bing.com/videos/search?q=how+to+use+a+whiney+punch&&view=detail&mid=94426538A09825CF06DD94426538A09825CF06DD&FORM=VRDGAR>

Beverly shear

<http://www.bing.com/videos/search?q=how+to+use+a+beverly+shear&&view=detail&mid=EE2EE6F39C76DEA3A5DAEE2EE6F39C76DEA3A5DA&rvsmid=074FB5E6FA3B3931B7F7074FB5E6FA3B3931B7F7&fsscr=0&FORM=VDMCNR>

Bar folder

<http://www.bing.com/videos/search?q=how+to+use+a+bar+folder&&view=detail&mid=300C3F9B87B7F4360FE7300C3F9B87B7F4360FE7&FORM=VRDGAR>

English wheel

<https://www.youtube.com/watch?v=omRIIBONJAM>

“HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

BC Technology Education Association Best Practices Guide

<http://www.bctea.org/best-practice-guide/>

Modern Metalworking, textbook by John R. Walker, copyright 2004, Goodheart-Wilcox Company Inc.

Teacher-led Activity 1: Introduction to Sheet Metal

1. Begin by gathering all tools, materials and equipment.
2. Introduce each type of sheet metal and give a brief description of each individual type, common uses and identifying characteristics. (See Material Identification & Stock Identification Activity Plans for more detailed information.)
3. Distribute the attached sheet metal identification/description information sheet.
4. Demonstrate how to check thickness of sheet metal stock using the thickness gauge.
5. Provide sample pieces for students to handle and become familiar with.

Student Activity

1. Set up stations with sample pieces of sheet metal.
2. Have students identify and describe each sample, using the attached sheet metal identification worksheet.
3. Provide magnets for students to test for magnetic properties of the samples.
4. Students will also need a thickness gauge to correctly test for material gauges.

Teacher-led Activity 2: Introduction to Fabrication Processes

1. Set up a workstation with all hand tools commonly used in the metal shop.
2. Work through each hand tool, describing its name, use and any other specialty instructions. (See Introduction to Tools and Equipment Activity Plan and subsequent PowerPoint presentations for more detailed information.)
3. Once hand tools are complete, move the student group to each of the stationary pieces of equipment located in the metal shop. At each describe the tool name and use and demonstrate safe working practices.
4. When all tools and equipment have been appropriately and safely demonstrated, students can begin the individual hands-on portion of the activity.

Student Activity

1. Set up workstations that include one or two of the hand tools commonly used in the metal shop (e.g., Roper Whitney punch along with rivets and a rivet gun).
2. Have students work through each station, completing the task of using the equipment on a sample piece of sheet metal.
3. Workstations should also include the stationary equipment such as squaring foot shear, box and pan break and spot welder.
4. Once students have completed each activity they should have a variety of sample pieces of sheet metal that have been cut, formed or joined in some way.
5. The attached student station worksheet will act as a guide to ensure students work through each station. More experienced students or peer tutors could be used to sign off on each student as they complete a station.

Additional stations could include combination roller, English wheel, bead roller or brazing. These additional stations may require larger sample pieces of material to ensure safe working practices.

Note: Both activity worksheets are general in nature and are designed to provide a guide for the student activities. They can be added to or subtracted from to suit individual teacher and shop classroom environments.

Assessment

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Safe working procedures at all times
- Personal and project management: good use of time, attitude, effort
- Accurate measurements and layout
- Appropriate use of tools
- All burrs and sharp edges are smooth
- Instructions were followed throughout the activity
- Correct identification of materials
- Description of materials is complete and includes characteristics and properties

Sheet Metal Identification Worksheet

Name _____

Date _

Sample number	Name of sample	Gauge/ thickness	Ferrous yes/no	Conductivity	Describe the sample (colour, texture, etc.)
#1					
#2					
#3					
#4					
#5					
#6					
#7					

Sheet Metal Fabrication Introduction Activity

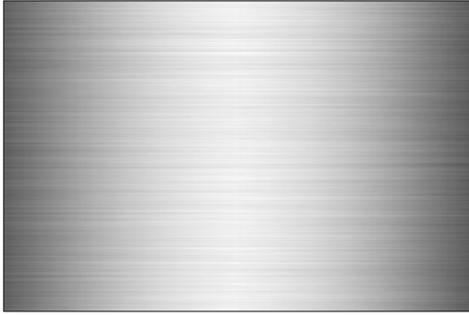
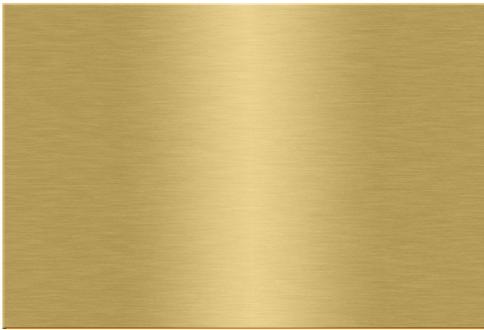
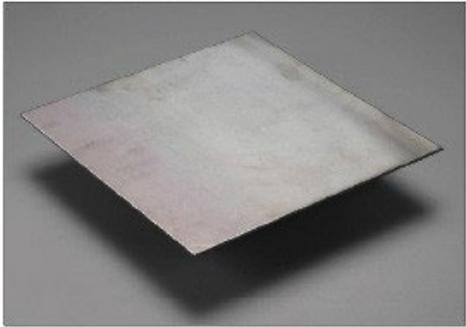
Name _____

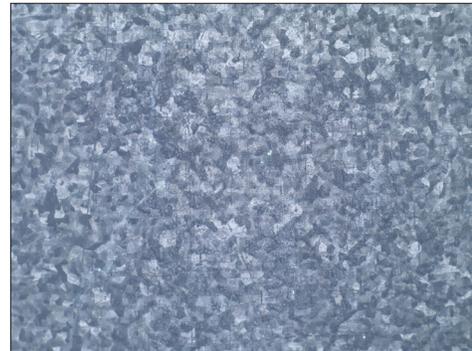
Date _

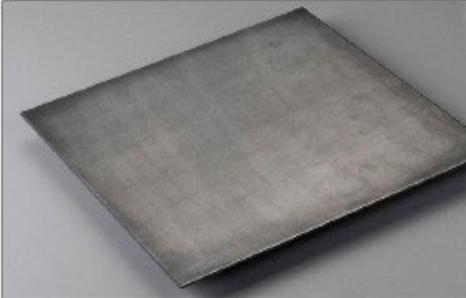
Material: 6" × 6" sheet metal

- Station 1:** Using the materials and equipment provided, measure, lay out and scribe lines that divide your metal into nine 2" × 2" even squares.
- Station 2:** Squaring foot shear: Cut your material into three long strips. They should be 2" wide × 6" long.
- Station 3:** Tin snips and files: Using the snips, cut two of your long strips into six 2" squares. Using the files, file all edges on each square to remove all burrs and sharp edges.
- Station 4:** Beverly shear: Cut your last long strip into one piece that is 2" × 2" and a second piece that measures 2" × 4".
- Station 5:** Letter/number stamps and hammer: On each square stamp your initials and a number from 1 through 8.
- Station 6:** Centre punch, Roper Whitney punch and riveting: Centre punch two holes on each of two of your samples, for a total of four holes. Then use the Roper Whitney to punch out all four holes. Once that is complete, use the rivets and riveting gun to join your sample pieces together, aligning all the holes.
- Station 7:** Spot welder: **Be sure to use ALL safety gear.** Select two different samples of material and join them together using the spot welder. Be creative.
- Station 8:** Bar folder or box and pan brake: Fold the 2" × 4" sample piece to a 90° angle on the scribed line. Your finished product should be an L shape.
- Station 9:** Aviation snips and files: Use the snips to cut, round or create slightly curved corners on one of your sample pieces. Smooth any burrs or sharp edges on the corners using the file.
- Station 10:** Emery cloth and peening hammer: Use the hammer to texture one of your samples to create a dimpled pattern. Use the emery cloth to add patterns and texture as well as smooth the surface.
- Station 11:** Bar folder: Fold a single hem on one of the sample pieces you have not previously worked on.
- Station 12:** Roper Whitney punch: Punch a hole in one corner of each of your samples. Join your samples together using the string/wire/key ring provided and hand in to your teacher. Make sure you have completed all station tasks.

Sheet Metal Identification: Characteristics and Properties

Sheet metal name	Characteristics and properties	Sample image
Aluminum	<p>A cold-rolled non-ferrous material over 0.2 mm thick but not exceeding 6 mm.</p> <p>A silver-coloured, low-density metal with a huge variety of commercial applications. Unalloyed aluminum is ductile, exhibits moderate strength and is very resistant to corrosion under most circumstances.</p> <p>Aluminum can be dramatically strengthened by the addition of appropriate alloying elements (Cu, Mg, Mn, Si, etc.) and subsequent heat/work treatments. The low density of aluminum makes it a perfect material for aerospace and in other transportation fields.</p>	
Brass	<p>Brass is an alloy of copper and zinc. Brass has low friction properties and acoustic properties.</p> <p>Applications include decorative and architectural uses, condenser/heat exchangers, plumbing, musical instruments, and fasteners. Non-ferrous.</p>	
Cold rolled steel	<p>Rolling steel at ambient temperature (or below its recrystallization temperature) increases its strength and hardness and decreases its ductility. In addition to improvement of mechanical properties, cold rolling results in more control over the shape and dimensions of the finished product.</p> <p>Cold rolled steel has an improved surface finish, which makes it common in the creation of furniture, appliances and other consumer goods. Ferrous.</p>	

Sheet metal name	Characteristics and properties	Sample image
Copper	<p>Excellent corrosion resistance and high thermal conductivity. Applications include architectural uses, coinage, condenser/heat exchangers, plumbing, radiator cores, musical instruments, locks, fasteners, hinges. Non-ferrous.</p> <p>Small amounts of alloying elements are often added to copper to improve certain characteristics.</p>	
Expanded sheet metal	<p>Sheets are made by cutting slits into regular metal sheets and stretching them out to create numerous openings in a diamond pattern.</p> <p>Expanded sheets are lighter, stronger and less expensive than regular flat sheets. They also allow for the free passing of liquids, light and sound. Ferrous.</p>	
Galvanized steel	<p>Hot-dip galvanizing is the process of coating iron or steel with a thin zinc layer, by passing the steel through a molten bath of zinc at a temperature of around 460°C (860°F). When exposed to the atmosphere, pure zinc reacts with oxygen to form zinc oxide, which further reacts with carbon dioxide to form zinc carbonate, a dull grey, fairly strong material that stops further corrosion in many circumstances, protecting the steel below from the elements.</p> <p>Galvanized steel is widely used in applications where rust resistance is needed, and can be identified by the crystallization patterning on the surface (often called a <i>spangle</i>).</p> <p>Ferrous.</p> <p><u>Technically, galvanized steel can be welded, but extreme caution is needed, as the resulting zinc fumes are lethal if inhaled.</u></p>	

Sheet metal name	Characteristics and properties	Sample image
Hot rolled steel	Hot rolling involves the production of sheet metal from billets by passing the steel through rollers while above its recrystallization temperature (over 926°C / 1700°F). Multiple passes through the rollers may be necessary to produce the final desired dimensions. It is identified by the black oxide coating that is formed during the rolling process. Ferrous	
Stainless steel	An alloyed steel designed to have greatly increased corrosion resistance compared to carbon/alloy steel. Common alloying ingredients include chromium (usually at least 11%), nickel and molybdenum. Ferrous.	

Make a Mini Shield and Letter Opener

Description

Metal fabrication involves the use of a basic set of skills—cutting, bending, and assembling processes—to create something from raw material. In this activity plan, students will put all the various stages of fabrication to work as they fabricate their own mini shield and letter opener. Teachers will demonstrate equipment and process and the students will follow up by building their own mini shield and letter opener.

Lesson Objectives

The student will be able to:

- Identify common metals
- Demonstrate appropriate shop behaviour
- Demonstrate safe and appropriate use of hand tools and equipment
- Use appropriate layout tools
- Place and rivet components in the correct location
- Demonstrate proficient riveting

Assumptions

The student:

- Has demonstrated previous metallurgical knowledge
- Understands basic layout techniques
- Can perform basic measurement
- Demonstrates safe tool and equipment use

Terminology

Hilt: handle of a tool or sword.

Hilt topper: top section of the handle that separates your hand from the blade.

Estimated Time

5–10 hours

The time for this activity will depend on the familiarity of students with tools and the amount of equipment available.



Recommended Number of Students

20, based on *BC Technology Educators' Best Practices Guide*

Facilities

Secondary school metal shop or equivalently equipped technology education shop

Equipment/Machinery

- Bench grinder
- Drill press
- Foot shear
- Slip roller

Tools

- Aviation snips
- Ball peen hammer
- Beverly shear
- Whitney punch
- Centre punch
- Scribe
- Permanent marker
- Square
- Steel scale
- File
- Emery cloth

Materials

Item	# of pieces	Material	Thickness	Width	Length
Shield body	1	22 ga sheet metal	22 ga	6"	6"
Shield dome	1	22 ga sheet metal	22 ga	3"	3"
Shield back plate	1	22 ga sheet metal	22 ga	½"	3"
Letter opener	1	½" band iron	⅛"	½"	9"
Hilt topper	1	½" band iron	⅛"	½"	3"

5 – ⅛" aluminum pop rivets

Resources

How to use a Beverly shear

<https://www.youtube.com/watch?v=1vKggqse-40k>

How to use a foot shear

https://www.youtube.com/watch?v=w8d3n_kvlyM

How to rivet

<https://www.youtube.com/watch?v=xv2RBLPYikY>

How to use a slip roller

<https://www.youtube.com/watch?v=bmt5ixgpKTY>

Teacher-led Activity

Lead the class through the following steps to fabricate a mini shield and letter opener.

Shield body

1. Obtain a piece of 22 ga aluminum sheet metal.
2. Teacher demonstrates layout and foot shear safety. Use aviation snips if a foot shear is unavailable.
3. Lay out and cut a 6" × 6" square of sheet metal.
4. Trace template and cut along layout lines with aviation snips.
5. File shield to uniform shape and remove sharp edges.
6. Teacher demonstrates slip roller to students. You can leave the shield flat if a slip roller is unavailable.
7. Roll shield through slip roller to give shield a slightly convex shape.
8. Using emery cloth, sand entire surface of shield.
9. Using your thumb over the emery cloth, twist emery cloth to create swirls over the entire surface of the shield.

Shield back plate

1. Obtain a piece of ½" sheet metal strip. Measure 3" and cut.
2. Use emery cloth to smooth any burrs around edges.

Shield dome

1. Cut a piece of aluminum sheet metal 3" × 3" square.
2. Clamp a 2" diameter pipe vertically into a vise.

3. Centre sheet metal over pipe. Begin peening the centre of sheet metal starting from the centre and moving out towards the edges in circular patterns, to create a dome shape.
4. Trace and cut a 3" diameter circle around the dome to leave a ½" lip around the dome.
5. File edges of the circle uniform and smooth.
6. Mark out 4 evenly spaced holes around dome.
7. Teacher demonstrates Whitney punch. Use ⅛" drill bit in hand drill or drill press, if Whitney punch is unavailable.
8. Using the Whitney punch with a ⅛" die, punch out 4 marks.
9. Place the dome on the shield and transfer 4 Whitney punch marks with scribe.

Assembly of shield

1. Use the Whitney punch to punch holes in shield.
2. Lay out shield back plate behind two horizontal holes on shield and transfer marks with scribe.
3. Use the Whitney punch to punch holes in the backing plate.
4. Place a rivet through the dome, shield, and backing plate.
5. Place the rivet in a suitable recess of the rivet set and flatten the rivet with a ball peen hammer.
6. Rivet the other side of the backing plate.

Small sword letter opener

1. Obtain a piece of ⅛" × ½" flat bar and cut to 9".
2. File one end of flat bar to ½" diameter and the other end to a ⅛" diameter taper, as per plans.
3. File 90° notches that are ⅛" deep into flat bar, as per plans, to create the hilt.
4. File edges of letter opener blade to a mild chamfer.
5. Obtain a piece of ½" flat bar and cut to 3" long to create hilt topper.
6. Lay out radius lines on hilt topper as per plans.
7. File to lines to create shape on hilt topper.
8. Centre punch middle of hilt topper and drill with ⅛" drill bit.
9. Lay out centre punch mark on sword handle as per plans and drill with ⅛" drill bit.

10. Countersink hole with $\frac{3}{8}$ " drill bit on one side.
11. File both pieces to remove any burrs after drilling.

Assembly of letter opener

1. Place a rivet set in the vise.
2. Place a $\frac{1}{8}$ " rivet through the hilt topper and letter opener.
3. Position the rivet head into the corresponding hole on the rivet set anvil.
4. Use a ball peen hammer to mushroom the rivet.
5. Hammer the rivet flat against the letter opener back.
6. File any excess material from the rivet to make it smooth against the hilt.

Finishing

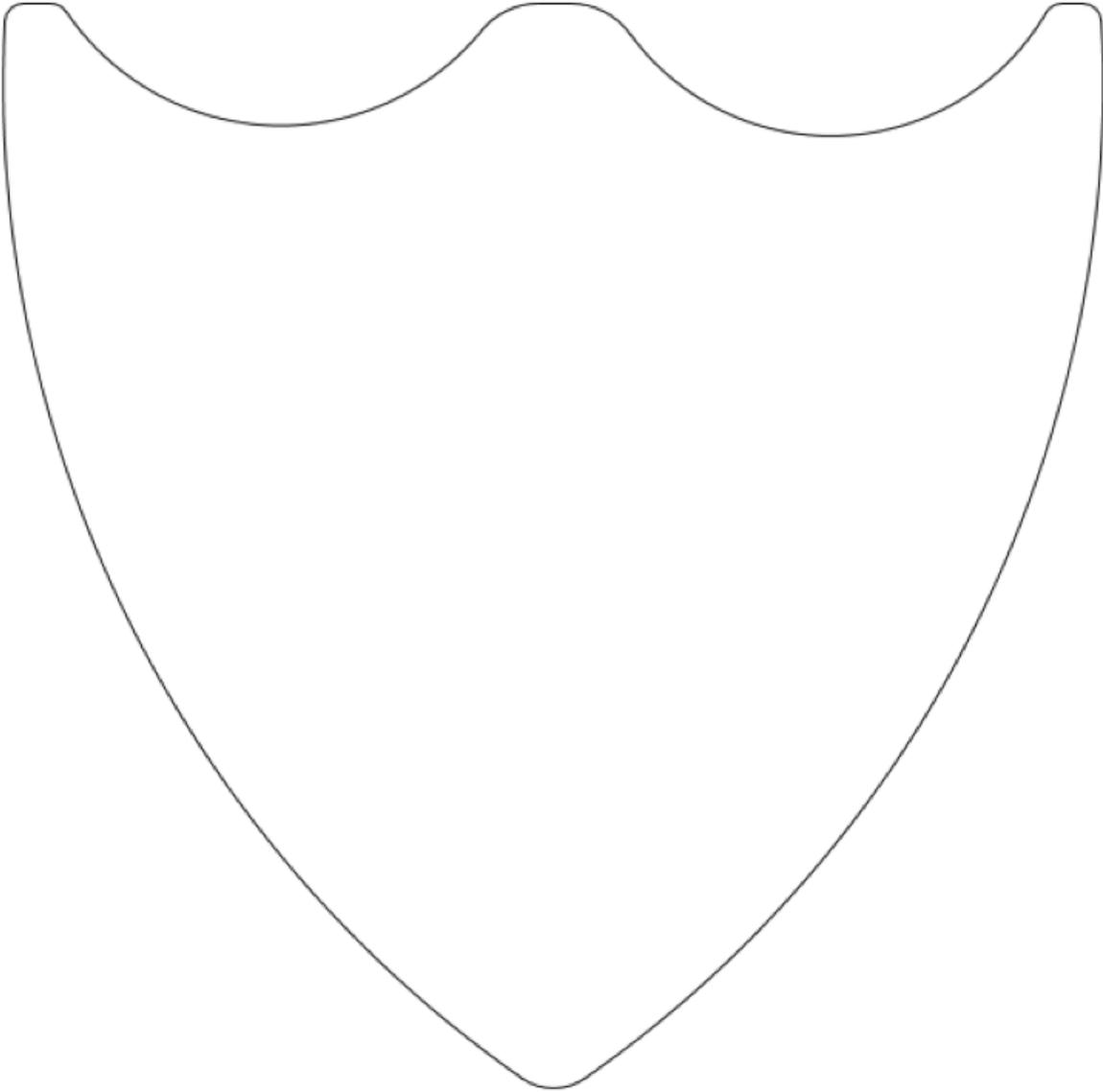
1. Clean any grease, dirt, or scratches in the metal using emery cloth.
2. Choose an appropriate method of finishing (painting, powder coating, etc.).

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

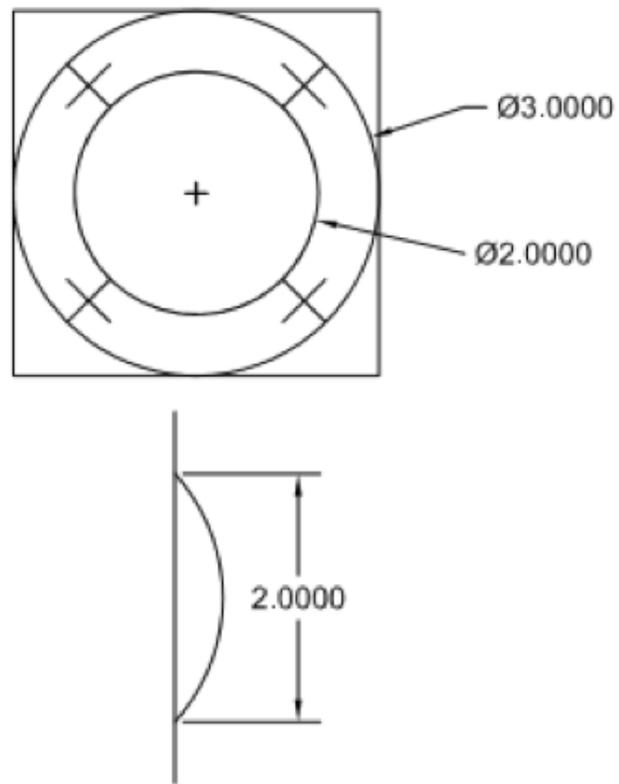
- Shield size is within $\frac{1}{16}$ " to $\frac{1}{8}$ " of the template size overall
- Dome is evenly hammered out
- Outside edge of dome is within $\frac{1}{16}$ " of a 3" circle
- Shield riveting is flat and smooth
- Letter opener length is within $\frac{1}{16}$ "
- Handle riveting is flat and smooth to handle
- Hilt is within $\frac{1}{16}$ " of length
- Finishing: all edges are smooth

Shield Template – full size



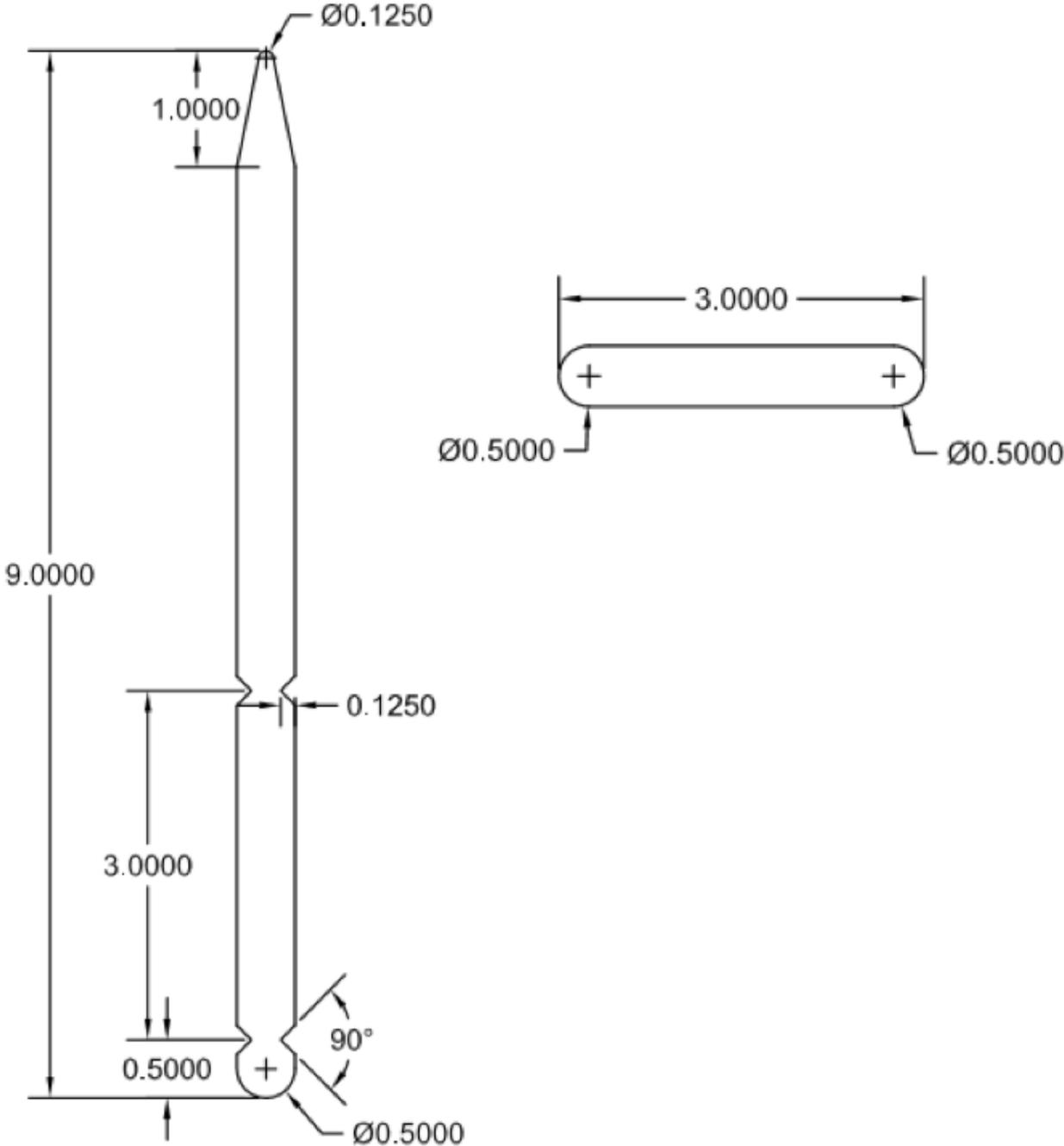
Shield template

Dome Specifications



Dome specifications

Letter Opener / Hilt Topper Specifications



Letter opener/hilt topper specifications

Completed Projects



Fabricate a Trivet

Description

Metal fabrication involves basic skills such as cutting, bending, and assembling to create something from raw material. In this activity plan, students will lay out, cut, bend and assemble a trivet according to the blue prints. Trivets are a functional low platform used to keep hot objects off surfaces that cannot tolerate high heat. Teachers will lead equipment and process demonstrations and the students will follow up by building a trivet.

Lesson Objectives

The student will be able to:

- Identify common metals
- Identify common fasteners
- Demonstrate appropriate shop behaviour
- Demonstrate safe and appropriate use of hand tools and equipment
- Use appropriate layout tools and scales

Assumptions

The student:

- Knows basic metallurgy
- Knows how to use hand tools safely
- Knows basic measurement
- Understands basic layout techniques

Estimated Time

5–10 hours

The time for this activity will depend on the familiarity of students with tools and the scope of the project (how much teachers prepare for students ahead of time, or how far they take the finishing portion of the project, based on the availability of tools/equipment).

Recommended Number of Students

20, based on *BC Technology Educators' Best Practices Guide*

Facilities

Secondary school metal shop or equivalently equipped technology education shop



Equipment/Machinery

- Bench grinder
- Box and pan brake or bar folder
- Di-Acro bender
- Drill press
- Foot shear
- Hand drill

Tools

- Aviation snips
- Beverly shear or hacksaw
- Centre punch
- Pop rivet gun
- Scribe
- Sharpie
- Square
- Steel scale
- Emery cloth

Materials

Item	# of pieces	Material	Thickness	Width	Length
Trivet legs	4	1/2" flat bar	1/8"	1/2"	6"
Trivet body	1	22 ga sheet metal	22 ga	7"	7"

8 – 1/8" steel rivets

Resources

How to use a Beverly shear

<https://www.youtube.com/watch?v=1vKqqse-40k>

How to use a foot shear

https://www.youtube.com/watch?v=w8d3n_kvlyM

How to use a pop rivet gun

<https://www.youtube.com/watch?v=WPwNsQMnx88>

How to use a box and pan brake

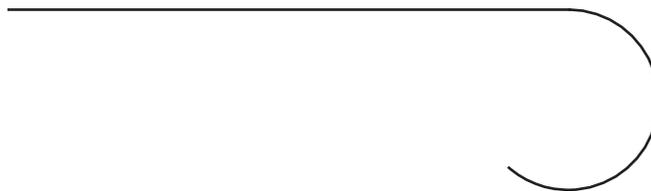
<https://www.youtube.com/watch?v=d4RWkf7eo1g>

Teacher-led Activity

Lead the class through the following steps to fabricate a trivet. Refer to the plans provided below.

Legs

1. Obtain $\frac{1}{2}$ " flat bar.
2. Teacher demonstrates safe and correct use of Beverly shear or hacksaw.
3. Lay out lines at 6" and cut bar stock on Beverly shear (4 pieces required). (If Beverly shear is not available, have students use a hacksaw.)
4. File ends of 6" bar stock round and remove any sharp edges.
5. Using layout tools:
 - a. Draw a centreline down the length of the flat stock.
 - b. From one end, measure $\frac{1}{2}$ " and mark with centre punch.
 - c. Then measure $\frac{1}{2}$ " from previous mark.
 - d. Centre-punch both marks.
6. Teacher demonstrates safe and correct use of drill press.
7. Drill $\frac{1}{8}$ " holes at centre punch marks.
8. File excess metal from drilling.
9. Teacher demonstrates safe and correct use of the Di-Acro bender.
10. Use Di-Acro bender to bend a 1" radius bend on all four bars of metal, at opposite ends to the drilled holes.



Di-Acro bender

If no bender is available, a simple jig can be made for students using a 1" diameter pipe held in a bench vise to create radius.

Base

1. Get 7" strip of sheet stock (22 gauge mild steel).
2. Teacher demonstrates safe and correct use of the foot shear.
3. Cut one piece at 7" (perfectly square).
4. Using layout tools on one side:
 - a. Scribe lines from corner to corner diagonally on one side of sheet metal.
 - b. Measure and centre-punch holes 1" from the intersection.
5. Using layout tools on reverse side:
 - a. Scribe a line 4 mm from edge of all four corners.
 - b. Scribe a second line 8 mm parallel to the first.
 - c. At 24 mm from each corner on the outside edge, mark a point, draw a line on each corner to join these points.
6. Cut off corners with foot shear.
7. Drill $\frac{1}{8}$ " holes on centre punch marks along the diagonal lines.
8. Teacher demonstrates safe and correct use of bar folder (or box and pan brake).
9. Fold along scribed lines using bar folder (or box and pan brake).
 - a. First fold, all the way.
 - b. Second fold, 90 degrees.

Assembly

Teacher demonstrates safe and correct use of pop riveter.

1. Using a pop riveter, rivet the first hole in the sheet metal to the legs.
2. Use the second hole in the legs to line up the second hole on the base.
3. Drill second $\frac{1}{8}$ " hole with hand drill.
4. Rivet second $\frac{1}{8}$ " hole.

Finishing

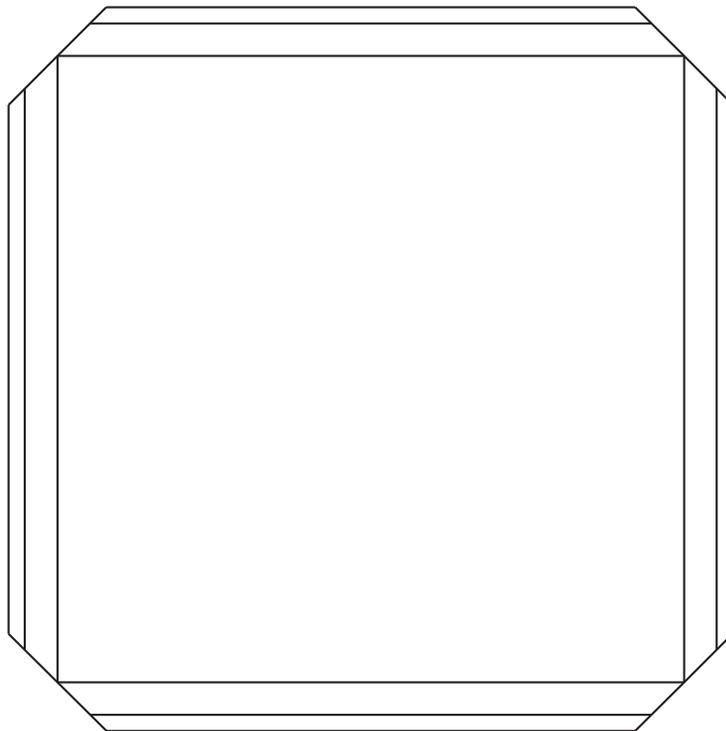
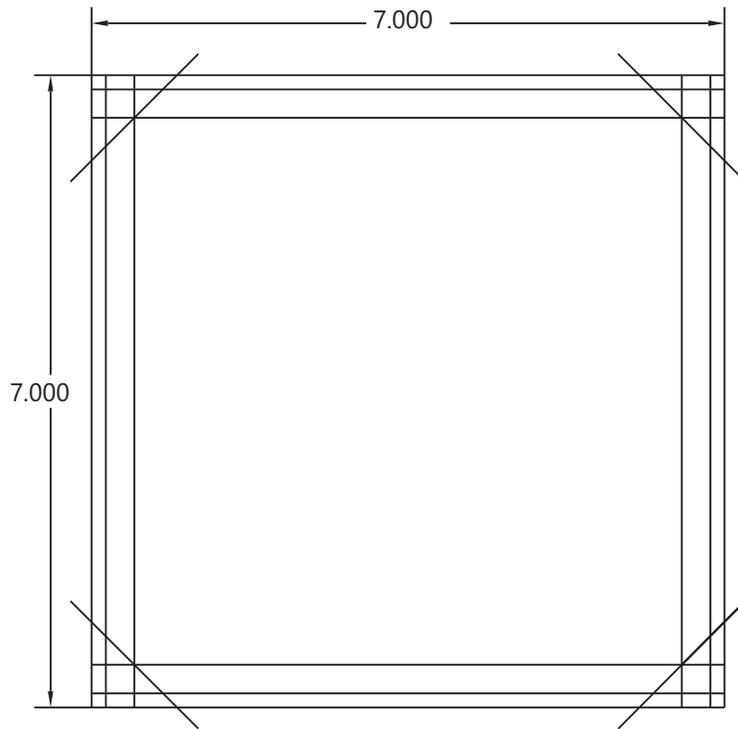
1. Clean any grease, dirt, or scratches off metal using emery cloth.
2. Choose an appropriate method of finishing (painting, powder coating, etc.).

Evaluation

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

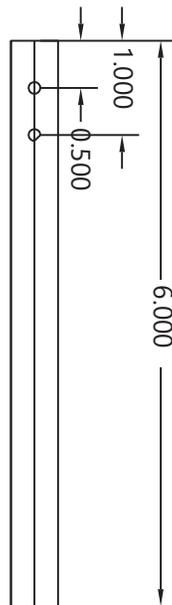
- All four corners are square
- All four sides are the same height and all sides are parallel to bottom
- Rivets are secure and filed flat and smooth
- All four legs are of uniform size and bend
- Finish: All files marked are removed, and sanding is uniform

Trivet Body drawings



Trivet body drawings

Trivet Leg specifications



Trivet leg specifications

Fabricate a Coat Hook

Description

Metal fabrication involves the use of a basic set of skills—cutting, bending, and assembling processes—to create something from raw material. Such a simple project as a coat hook incorporates many skills that will be used many times in other projects of various sizes and degrees of difficulty. Various hand tool skills learned while completing this project will be applied to all future metalworking projects and possibly other trade areas.

Lesson Objectives

The student will be able to:

- Identify common metals
- Identify common fasteners
- Demonstrate appropriate shop behaviour
- Demonstrate safe and appropriate use of hand tools and equipment
- Use appropriate layout tools

Assumptions

The student will:

- Know basic metallurgy
- Understand basic layout techniques
- Know basic measurement
- Know how to use hand tools safely

The teacher will:

- Possess layout skills
- Know and be able to demonstrate the safe and correct use of the tools and equipment used for this activity plan
- Know and be able to demonstrate riveting processes

Terminology

Burr: a sharp edge on metal left after cutting.

Countersink drill bit: a drill bit that creates a chamfered edge around the top of the drill hole to accommodate a machine screw or rivet head.



Rivet: a short piece of metal, typically aluminum or steel, used to join two or more pieces of metal together. One end of the rivet will have a flat or rounded head, and the other end is headless and is beaten with a hammer to spread it out and fasten the metal together.

Rivet set: a metal block with hemispheres drilled out to allow the rivet head to sit in while riveting.

Estimated Time

5–8 hours

The time for this activity will depend on the familiarity of students with tools and the scope of the project (how much teachers prepare for students ahead of time, or how far they take the finishing portion of the project, availability of tools/equipment).

Recommended Number of Students

20, based on *BC Technology Educators' Best Practices Guide*

Facilities

Secondary school metal shop or equivalently equipped technology education shop

Tools

- Hacksaw
- Scribe
- Hand drill
- $\frac{3}{8}$ " countersink
- Double cut file
- Single cut file
- Emery cloth
- Compact bender
- $\frac{3}{16}$ " drill bit
- Centre punch
- Rivet set

Materials

Note: Material can be partially or completely pre-cut by the instructor in order to facilitate ease of construction. This would be determined by the experience of students in the class, time constraints, and tools available.

Item	# of pieces	Material	Thickness	Width	Length
Backing plate	1	2" flat bar	1/8"	2"	2"
Hook	1	1" flat bar	1/8"	6"	1"
Rivets	2	Steel	N/A	1/2"	7"

Resources

How to use a Di-Acro bender to bend flat stock:

<https://www.youtube.com/watch?v=bt7ocmHzsnc>

How to rivet

<https://www.youtube.com/watch?v=xv2RBLPYikY>

Teacher-led Activity

Lead the class through the following steps to fabricate a coat hook.

Hook

1. Acquire a piece of 1" × 1/8" flat bar.
2. Teacher demonstrates the Beverly shear to students. You can use a hacksaw if a Beverly shear is unavailable.
3. Lay out a line at 7 1/8". Cut with a Beverly shear or hacksaw.
4. Deburr and file flat bar ends square until overall length of the hook piece is 7".
5. Using emery cloth, sand off any scale.
6. Lay out radius on both ends of hook and file to lines.
7. Use a smooth file to finish the ends and edges.
8. Draw a line down centre of hook.
9. Measure 2 1/2" down from one end and centre-punch.
10. Measure 1" down from previous mark and centre-punch.
11. Teacher demonstrates a drill press to students. You can use an electric hand drill if a drill press is unavailable.

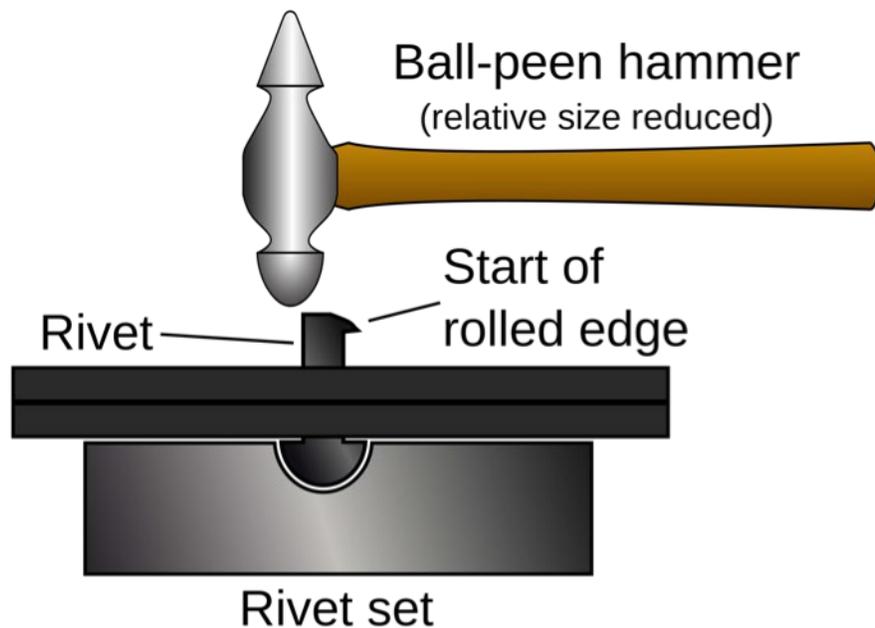
12. Drill centre-punch marks with $\frac{1}{8}$ " drill bit.
13. File any burrs from drill holes.
14. Use a vise to bend top 2" section to 45° angle.
15. Teacher demonstrates a bender to students.
16. Use manual bender with $1\frac{1}{2}$ " radius die to create bend at the bottom.

Backing Plate

1. Acquire a piece of 2" \times $\frac{1}{8}$ " flat bar. Lay out a line $2\frac{1}{8}$ " from a square end.
2. Cut a piece $2\frac{1}{8}$ " long using a bench shear or hacksaw.
3. Deburr and square up the ends with a file. File the bar until it is exactly 2" long.
4. File a small chamfer along outside edges on front side of plate.
5. Using emery cloth, clean off any scale from project.
6. Draw diagonal lines across the backing plate that run from corner to corner.
7. Mark drill holes $\frac{1}{2}$ " from centre intersection along lines, as per drawing, for rivet holes.
8. Mark drill holes $\frac{5}{8}$ " from 2 opposite corners along lines, as per drawing, for mounting holes.
9. Centre-punch intersections for drill holes.
10. Drill rivet holes with $\frac{1}{8}$ " drill bit in the drill press.
11. Drill mounting holes with $\frac{3}{16}$ " drill bit in drill press.
12. Countersink mounting holes with $\frac{3}{8}$ " drill bit on front side of plate.
13. Countersink rivet holes with $\frac{3}{8}$ " drill bit on back side of plate.

Assembly

1. Teacher demonstrates the riveting process to students.
2. Place rivet set in the vise.
3. Acquire a $\frac{1}{8}$ " rivet and place through hook and backing plate. Ensure the back is facing upwards at this step.
4. Position head of rivet into the correct rivet set anvil hole.



<https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Riveting.svg/2000px-Riveting.svg.png>

5. Using a ball peen hammer, hammer the rivet into a mushroom head shape to fill the countersink hole.
6. Repeat steps 2–4 for second rivet.
7. Hammer both rivets as flat as possible against backing plate.
8. File off any excess material from rivets on backing plate.

Finishing

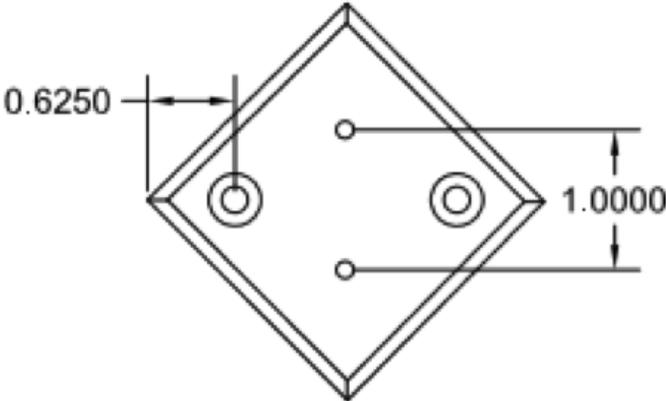
1. Clean any grease, dirt or scratches off metal using emery cloth.
2. Choose an appropriate method of finishing (painting, powder coating, etc.).

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

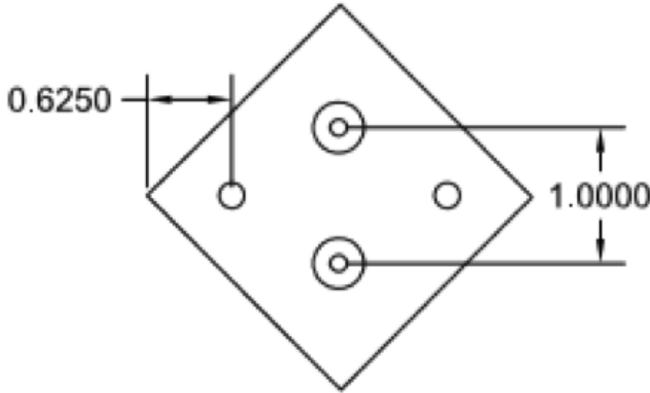
- Hook filed radii are within $\frac{1}{16}$ "
- Hook top bend is a perfect 45°
- Bottom bend is uniform, even, and straight to the back of hook
- Backing plate sides are within $\frac{1}{16}$ " and four corners are square
- Mounting holes are within $\frac{1}{16}$ " of plan
- Both rivets sit flat into backing plate

Backing Plate – front view



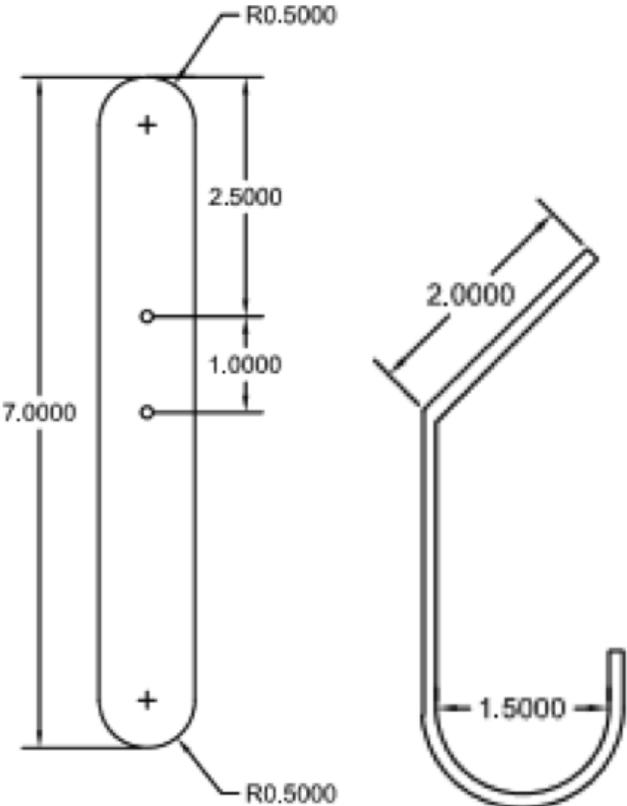
Backing plate—front view

Backing Plate – back view



Backing plate—back view

Hook



Hook

Make a BBQ Flipper

Description

The purpose of this activity is to introduce students to the metal shop through practical activity. This activity is an introduction to sheet metal fabrication and basic hand tools used in working with sheet metal. It also includes a design element that allows students to personalize their finished product while increasing their skill level.

Lesson Objectives

The student will be able to:

- Break out and lay out stock
- Cut sheet metal
- Form sheet metal
- Assemble sheet metal
- Finish sheet metal

Assumptions

The teacher will:

- Be a certified technology education/industrial education teacher
- Be familiar with the metal shop where this Activity Plan is being conducted
- Have experience with all aspects of the given metal shop, including machines, tools and processes

The student will:

- Be attentive and participatory
- Recognize that appropriate attitudes are the best insurance for safety
- Cut, form and join sheet metal material to create the desired project
- Safely work in the metal shop
- Demonstrate safe and appropriate use of hand tools and equipment
- Use appropriate layout tools
- Demonstrate appropriate finishing techniques



Terminology

Aviation snips: a hand tool designed to cut sheet metal into intricate designs. Can be used to cut compound curves. Red = left cutting; Green = right cutting; Yellow = universal, able to cut in any direction.

Box and pan brake: a sheet metal machine that is used to create bends, hems and boxes in sheet metal.

Breaking: bending the sheet metal along a line.

Centre punching: marking the centre of a hole.

Combination square: a ruled blade with both 45° and 90° heads. Used to lay out right angles and 45° angles.

Emery cloth: an abrasive cloth used to remove material and smooth surfaces.

File: a hand tool designed to shape and smooth metal. Available in a variety of shapes and sizes to fit different projects. Made of hardened steel with varying textures to remove large or very minimal amounts of material.

Finishing: the process of using sanding, polishing, sandblasting or painting to create a desirable end product appearance.

Jewellers saw: a hand saw with very fine teeth used to cut internal designs into metal.

Layout: the process of transferring a pattern from paper to the material using pens, scribes, centre punches, squares and scales.

Letter and number stamps: hardened steel bars with letters and numbers. Used to permanently label metal projects.

Pattern: a model or design used as a guide.

Riveting: a mechanical joining technique used to join two or more pieces of sheet metal together with a rivet.

Roper Whitney punch: a hand tool used to punch holes in sheet metal stock.

Ruler: a precision measurement tool that is a length of steel with marks at regular intervals.

Scribe: a long, pointed piece of hardened steel that is used to mark layout lines on metal.

Sheet metal: a term used to describe a variety of thin rolled metal sheet stock.

Squaring foot shear: a foot-controlled machine used to cut sheet metal stock.

Estimated Time

2–3 hours

Recommended Number of Students

20, based on the *BC Technology Education Association Best Practices Guide*

Facilities

Metal shop facility with all necessary equipment

Tools

- Aviation snips
- Bar folder
- Box and pan brake
- Centre punch
- Emery cloth
- Files – both coarse and smooth
- Hammer
- Jewellers saw
- Letter stamps
- Pop rivet gun
- Personal protection equipment
- Ruler
- Scribe
- Squaring foot shear
- Vise – with soft jaws/vise caps
- Whitney punch with a $\frac{3}{16}$ " die (other dies may be required on an individual basis depending on student design choices)

Resources

“HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

BC Technology Education Association Best Practices Guide

<http://www.bctea.org/best-practice-guide/>

Modern Metalworking, textbook by John R. Walker, copyright 2004, Goodheart-Wilcox Company Inc.

Videos

Box and pan brake

<http://www.bing.com/videos/search?q=how+to+use+a+box+and+pan+brake&view=detail&mid=0B5F895025F7C74515AE0B5F895025F7C74515AE&FORM=VIRE>

Roper Whitney punch

<http://www.bing.com/videos/search?q=how+to+use+a+whiney+punch&&view=detail&mid=94426538A09825CF06DD94426538A09825CF06DD&FORM=VRDGAR>

Bar folder

<http://www.bing.com/videos/search?q=how+to+use+a+bar+folder&&view=detail&mid=300C3F9B87B7F4360FE7300C3F9B87B7F4360FE7&FORM=VRDGAR>

Foot shear

https://www.youtube.com/watch?v=w8d3n_kvlyMhttps://www.youtube.com/watch?v=S0VI77nS_5U

Pop rivet gun

<https://www.youtube.com/watch?v=WPwNsQMnx88>

Aviation snips

<https://www.youtube.com/watch?v=5Nrc2xvLmC0>

Materials (per student)

Number of pieces	Material and size specifications
1 Handle	1" × 14" 14 gauge stainless steel
1 Head	4" × 6 ³ / ₄ " 14 gauge stainless steel
2	1" × 6" × ³ / ₁₆ " plywood (plus paint or stain)
2	³ / ₁₆ " machine screws, countersunk heads
2	³ / ₁₆ " nuts
2	³ / ₁₆ " shank tinner's rivets (or blind/pop rivets) ⁵ / ₁₆ " long – aluminum

Student Activity

1. On a blank sheet of paper, sketch out 6 design ideas for the head of your flipper (e.g., flames, #1 griller, starburst). These designs should be in pencil, neat and detailed.
2. Choose one of your designs, and on a separate piece of paper draw out your BBQ flipper head to scale, including your chosen design. The head should measure 4" × 6¾", including the 1¾" fold line. (See Dimension diagram on page 141.)

3. Once your design and template are complete, show your teacher and gather your materials: 1 handle piece, 1 flipper head piece.

Note: Sheet metal is very sharp and can cut skin easily.

4. Using the dimensioned diagram attached, lay out all holes on both the handle and the flipper head using the scribe and ruler. There should be 6 holes in total.
5. Lay out the fold line on both the handle and flipper head. This should be a solid scribed line.
Show your teacher before proceeding.

6. Centre punch each hole location on both pieces of your flipper.
7. Punch both holes on the flipper head using the Roper Whitney punch and a ⅜" die.
8. Punch all 4 of the holes on your flipper handle using the ⅜" die on the Roper Whitney punch. Be sure to centre the Roper Whitney punch on the layout marks.
9. With a smooth cut file, make sure there are no burrs or sharp edges where your holes have been punched.
10. Test fit to ensure your handle holes line up with the flipper head.
11. Set your handle aside. Using a permanent marker and layout tools, trace out your chosen design onto the flipper head. Be careful to centre your design and leave space along the outside edges.
12. Show your teacher your layout and confirm you are ready to cut out the design.
13. Using the Roper Whitney punch and a jewellers saw, cut out your design carefully. This may take some time.
14. File any rough or sharp edges until smooth and free of burrs.
15. Sharpen the edge of your flipper head opposite your holes for the handle attachment. Use a file first, then emery cloth to smooth the edge.
16. Using the vise and soft jaws to secure your flipper head, slightly round the four corners to ensure there are no sharp edges. This could be done using a smooth cut file or emery cloth.

17. Now that all surfaces and edges are smooth, the handle and flipper head need to be bent to a 30° angle using either the box and pan brake or bar folder. Line up your fold line evenly to guarantee a good bend.
18. Finish off your handle piece and flipper head with 400 grit emery cloth. Make sure you sand in the same direction to ensure your flipper parts have a uniform finish.
19. Ask your teacher for 2 rivets and join the handle piece to the flipper head using the rivet gun. Make sure your pieces are lined up correctly before you complete the riveting process.
20. Gather 2 pieces of 1" × 6" × 3/16" wood from your teacher and the required hardware (3/16" machine screws, countersunk heads and nuts) to attach the wood to your flipper handle.
21. Sand the wood pieces with 120 grit sandpaper and finish using a wood stain or oil.
22. Using the letter stamps and a hammer, stamp your initials or name into ONE of the two wooden handle pieces.
23. Attach the wood pieces to your flipper handle, being sure to tighten the screws.
24. Hand in for marking along with your design drawings.

Extension Activity

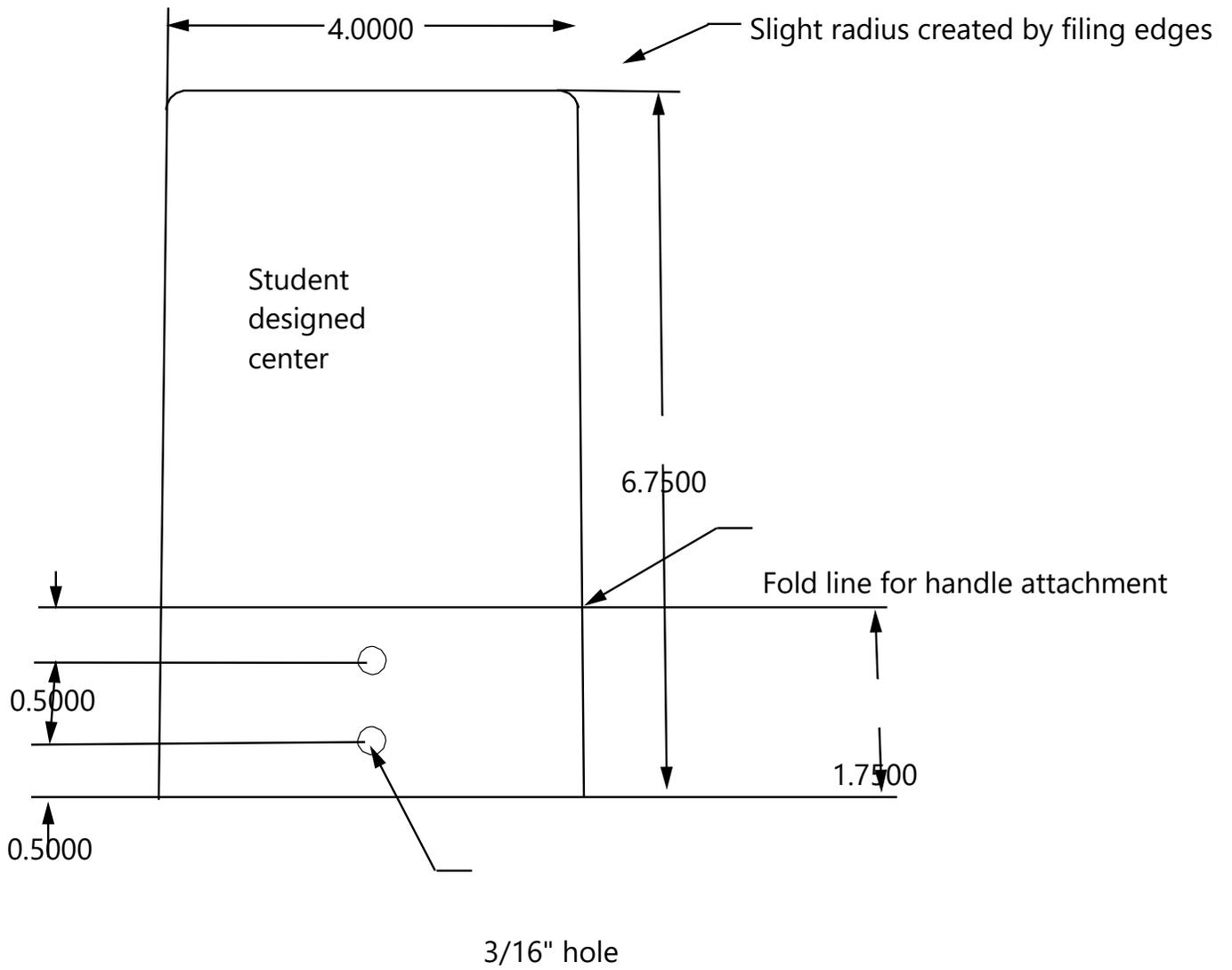
If AutoCAD or similar design software is available, use it to create the flipper head design, then either laser engrave or CNC machine your design, depending on the equipment available in the shop.

Assessment

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

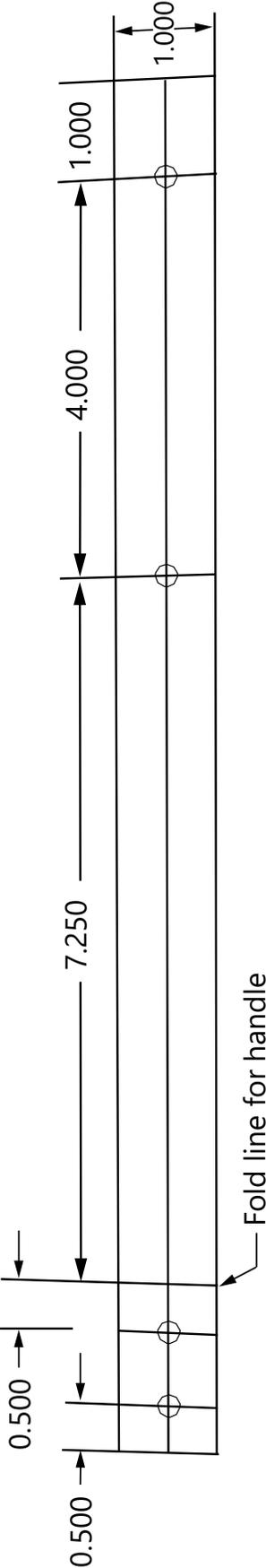
- Safe working procedures at all times
- Personal and project management: good use of time, attitude, effort
- Design drawings are neat and organized and include details
- Accurate measurements and layout
- Appropriate use of tools
- All burrs are removed and sharp edges are smooth
- Project is assembled correctly and securely
- Name stamp located on wooden handle is easy to read. Equally spaced and lined up horizontally
- All folds are even and square

BBQ Flipper Body



BBQ Flipper Handle

Note: All holes are 3/16" in



Fabricate a Cookie Sheet

Description

The purpose of this Activity Plan is to introduce students to the metal shop through a practical activity. This activity is an introduction to sheet metal fabrication and basic hand tools used in working with sheet metal.

Lesson Objectives

The student will be able to:

- Break out and lay out stock
- Cut sheet metal
- Form sheet metal
- Spot weld sheet metal
- Finish sheet metal

Assumptions

The teacher will:

- Be a certified technology education/industrial education teacher
- Be familiar with the metal shop where this Activity Plan is conducted
- Have experience with all aspects of the given metal shop, including machines, tools and processes

The student will:

- Be attentive and participatory
- Recognize that appropriate attitudes are the best insurance for safety
- Cut, form and join sheet metal material to create the desired project
- Safely work in the metal shop
- Demonstrate safe and appropriate use of hand tools and equipment
- Use appropriate layout tools
- Demonstrate appropriate finishing techniques

Terminology

Aviation snips: a hand tool designed to cut sheet metal into intricate designs. Can be used to cut compound curves. Red = left cutting; Green = right cutting; Yellow = universal, able to cut in any direction.



Box and pan brake: a sheet metal machine that is used to create bends, hems and boxes in sheet metal.

Breaking: bending the sheet metal along a line.

Combination square: a ruled blade with both 45° and 90° heads. Used to lay out right angles and 45° angles.

Emery cloth: an abrasive cloth used to remove material and smooth surfaces.

File: a hand tool designed to shape and smooth metal. Available in a variety of shapes and sizes to fit different projects. Made of hardened steel with varying textures to remove large or very minimal amounts of material.

Finishing: the process of using sanding, polishing, sandblasting or painting to create a desirable end product appearance.

Layout: the process of transferring a pattern from paper to the material using pens, scribes, centre punches, squares and scales.

Letter and number stamps: hardened steel bars with letters and numbers. Used to permanently label metal projects.

Pattern: a model or design used as a guide.

Roper Whitney punch: a hand tool used to punch holes in sheet metal stock.

Ruler: a precision measurement tool that is a length of steel with marks at regular intervals.

Scribe: a long pointed piece of hardened steel that is used to mark layout lines on metal.

Sheet metal: a term used to describe a variety of thin rolled metal sheet stock.

Spot weld: a resistance welding technique.

Squaring foot shear: a foot-controlled machine used to cut sheet metal stock.

Estimated Time

2–4 hours

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Metal shop facility with all necessary equipment

Tools

- Aviation snips
- Bar folder
- Box and pan brake

- Combination square
- Emery cloth
- Coarse and smooth files
- Hammer
- Letter stamps
- 24" ruler
- Scribe
- Spot welder
- Squaring foot shear
- Whitney punch with a $\frac{1}{8}$ " die

Materials

1 – 13½" × 19½" 18 ga. stainless steel metal

Resources

Box and pan brake

<http://www.bing.com/videos/search?q=how+to+use+a+box+and+pan+brake&view=detail&mid=0B5F895025F7C74515AE0B5F895025F7C74515AE&FORM=VIRE>

Roper Whitney punch

<http://www.bing.com/videos/search?q=how+to+use+a+whiney+punch&&view=detail&mid=94426538A09825CF06DD94426538A09825CF06DD&FORM=VRDGAR>

Aviation snips

<https://www.youtube.com/watch?v=5Nrc2xvLmC0>

“HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

BC Technology Education Association Best Practices Guide

<http://www.bctea.org/best-practice-guide/>

Modern Metalworking, textbook by John R. Walker, copyright 2004, Goodheart-Wilcox Company Inc.

Student Activity

1. Gather materials and all layout tools.
2. Handling your material carefully, lay your sheet metal flat on your work table and use the letter stamps and a hammer to stamp your name or initials into the centre of your material.
3. With emery cloth or a smooth cut file, gently file all edges of your material on both sides to remove any burrs or sharp edges.
Note: Sheet metal is very sharp and can cut skin easily.
4. Using a ruler and scribe, measure and scribe a line $\frac{1}{4}$ " from the top and both side edges of your material.
5. Measure and scribe a line $\frac{1}{2}$ " from the previously drawn line. (It will be $\frac{3}{4}$ " from the outside edge.)
Have your teacher check your lines before proceeding to the next step.
6. Turn your material over and lay it flat on your work table again. Measure and scribe a line $\frac{1}{4}$ " from the bottom edge only.
7. Measure and scribe a line $\frac{1}{2}$ " from the previously scribed line across the bottom edge. (It will be $\frac{3}{4}$ " from the outside edge.)
Have your teacher check your lines before proceeding to the next step.
8. Using the box and pan brake, fold the $\frac{1}{4}$ " hem on the bottom edge of your material. Make sure the hem is smooth and flat.
9. Using the brake, fold the second hem at the $\frac{1}{2}$ " line to create a double hem. This will make the edge of your cookie sheet firm and durable.
Have your teacher check your folds before proceeding to the next step.
10. Turn your material over so the bottom edge hem is on the underside of your project. Using the Roper Whitney punch and a $\frac{1}{8}$ " die, punch a hole in the corner where the $\frac{1}{2}$ " lines of the sides and top edge intersect ($\frac{3}{4}$ " in from the top and side edges).
11. Make sure there is no burr or sharp edge by smoothing with a smooth cut file or emery cloth.
12. Return to the box and pan brake and fold a hem at the $\frac{1}{4}$ " line of both of your sides. Make sure the hem is smooth and flat. This hem gets folded toward the centre of the top side of your cookie sheet.
Have your teacher check your folds before proceeding to the next step.
13. Now fold the $\frac{1}{4}$ " hem on the top edge. Make sure it is smooth and flat.

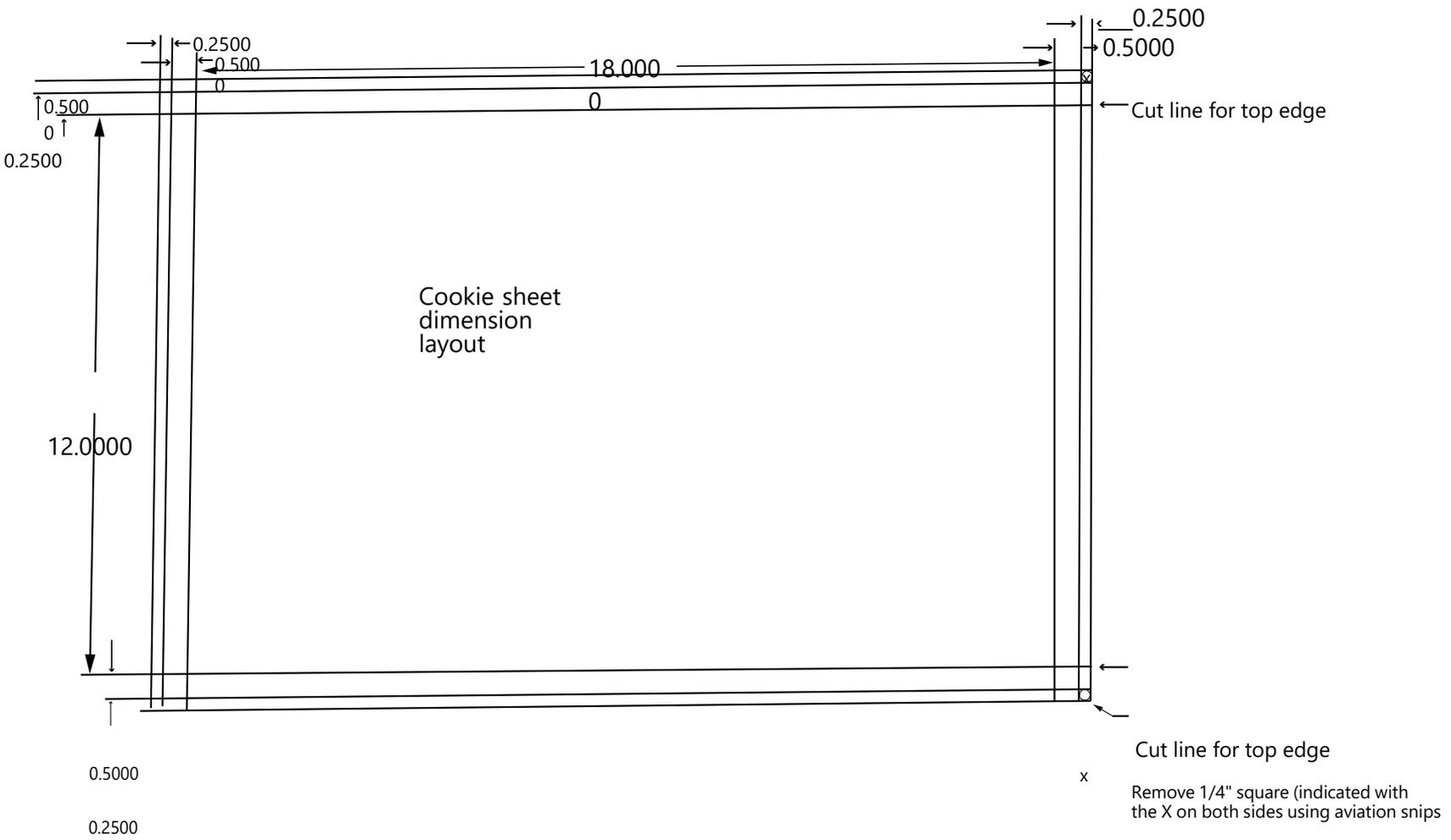
14. At your work table, use aviation snips to cut from the top edge down to meet the $\frac{1}{8}$ " hole you punched in step 10. This will create a tab at either end of your sides.
15. Using the box and pan brake, fold the top edge to 90° . This creates a lip edge. As you are folding the top edge, you will also be folding the tabs to 90° at the same time. Make sure you are lining up your fold lines to be square with the edge of the box and pan brake. (The $\frac{1}{4}$ " hem will be on the inside of the cookie sheet.)
16. Adjust the keys on the box and pan brake, and from the $\frac{1}{2}$ " line fold the side edges to 90° . Make sure the tabs fold to the inside of your top edge.
17. Repeat step 16 for the second side.
18. File any rough edges or burrs on your corners.
Have your teacher check your cookie sheet before proceeding to the next step.
19. Using all appropriate safety gear, spot weld your tabs to the top edge of your cookie sheet. You may have to spot weld twice in each corner to ensure they are secure.
20. Once the spot welds are cool, remove any rough or sharp spots using emery cloth. Wipe down your cookie sheet with a damp cloth to ensure no particulate is left on it.
21. Hand in your project for marking.

Assessment

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Safe working procedures at all times
- Personal and project management: good use of time, attitude, effort
- Accurate measurements and layout
- Appropriate tools use
- All hems and folds are clean, straight and uniform
- All burrs and sharp edges are smooth
- Instructions were followed throughout the activity
- Name stamp is easy to read, letters are evenly spaced and uniform

Cookie Sheet Dimension Layout



Make a Picture Frame

Description

The purpose of this activity is to introduce students to the metal shop through a practical activity. This activity is an introduction to sheet metal fabrication and basic hand tools used in working with sheet metal. It also includes a design element that allows students to personalize their finished product while increasing their skill level.

Lesson Objectives

The student will be able to:

- Break out and lay out stock
- Cut sheet metal
- Form sheet metal
- Assemble sheet metal
- Finish sheet metal

Assumptions

The teacher will:

- Be a certified technology education/industrial education teacher
- Be familiar with the metal shop where this Activity Plan is being conducted
- Have experience with all aspects of the given metal shop, including machines, tools and processes

The student will:

- Be attentive and participatory
- Recognize that appropriate attitudes are the best insurance for safety
- Cut, form and join sheet metal material to create the desired project
- Safely work in the metal shop
- Demonstrate safe and appropriate use of hand tools and equipment
- Use appropriate layout tools
- Demonstrate appropriate finishing techniques

Terminology

Aviation snips: a hand tool designed to cut sheet metal into intricate designs. Can be used to cut compound curves. Red = left cutting; Green = right cutting; Yellow = universal, able to cut in any direction.



Box and pan brake: a sheet metal machine that is used to create bends, hems and boxes in sheet metal.

Breaking: bending the sheet metal along a line.

Centre punching: marking the centre of a hole.

Combination square: a ruled blade with both 45° and 90° heads. Used to lay out right angles and 45° angles.

Countersink: the process by which a chamfer is created to fit a flathead screw.

Drill press: a fixed-base machine that is used for drilling holes.

Emery cloth: an abrasive cloth used to remove material and smooth surfaces.

File: a hand tool designed to shape and smooth metal. Available in a variety of shapes and sizes to fit different projects. Made of hardened steel with varying textures to remove large or very minimal amounts of material.

Finishing: the process of using sanding, polishing, sandblasting or painting to create a desirable end product appearance.

Layout: the process of transferring a pattern from paper to the material using pens, scribes, centre punches, squares and scales.

Letter and number stamps: hardened steel bars with letters and numbers. Used to permanently label metal projects.

Pattern: a model or design used as a guide.

Riveting: a mechanical joining technique used to join two or more pieces of sheet metal together with a rivet.

Roper Whitney punch: a hand tool used to punch holes in sheet metal stock.

Ruler: a precision measurement tool that is a length of steel with marks at regular intervals.

Scribe: a long pointed piece of hardened steel that is used to mark layout lines on metal.

Sheet metal: a term used to describe a variety of thin rolled metal sheet stock.

Squaring foot shear: a foot-controlled machine used to cut sheet metal stock.

Estimated Time

2–3 hours

Recommended Number of Students

20, based on the *BC Technology Education Association Best Practices Guide*

Facilities

Metal shop facility with all necessary equipment

Tools

- Aviation snips
- Bar folder
- Beverly shear
- Box and pan brake
- Centre punch
- Emery cloth
- Coarse and smooth files
- Hacksaw
- Ball peen hammer
- Letter stamps
- Rivets
- Ruler
- Scribe
- Squaring foot shear
- Vise with soft jaws/vise caps
- Whitney punch with a $\frac{3}{16}$ " die (other dies may be required on an individual basis depending on student design choices)

Materials (per student)

1 – Frame	5½" × 7" piece 18 ga. sheet metal (steel, galvanized, perforated or aluminum)
1 – Base	1" × 4" band iron
2 – Rivets	⅛" × ¼" solid round head rivets

Resources

“HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

BC Technology Education Association Best Practices Guide

<http://www.bctea.org/best-practice-guide/>

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Box and pan brake

<http://www.bing.com/videos/search?q=how+to+use+a+box+and+pan+brake&view=detail&mid=0B5F895025F7C74515AE0B5F895025F7C74515AE&FORM=VIRE>

Roper Whitney punch

<http://www.bing.com/videos/search?q=how+to+use+a+whiney+punch&&view=detail&mid=94426538A09825CF06DD94426538A09825CF06DD&FORM=VRDGAR>

Bar folder

<http://www.bing.com/videos/search?q=how+to+use+a+bar+folder&&view=detail&mid=300C3F9B87B7F4360FE7300C3F9B87B7F4360FE7&FORM=VRDGAR>

Aviation snips

<https://www.youtube.com/watch?v=5Nrc2xvLmC0>

Student Activity

Frame

1. Gather sheet metal materials from teacher.
2. On both of the long sides of your sheet metal piece, use a ruler and scribe to measure in $\frac{3}{4}$ " from the outside edge and scribe a long line (see diagram page 156). These will be fold lines and will create the picture holding tabs on the front of the picture frame.
3. Measure 1" up from the bottom edge and scribe a line across the front side of the picture frame.
4. Turn the frame over and measure up 1" from the bottom edge, then scribe a line across the bottom. This is the back side of the picture frame and this will become part of the base of the frame.
5. Still on the back side of the picture frame (in the 1" section at the bottom), measure and lay out the two holes for punching as per the diagram.
6. Centre punch each of the holes you have laid out.
7. Cut out corner notches with aviation snips/tin snips. (see diagram).
8. Round the edges and remove any rough spots and burrs with a smooth fine file.
9. Using the Roper Whitney punch and a $\frac{1}{8}$ " die, punch the two holes on the bottom edge that were centre punched.

Show your teacher before proceeding.

10. Using the box and pan brake or the hemming machine, fold both sides of your frame over. Do not flatten the sides. as this is where the picture will slide into.
11. With the box and pan brake: Insert the frame to your 1" fold line. The back side of your frame should be facing up. Bend to 30° .
12. Double check all edges, corners and surfaces for rough or sharp spots, and remove using smooth files or emery cloth. Set frame aside.

Base

1. Gather band iron bar stock from teacher.
2. Lay out the cut line at 4" in length and cut the band iron to length with a hacksaw/Beverly shear. Remove any burrs with a file.
3. Lay out the measurements for the holes according to the diagram, and centre punch.

4. Secure your flat iron and drill the two $\frac{1}{8}$ " holes all the way through. **This operation should be done with confirmation from teacher that your material is secured.**
5. While your material is still secure, countersink both holes halfway through with a countersink drill bit or $\frac{3}{16}$ " drill. Sweep away any debris with a brush.
6. Remove your base from the drill press and smooth any rough edges left around the holes.
7. Smooth any rough spots using emery cloth.

Assembly

1. Secure the rivet setter in the jaws of a table-mounted vise with the dimple facing up.
2. Stand the frame on the top side of the band iron. The countersunk holes should be on the bottom. Ensure the holes line up evenly.
3. Insert a $\frac{1}{8}$ " round head rivet down through one hole in the sheet metal frame and through the band iron.
4. Flip the frame assembly over and insert the round head of the rivet into the rivet set's dimple. With the ball side of the hammer, start to deform the bottom of the rivet into the countersunk area.
5. Once the rivet is secured enough not to fall out, insert the second rivet and hammer down to deform the rivet into the countersunk area.
6. Now firmly secure the frame to the base with the rivets. With the flat side of the hammer, flatten out the deformed mound on the bottom side of the band iron until the rivet is flush with the band iron.
7. If there is excess rivet material, file it smooth and level with the band iron base.
8. Flip frame over and make sure there are no further sharp edges or burrs.
9. Finish the picture frame with clearcoat spray.

Extension Activity

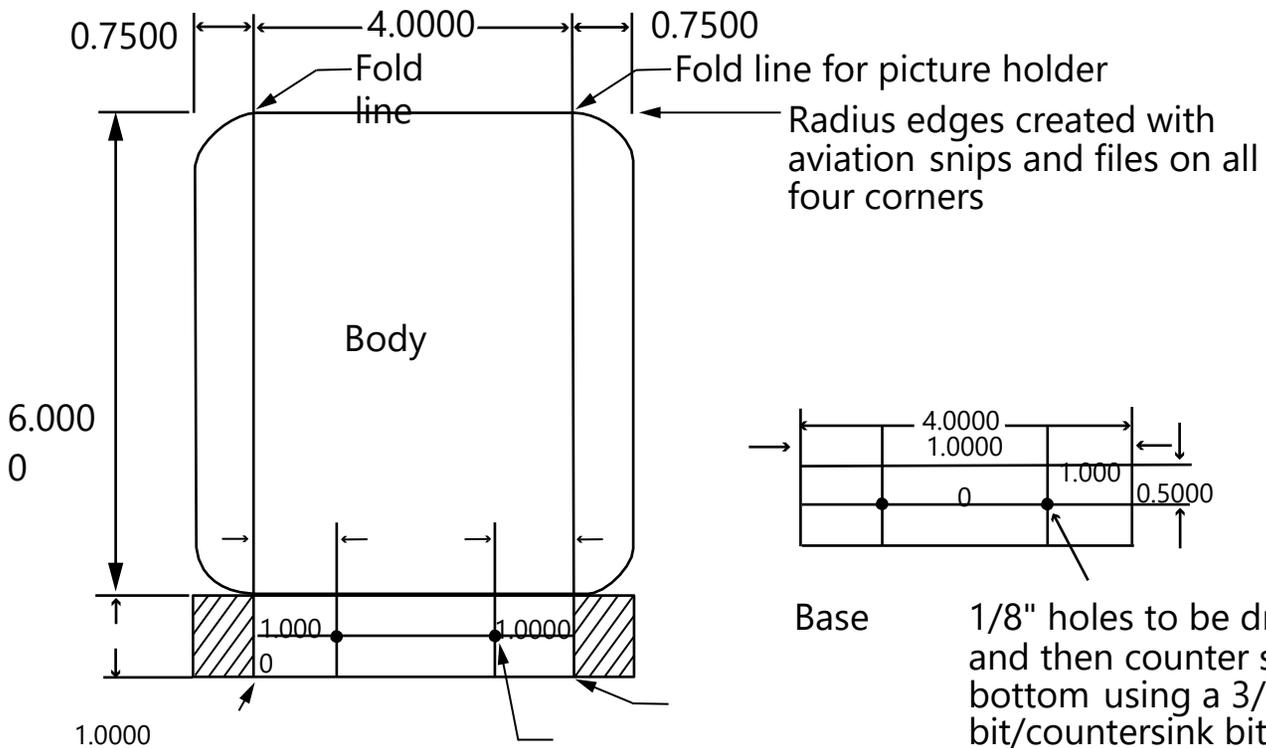
If AutoCAD or other design software is available, students could design a pattern using that could be laser engraved into the front edges of the picture frame for decorative purposes.

Assessment

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Safe working procedures at all times
- Personal and project management: good use of time, attitude, effort
- Accurate measurements and layout
- Appropriate tools use
- All hems and folds are clean, straight and uniform
- All burrs and sharp edges are smooth
- Instructions were followed throughout the activity
- Product is painted/finished neatly

Picture Frame Body and Base Layouts



Base 1/8" holes to be drilled through and then counter sunk on the bottom using a 3/16" drill bit/countersink bit

Remove this tab by cutting on the line using aviation snips

Remove tab using aviation snips 1/8" holes to be punched

Fabricate a Tool Caddy

Description

Fabrication is a basic set of skills that include cutting, bending and assembling processes. In this Activity Plan, students will be fabricating a tool caddy using a variety of sheet metal fabrication tools, equipment and fabrication processes.

Lesson Objectives

The student will be able to:

- Break out and lay out stock
- Cut sheet metal
- Form sheet metal
- Assemble sheet metal
- Finish sheet metal

Assumptions

The teacher will:

- Be a certified technology education/industrial education teacher
- Be familiar with the metal shop where this Activity Plan is being conducted
- Have experience with all aspects of the given metal shop, including machines, tools and processes

The student will:

- Be attentive and participatory
- Recognize that appropriate attitudes are the best insurance for safety
- Cut, form and join sheet metal material to create the desired project
- Safely work in the metal shop
- Demonstrate safe and appropriate use of hand tools and equipment
- Use appropriate layout tools
- Demonstrate appropriate finishes

Terminology

Aviation snips: a hand tool designed to cut sheet metal into intricate designs. Can be used to cut compound curves. Red = left cutting; Green = right cutting; Yellow = universal, able to cut in any direction.



Bar folder: a sheet metal machine that is used to create straight bends in sheet metal.

Box and pan brake: a sheet metal machine that is used to create bends, hems and boxes in sheet metal.

Breaking: bending the sheet metal along a line.

Centre punching: marking the centre of a hole.

Combination square: a ruled blade with both 45° and 90° heads. Used to lay out right angles and 45° angles.

Emery cloth: an abrasive cloth used to remove material and smooth surfaces.

File: a hand tool designed to shape and smooth metal. Available in a variety of shapes and sizes to fit different projects. Made of hardened steel with varying textures to remove large or very minimal amounts of material.

Finishing: the process of using sanding, polishing, sandblasting or painting to create a desirable end product appearance.

Hem: a border made by folding over the edge of a piece of sheet metal to increase strength and durability.

Hemming: the process in which the edge is rolled flush to itself.

Layout: the process of transferring a pattern from paper to the material using pens, scribes, centre punches, squares and scales.

Letter and number stamps: hardened steel bars with letters and numbers. Used to permanently label metal projects.

Pattern: a model or design used as a guide.

Riveting: a mechanical joining technique used to join two or more pieces of sheet metal together with a rivet.

Roper Whitney punch: a hand tool used to punch holes in sheet metal stock.

Ruler: a precision measurement tool that is a length of steel with marks at regular intervals.

Scribe: a long pointed piece of hardened steel that is used to mark layout lines on metal.

Sheet metal: a term used to describe a variety of thin rolled metal sheet stock.

Spot welder: a resistance welding technique.

Squaring foot shear: a foot-controlled machine used to cut sheet metal stock.

Estimated Time

3–5 hours

Recommended Number of Students

20, based on the *BC Technology Education Association Best Practices Guide*

Facilities

Metal shop with all necessary tools and equipment

Tools

Personal protection equipment

Stationary Equipment/Machinery

- Beverly shear
- Bar folder
- Box and pan brake
- Squaring foot shear
- Spot welder

Hand Tools

- Aviation snips
- Centre-punch
- Combination square
- Coarse and smooth files
- Rivet gun
- Roper Whitney punch
- Ruler
- Square
- Scribe

Materials (per student)

1 – Body	15" × 14½" 18 ga. sheet metal
1 – Handle	14½" × 3" 18 ga. sheet metal
2 – Ends	8" × 8" 18 ga. sheet metal

Resources

Box and pan brake

<http://www.bing.com/videos/search?q=how+to+use+a+box+and+pan+brake&view=detail&mid=0B5F895025F7C74515AE0B5F895025F7C74515AE&FORM=VIRE>

Roper Whitney punch

<http://www.bing.com/videos/search?q=how+to+use+a+whiney+punch&&view=detail&mid=94426538A09825CF06DD94426538A09825CF06DD&FORM=VRDGAR>

Bar folder

<http://www.bing.com/videos/search?q=how+to+use+a+bar+folder&&view=detail&mid=300C3F9B87B7F4360FE7300C3F9B87B7F4360FE7&FORM=VRDGAR>

Foot shear

https://www.youtube.com/watch?v=S0VI77nS_5U

Pop rivet gun

<https://www.youtube.com/watch?v=WPwNsQMnx88>

Aviation snips

<https://www.youtube.com/watch?v=5Nrc2xvLmC0>

“HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

BC Technology Education Association Best Practices Guide

<http://www.bctea.org/best-practice-guide/>

Modern Metalworking, textbook by John R. Walker, copyright 2004, Goodheart-Wilcox Company Inc.

Student Activity

Body and Ends

1. Gather all materials from your teacher.

Note: Sheet metal is very sharp and can cut skin easily.

2. Lay out the body and both ends. Using a ruler and scribe, measure out all dimensions (see dimensions on diagram page 164), making sure that all cut and fold lines are easily visible.

Have your teacher check the layout of each piece before proceeding to the cutting step.

3. Using the shear, cut out the body. Be careful to line up each edge precisely with the cutting surface of the shear.

New material will not be handed out. If you are unsure of the process, consult your teacher.

4. File away any burrs or sharp edges on all exposed edges.
5. Cut angles on both end pieces using the squaring foot shear.
6. File away any burrs or sharp edges on all exposed edges.

Have your teacher check your edges before proceeding with folding your hems.

7. Hemming machine: Set to the correct depth before folding (if available). If using the box and pan brake, fold each long edge on the body. It should be a $\frac{1}{2}$ " hem. Fold the material completely over and make sure the hem is smooth and flat.
8. Aviation shears/tin snips: Cut tabs on your base. Keep your lines straight and accurate.

Have your teacher check your tabs and hems before proceeding to the next step.

9. Using the letter stamps and a hammer, stamp your name into the base of your caddy.
10. Box and pan brake: You may have to adjust the keys/fingers to make room for the various folds that need to take place. Folded edges should be square and crisp.
11. End pieces: Use the box and pan brake fold the angled edges on your end piece into a hem. The hem should be $\frac{1}{2}$ ". Make sure each hem is flat and smooth. You will repeat this step until all four hems are complete: two on each end piece.
12. Set your folded body and both end pieces off to the side.

Base

1. Fold tabs 90° in relation to the sides.
2. Fold both sides up 90° in relation to the bottom. You should end up with a U-shaped body piece.

Have your teacher check your folds.

Handle

1. Using your ruler and scribe, lay out the handle pattern on your pre-cut piece of sheet stock (see dimensions on the diagram on page 164).

Have your teacher check your layout before you begin cutting.

2. Aviation snips: Cut out corners according to the pattern. File all edges to make sure they are smooth and free of burrs and sharp edges.
3. Hemming machine: Set to the correct depth before folding (if available). If using box and pan brake, make sure work is square to the finger. Fold all ½" hems completely over. Make sure all hems are smooth and as flat as possible.

Have your teacher check your tabs and hems before proceeding to the next step.

4. Box and pan brake: Adjust fingers as needed.
 - Fold long length on both sides 90°.
 - Fold end tabs to 90°.

Assembly and Finishing

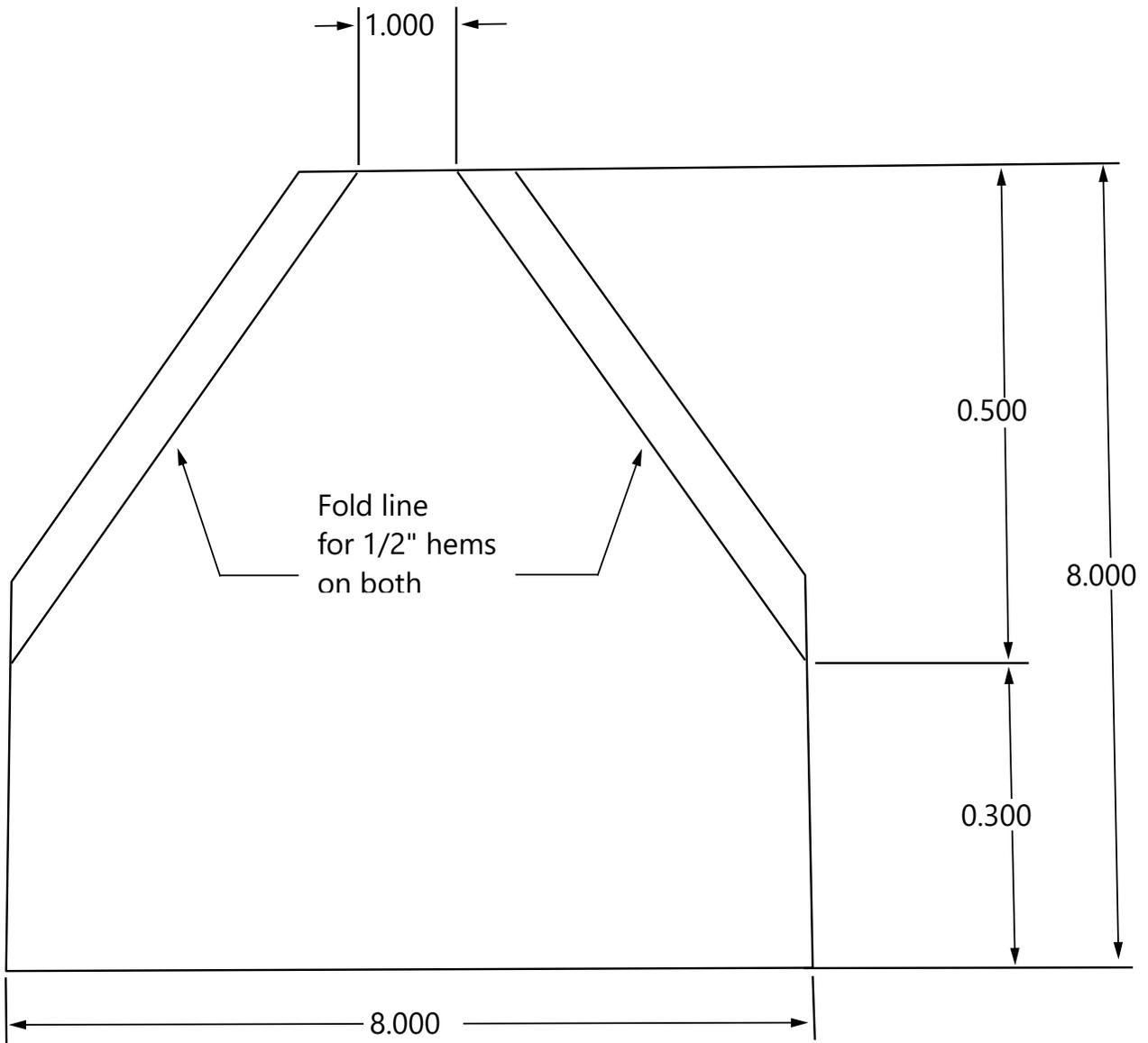
1. Place the end pieces inside the body and spot weld evenly along both edges and the bottom.
2. Repeat step 1 for the other end.
3. Add handle and spot weld the tab at the top of each end piece. Ensure your welds have good contact points and are secure.
4. Once all of your spot welds have been completed, use the files to remove any rough edges.
5. Use emery cloth to sand all surfaces and make sure they are smooth and clean.
6. Paint or decorate as you see fit.
7. Hand in for marking.

Assessment

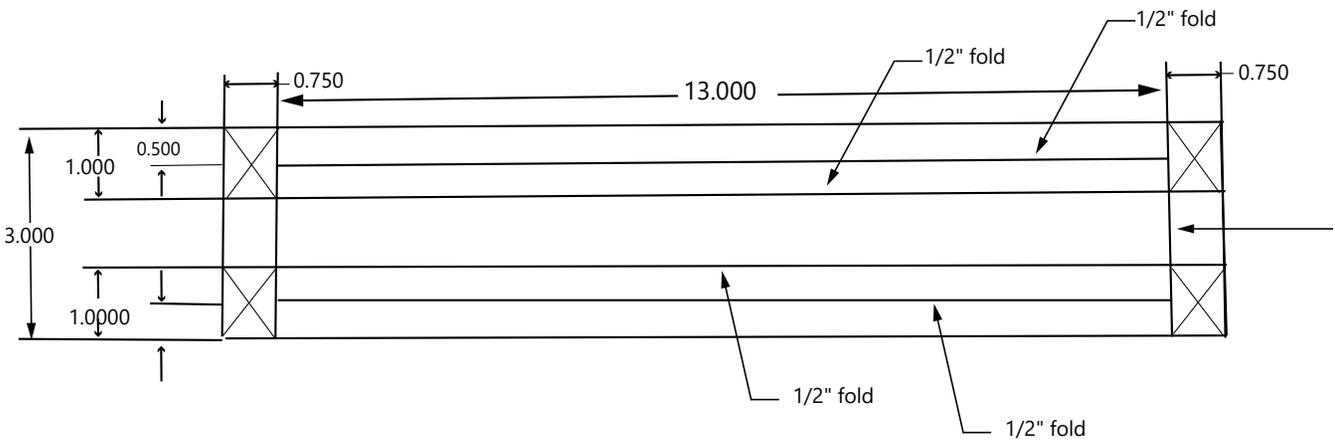
Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Safe working procedures at all times
- Personal and project management: good use of time, attitude, effort
- Accurate measurements and layout
- Appropriate tools use
- All hems and folds are clean, straight and uniform
- All burrs and sharp edges are smooth
- Instructions were followed throughout the activity
- Product is painted/finished neatly
- Name stamp located on body base is easy to read. Letters are uniformly spaced and lined up horizontally

Tool Caddy Ends



Tool Caddy Handle



Using aviation snips remove all 4 corners marked with the X

Fold line to create end tabs, same line O opposite end

Introduction to Welding

Description

Welding is an important trade and is always in demand. Welding is needed in many trade areas and in many industries. Welding is used to permanently join pieces or parts of metal. Skilled welders can weld most metals using a variety of processes. The most common material for welding is steel. Steel is commonly welded by the use of a MIG welder (GMAW), stick welder (SMAW), or TIG welder (GTAW). In this activity plan students will learn and practise MIG, one of the easiest welding methods to learn.

Lesson Objectives

Students will learn to:

- Work safely using metalworking tools
- Cut and form materials using hand tools and power tools
- Join metal with a MIG welder (GMAW)

Assumptions

Students will:

- Have an understanding of safe shop practices
- Know the safe use and procedures of hand tools, bench grinders, belt sanders, and MIG welders

Terminology

Adjusted voltage: the constant voltage output of a GMAW unit that has been adjusted to suit the required transfer mode, from short arc transfer through globular arc transfer to spray arc transfer, which requires the highest voltage.

MIG welding (GMAW): a welding method in which electric current flows through the filler metal wire to maintain the arc. An inert or semi-inert gas shields the arc from outside air. MIG is an abbreviation of “metal inert gas” and GMAW is an abbreviation of “gas metal arc welding.”

Porosity: a condition in which bubbles form in the weld due to the absorption of atmospheric gases in the molten weld.

Shielding gas: an inert or semi-inert gas used to protect the weld area from atmospheric gases such as oxygen, nitrogen, and water vapour.

Stick welder (SMAW): a welding method that uses flux-coated electrodes within a high-amperage circuit to melt and deposit metal for surfacing and joining metal components. An abbreviation of “shielded metal arc welding.”



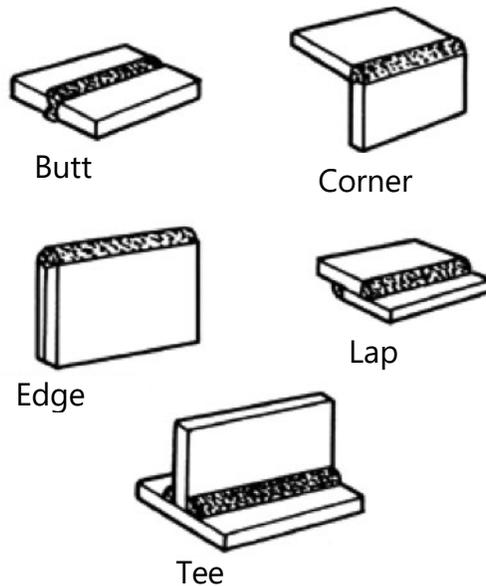
Tack weld: a small weld(s) that holds pieces together for assembly. They can be removed more easily than a full weld if adjustments are needed.

Weld bead: a deposit of filler material into the weld joint.

Welder voltage: the input voltage required for a welding transformer to operate.

Weld joint types:

- a. Butt joint
- b. Lap joint
- c. Corner joint
- d. Edge joint
- e. Tee joint



Welding coat: body protection from heat, light, and sparks.

Welding gloves: hand protection from heat, light, and sparks

Welding helmet: face, head, and eye protection from heat, light, and sparks.

Wire speed: the rate in feet or metres per minute at which wire is fed through the GMAW unit.

Estimated Time

3 hours

The time will depend on the students' experience in the metalwork shop and the number of tools and welders available to them.

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

A standard secondary school metalwork shop

Equipment/Machinery

- MIG welder (GMAW)
- Bench grinder
- Belt sander

Personal Protective Equipment

- Welding coat
- Welding gloves
- Welding helmet

Tools

- Hacksaw
- Ruler
- File or sandpaper

Materials

- Mild steel flat stock $\frac{1}{8}$ " x 1"
- MIG welding consumables

Resources

Safety tests: Generic safety tests are available in the “HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

Welding video and instructions ranging from preparation to various welding positions

<https://www.millerwelds.com/resources/article-library/mig-welding-the-basics-for-mild-steel>

Video explaining different types of welders: oxyacetylene, MIG, TIG, and stick

<https://www.youtube.com/watch?v=xrPeKfKW3Eo>

Video about the career of welding

<https://www.youtube.com/watch?v=rIOEBAIkmwg>

Weld joints and types

https://en.wikipedia.org/wiki/Welding_joint

BCIT Metal Fabrication trades video

<https://www.youtube.com/watch?v=IhvvUWH8Z5w>

Teacher-led Activity



Mig Welding the DIY Guide

Note: In the following activities, other dimensions of metal or scrap can be used, but measurements will need to be adjusted.

Part 1: Welding Demonstration

1. Explain safe MIG welder use. Topics should include:
 - a. Dangers of UV light produced and the PPE needed to protect the user, such as welding coats, welding gloves, and welding helmets.
 - b. Dangers of fumes produced. Discuss the PPE needed and ventilation required to protect the user, such as ventilation fans and respirators.
 - c. Dangers associated with heat related to the weld and the PPE needed to protect the user, such as welding coats, welding gloves, and welding helmets.
 - d. Dangers associated with electricity used by the welder and the importance of a dry work area and dry PPE.
 - e. Dangers associated with compressed gas cylinders related to the welder and the careful handling required.
2. Show students how to prepare the metal for welding using a grinder, sander, file, or sandpaper. Metal should be bare steel where the joint will occur and where the ground clamp will be.

3. In small groups (so welding can be seen up close) lay weld beads on a piece of steel:
 - a. Show good welds and explain what they should look like.
 - b. Adjust welder's voltage up and down to show what happens to the weld.
 - c. Adjust welder's wire speed up and down to show what happens to the weld.
 - d. Adjust welder's shielding gas up and down to show what happens to the weld.
 - e. Adjust the tip's distance (wire stick-out) from the weld to show what happens to the weld.
4. In small groups (so welding can be seen up close) demonstrate different weld joints:
 - a. Butt joint
 - b. Lap joint
 - c. Corner joint
 - d. Edge joint
 - e. Tee joint

Part 2: Laying Beads

1. To practise welding a simple bead, have students weld straight lines on top of a piece of steel.
2. Check the students' weld quality after each bead before allowing them to continue.
3. Welds should be inspected for porosity, speed of travel, and penetration.

Part 3: Welding Joints

1. Have students cut ten 6" long pieces of 1" × 1/8" flat bar for the welding joint samples.
2. Each student should create a weld sample for each of the five weld joints.
3. Weld joints should be letter punched with students' names for evaluation purposes.

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

- All five weld joints were completed
- Each joint is free of porosity
- Each joint is oriented correctly
- Welds have good penetration
- Welds show correct speed travel
- Safe work habits were displayed

Extension Activity

Students who have completed the weld samples or have experience with MIG welding steel could practise making the same welds using other welders such as a stick welder, TIG welder, or welding torch.

Make a Welded Die

Description

Welders are required to work with many other metalworking trades. To be successful as a welder, one must have an understanding of many other metalworking skill sets and an understanding of the entire project. This activity plan will demonstrate to students how to successfully cut, lay out, assemble, and weld a metal die for use as a paperweight or pencil/pen holder. These tasks will expose students to skills used by welders, metal fabricators, and millwrights.

Lesson Objectives

The student will be able to:

- Work safely using metalworking tools
- Use information from a drawing
- Perform accurate layout
- Cut and form materials using hand tools and power tools
- Join metal by welding processes
- Perform finishing techniques using hand tools and power tools

Assumptions

Students will:

- Have knowledge of measurement systems used in metalworking
- Have knowledge of layout procedures used in metalworking
- Have an understanding of safe shop practices
- Know the safe use of and procedures for hand tools, drill presses, bench grinders, belt sanders, and welders

Terminology

MIG welding (GMAW): a welding method in which electric current flows through the filler metal wire to maintain the arc. An inert or semi-inert gas shields the arc from outside air. MIG is an abbreviation of “metal inert gas”, and GMAW is an abbreviation of “gas metal arc welding.”

Outside corner joint: a welding orientation where the outside edges of two plates butt up to each other, leaving a groove to weld.

Perpendicular: when two lines, edges, or surfaces are at a 90° angle to each other.



Porosity: a condition in which bubbles form in the weld due to the absorption of atmospheric gases in the molten weld.

Shielding gas: an inert or semi-inert gas used to protect the weld area from atmospheric gases such as oxygen, nitrogen, and water vapour.

Tack weld: a small weld(s) that holds pieces together for assembly. They can be removed more easily than a full weld if adjustments are needed.

Estimated Time

6 hours

The time will depend on the students' experience in the metalwork shop and the number of tools available to them.

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

A standard secondary school metalwork shop

Equipment/Machinery

- MIG welder (GMAW)
- Bench grinder
- Belt sander
- Drill press
- Bench vise

Personal Protective Equipment

- Welding coat
- Welding gloves
- Welding helmet

Tools

- Welding magnets
- De-burring tool
- Hacksaw
- Metal file
- Machinist square

- Scriber
- Hermaphrodite caliper
- Centre punch

Materials

- Mild steel flat stock $\frac{1}{8}$ " \times 2" (or similar)
- Spray paint
- Sandpaper

Resources

Safety tests: Generic safety tests are available in the “HEADS UP! for Safety” handbook www.bced.gov.bc.ca/irp/resdocs/headsup.pdf

Welding video and instructions ranging from preparation to various welding positions
<https://www.millerwelds.com/resources/article-library/mig-welding-the-basics-for-mild-steel>

Video explaining different types of welders: oxyacetylene, MIG, TIG, and stick
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MIG vs TIG: differences and benefits of each explained
<https://www.youtube.com/watch?v=lju5tHB2UCc>

Video about the career of welding
<https://www.youtube.com/watch?v=rIOEBAIkmwg>

Weld joints and types
https://en.wikipedia.org/wiki/Welding_joint

BCIT Metal Fabrication trades video
<https://www.youtube.com/watch?v=lhvUWH8Z5w>

Teacher-Led Activity

Note: In the following activities, other dimensions of metal or scrap can be used, but measurements will need to be adjusted.

Part 1: Layout and Cutting

1. Using a ruler and a scribe, make a mark at 2" on a piece of $\frac{1}{8}$ " \times 2" mild steel flat stock.
2. Using a machinist square and scribe, make a line at the 2" mark perpendicular to the metal's length, creating a 2" \times 2" square.
3. Using a hacksaw, cut off the 2" \times 2" piece just on the outside edge of the line.
4. Use a metal file to file both ends to the scribed line to be exactly 2" square.

5. Repeat steps 1–4 five more times until you have six 2" × 2" pieces.

Each piece will require layout lines to produce one side of the six die sides (6a–6f).

6. a. For #1, scribe an "X" from corner to corner to find the centre (Figure 1), then centre-punch the intersection.

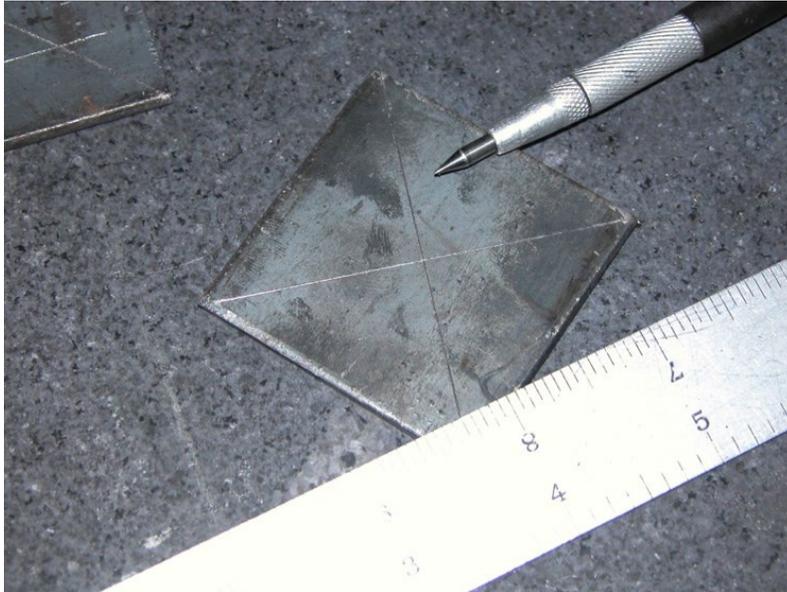


Figure 1—Scribing for #1

b. For #2, scribe a line from one corner to the diagonal corner. Then from the marked corners, make a line $\frac{1}{2}$ " from each corner along the line (Figure 2). Then centre-punch the two intersections.



Figure 2—Scribing for #2

- c. For #3, scribe an “X” from corner to corner to find the centre. Then from one corner and its diagonal corner, scribe a line at $\frac{1}{2}$ " (Figure 3), then centre-punch the three intersections.

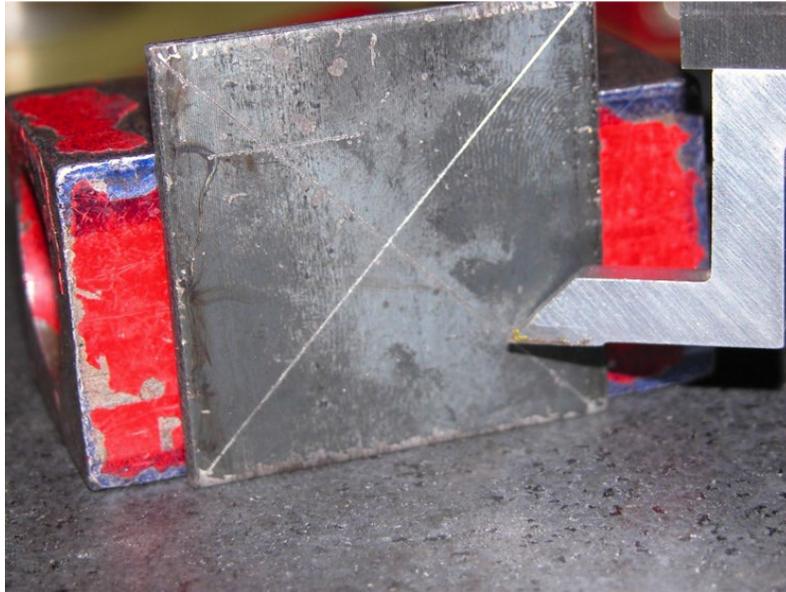


Figure 3—Scribing for #3

- d. For #4, scribe an “X” from corner to corner. From each corner, scribe a line toward the centre at $\frac{1}{2}$ " (Figure 4), then centre-punch the four intersections (do not centre-punch the centre of the “X”).



Figure 4—Scribing for #4

- e. For #5, scribe an “X” from corner to corner to find the centre. From each corner, mark a line at $\frac{1}{2}$ " (Figure 5), then centre-punch the five intersections.



Figure 5—Scribing for #5

- f. For #6, using a hermaphrodite caliper (or other available layout tools) set at $\frac{1}{2}$ ", scribe parallel lines around all four sides of square. Scribe a line with a hermaphrodite caliper at 1" from one edge (Figure 6), then centre-punch all six intersections.

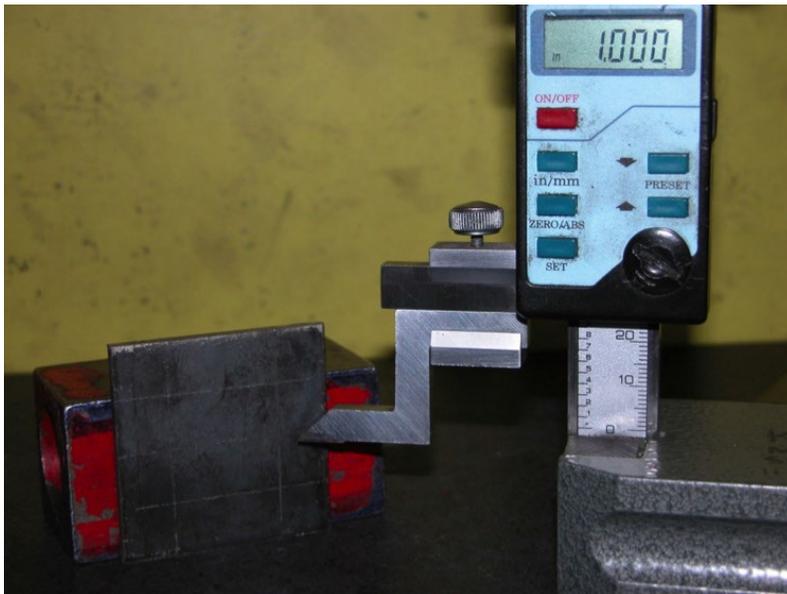


Figure 6—Scribing for #6

Part 2: Drilling

1. Drill through all centre-punch marks on a drill press with a $\frac{1}{4}$ " drill bit. For a variation, drill #6 with a bigger bit and make that side of the die into a pencil holder.



Figure 7—Centre-punch the intersections



Figure 8—Clamp the work piece in a bench vise



Figure 9—Drill at each centre-punched point

2. De-burr all drill holes on both sides of the stock with a file, sandpaper, de-burring tool, or countersink.

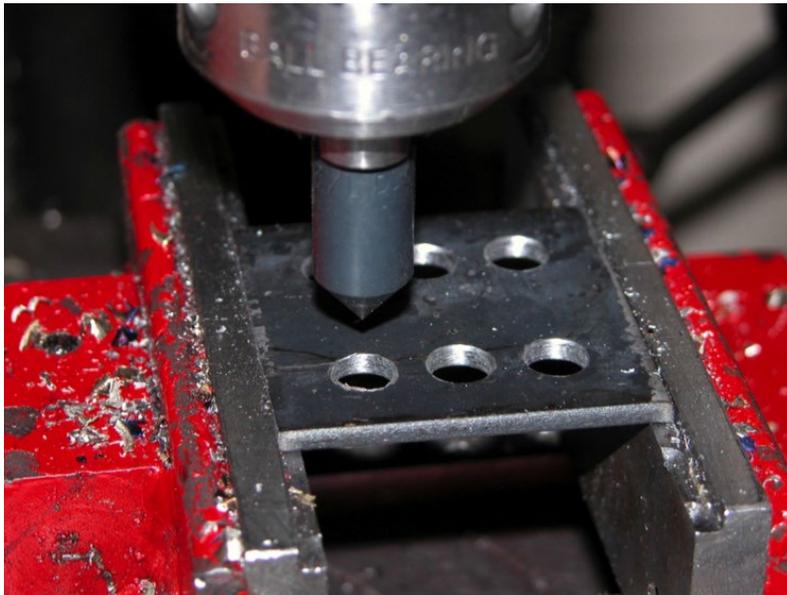


Figure 10—De-burr the holes



Figure 11—Sides ready for assembly

Part 3: Set-up and Welding

1. Set the welder's voltage, wire speed, and shielding gas pressure according to the manufacturer's specifications for $\frac{1}{8}$ " steel (Figures 12 & 13).



Figure 12



Figure 13

- Using a 90° welding magnet, set up pieces #4 and #5 in an open corner joint weld position (Figure 14).

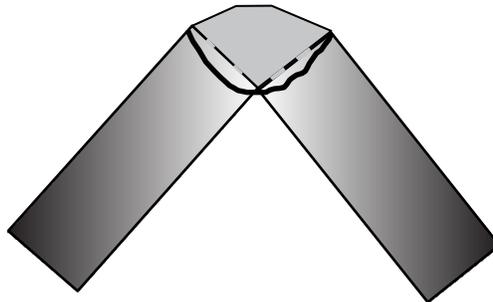


Figure 14

3. Tack pieces #4 and #5 together in an L shape using the MIG welder (Figure 15).

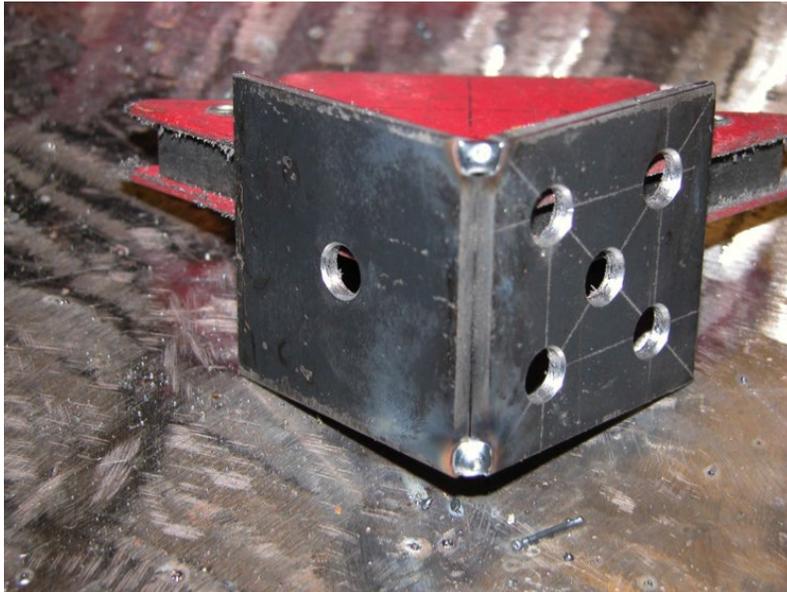


Figure 15

4. Repeat the previous two steps with pieces #2 and #3 (Figure 16).

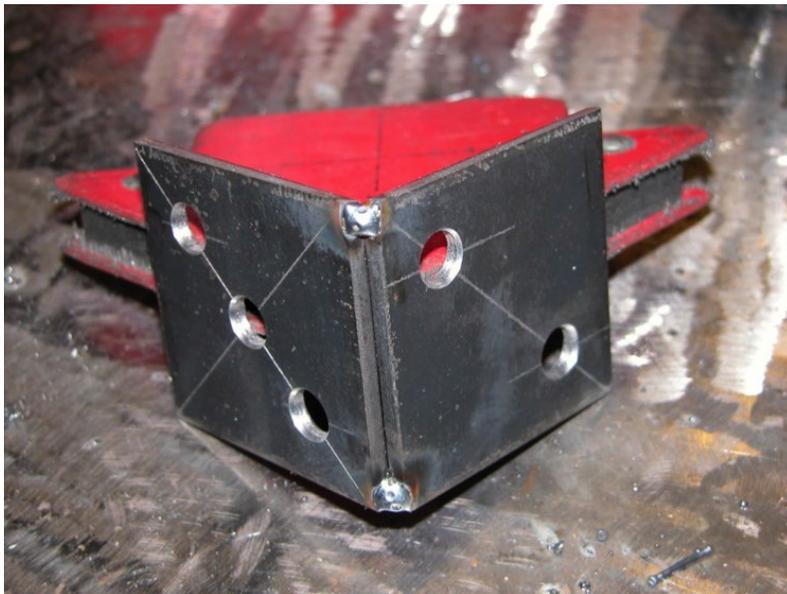


Figure 16

5. Place the tacked #4 and #5 on their side along with the tacked #2 and #3 on their side. Orient them toward each other to create a box/cube with no top or bottom.
6. Tack the assembly together with an outside corner joint.

- Place #6 on top of the assembly and tack it into place, leaving four outside corner joints.



Figure 17

- Flip the die over and place #1 piece on top. Tack it into place, leaving four outside corner joints (Figure 17).
- Fully weld all 12 outside corner joints (Figure 18).



Figure 18

Part 4: Finishing

1. Using a bench grinder or belt sander, clean up all welds, leaving gently rounded corners.
2. Re-weld all gaps and porosity discovered after grinding/sanding, then grind/sand the new welds.
3. Using the sander, a file, or sandpaper, smooth out all surfaces to pre-paint quality.
4. Spray paint the die to keep it from rusting.

Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

- Layout is correct.
- Completed die is welded square.
- Welds have no visible porosity.
- Sanding and grinding lines not seen in paint.
- Safe work habits were displayed.

Optional Extension Activity

Students who have experience with MIG welding of steel could fabricate the die using other welders such as a stick welder, oxyacetylene welder, TIG welder, or a combination of multiple types of welders.

Make a Pencil Holder

Description

Welders are required to work with many other metalworking trades. To be successful as a welder one must have an understanding of many other metalworking skill sets and an understanding of the entire project. This activity plan will demonstrate to students how to successfully cut, lay out, assemble, and weld a wood stump pencil holder for use as a paperweight and pencil/pen holder. These tasks will expose students to skills used by welders and metal fabricators.

Lesson Objectives

Students will learn to:

- Work safely using metalworking tools
- Perform accurate layout
- Cut and form materials using hand tools and power tools
- Join and shape metal by welding processes
- Perform finishing techniques using hand tools and power tools

Assumptions

Students will:

- Have knowledge of measurement systems used in metalworking
- Have knowledge of layout procedures used in metalworking
- Have an understanding of safe shop practices
- Know the safe use and procedures of hand tools, bench grinders, belt sanders, and welders

Terminology

MIG welding (GMAW): a welding method in which electric current flows through the filler metal wire to maintain the arc. An inert or semi-inert gas shields the arc from outside air. MIG is an abbreviation of “metal gas welding,” and GMAW is an abbreviation of “gas metal arc welding.”

Porosity: a condition in which bubbles form in the weld due to the absorption of atmospheric gases in the molten weld.

Shielding gas: an inert or semi-inert gas used to protect the weld area from atmospheric gases such as oxygen, nitrogen, and water vapour.



Stick welding (SMAW): a welding method that uses flux-coated electrodes within a high-amperage circuit to melt and deposit metal for surfacing and joining metal components. SMAW is an abbreviation of “shielded metal arc welding.”

Tack weld: a small weld(s) that holds pieces together for assembly. They can be removed more easily than a full weld if adjustments are needed.

Weld bead: a deposit of filler material into the weld joint.

Estimated Time

6 hours

The time will depend on the students’ experience in the metalwork shop and the number of tools available to them.

Recommended Number of Students

20, based on the *BC Technology Educators’ Best Practices Guide*

Facilities

A standard secondary school metalwork shop

Equipment/Machinery

- MIG welder (GMAW)
- Stick welder (SMAW)
- Drill press
- Bench grinder
- Belt sander
- Bench vice
- Beverly shear
- Foundry furnace
- Welding torch
- Wire wheel

Tools

- Hacksaw
- Metal file
- Machinist square
- Scribe
- Layout hammer

Materials

- Mild steel flat stock $\frac{1}{8}$ " × 2"
- Mild steel pipe 0.100"–0.1875" wall × 2" diameter or similar
- Mild steel round stock $\frac{3}{16}$ "
- Spray paint
- Sandpaper

Resources

Safety tests: Generic safety tests are available in the Heads Up for Safety booklet

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

Welding video and instructions ranging from preparation to various welding positions

<https://www.millerwelds.com/resources/article-library/mig-welding-the-basics-for-mild-steel>

Video explaining different types of welders: oxyacetylene, MIG, TIG, and stick

<https://www.youtube.com/watch?v=xrPeKfKW3Eo>

Video about the career of welding

<https://www.youtube.com/watch?v=rlOEBAIkmwg>

Weld joints and types

https://en.wikipedia.org/wiki/Welding_joint

BCIT Metal Fabrication trades video

<https://www.youtube.com/watch?v=IhvvUWH8Z5w>

Teacher-led Activity



Demonstrate the following procedures to the class. Students will then replicate the processes.

Note: In the following activities other dimensions of metal can be used, but measurements will need to be adjusted.

Part 1: Layout and Cutting of Stump

1. Use a ruler and a scribe to make a mark at 3" on a piece of mild steel pipe 0.100"–0.1875" wall × 2" diameter or similar.
2. Using a hacksaw or band saw, cut pipe to length.
3. Using a bench grinder, belt sander, or file, square both ends of the pipe.
4. Using a 2" hole saw on a drill press, or a hacksaw and grinder, cut a 2" circle out of mild steel flat stock $\frac{1}{8}$ " × 2".

Part 2: Layout and Cutting of Axe

1. Using a ruler and a scribe, make a mark at 1" on a piece of mild steel flat stock $\frac{1}{8}$ " × 2" and cut it off with a hacksaw or band saw.
2. Using a hacksaw or band saw and hand tools, cut out an axe head. Axe could be different styles, such as a battle axe, splitting axe, throwing axe, or a double-edge axe.
3. Using a hacksaw, cut a 2.5" piece of $\frac{3}{16}$ " mild steel round stock for the axe handle.

Part 3: Stump Fabrication

1. Tack weld the bottom of the stump onto the pipe with an open corner fillet weld.
2. If correctly placed after tacks, completely weld it on.
3. Grind the weld flush to the sides and flatten them on the bottom.
4. Weld multiple beads from the top to bottom. These welds will replicate the bark of a tree. Many overlapping welds may be required to produce the desired look.

Part 4: Axe Fabrication

1. Tack weld both sides of the axe head to the handle.
2. File the axe head and the tack welds into a realistically shaped axe.
3. With a hacksaw and small file, cut a notch in the blade of the axe. The notch needs to fit over the stump to look like the axe is stuck in.

Part 5: Stump and Axe Assembly

1. Place the axe notch over the top of the stump
2. Tack weld the axe to the stump in a manner that the attaching weld is not obvious.

Part 6: Finishing

1. Using a wire wheel or wire brush, polish all surfaces, removing welding tarnish and discoloration.
2. Apply finish coat. Options for finish could include spray paint, powder coating, or oil blackening.

**Assessment**

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

- Pipe length is correct.
- Stump sits flat and level.
- Axe is shaped realistically.
- Welds do not contain porosity.
- Finishing work was done correctly.
- Safe work habits were displayed.

Optional Extension Activity

Students who have experience with MIG welding steel could use a stick welder instead. A stump top could also be added to make it into a paperweight/sculpture instead of a pencil holder.

Make a Portable Hibachi

Description

The purpose of this activity plan is to introduce students to the metal shop through a practical activity. Students will gain valuable knowledge in using power tools and equipment as well as GMAW (MIG) welding processes. The end result of the project is a functioning, portable hibachi BBQ.

Lesson Objectives

The student will learn:

- Safe use of tools and equipment
- Correct layout and measurement techniques
- How to select cutting tools appropriate for the project
- How to cut, form, and join metal material into a desired project
- Finishing techniques: grinding, filing, and sanding
- GMAW (MIG) welding techniques for tack welds and beads

Assumptions

The teacher will:

- Be a certified technology education/industrial education teacher
- Be familiar with the metal shop that this activity plan is being produced in
- Have experience with all aspects of the given metal shop, including machines, tools, and processes

The student will:

- Be attentive and participatory
- Recognize that appropriate attitudes are the best insurance for safety
- Work safely in the metal shop

Terminology

Abrasive chop saw: a circular metal cutting saw that uses abrasive discs to cut.

Burr: a sharp edge of leftover material produced after a cut has been made.

Drill press: a fixed-base machine that is used for drilling holes.

Foot shear: a foot-controlled machine used to cut sheet metal stock.



Hacksaw: a fine-tooth hand saw with a blade held under tension in a frame.

Horizontal band saw: a saw in which the blade is a continuous band of metal that moves through the material.

Grinder: a hand-held power grinder.

Layout: the process by which measurements are transferred from drawings to material.

Measurement: assigning a number to represent a length or amount of something based on a standardized system of units.

MIG welding (GMAW): a welding method in which electric current flows through the filler metal wire to maintain the arc. An inert or semi-inert gas shields the arc from outside air. MIG is an abbreviation of “metal inert gas”, and GMAW is an abbreviation of “gas metal arc welding.”

Stock: the material being used; in this case metals of differing type and measurements.

Estimated Time

5–10 hours

Recommended Number of Students

20, based on the *BC Technology Educators’ Best Practices Guide*

Facilities

Metal shop facility with all necessary equipment

Personal Protective Equipment

- Welding coat
- Welding gloves
- Welding helmet

Tools

- Whiteboard for written instruction purposes in place of handouts
- Abrasive chop saw
- Beverly shear
- Centre punch
- Drill press
- File
- Foot shear
- Grinder

- Hacksaw
- Horizontal band saw
- MIG welder
- Scribe
- Tape measure
- Vertical band saw

Materials

Note: Substitutions can be made for materials not readily available or cost prohibitive.

- Expanded metal C $\frac{3}{4}$ -13R or C $\frac{3}{4}$ -16F
- $\frac{3}{4}$ " square bar stock – substitution could be square tube of same dimension
- $\frac{3}{16}$ " round bar stock
- $\frac{3}{8}$ " round bar stock
- 3" flat bar – $\frac{1}{4}$ " thick
- 3" × 6" × $\frac{1}{4}$ " thick steel channel – flat plate could be substituted to make up the bottom and walls of the hibachi
- Four $\frac{3}{8}$ " × 2 $\frac{1}{4}$ " hex bolt with nuts and washers
- Two pieces of 4" × 2" × 1" thick, hard wood
- Danish oil or another similar finish
- Sandpaper

Resources

“HEADS UP! for Safety” handbook

<https://www.bced.gov.bc.ca/irp/resdocs/headsup.pdf>

BC Technology Education Association Best Practices Guide

<http://www.bctea.org/best-practice-guide/>

Modern Metalworking, textbook by John R. Walker, copyright 2004. Goodheart-Wilcox Company Inc.

Teacher-led Activity

Demonstrate the procedures in the following steps to fabricate a hibachi. Students will then fabricate their own hibachis.

Part 1: Parts Manufacturing

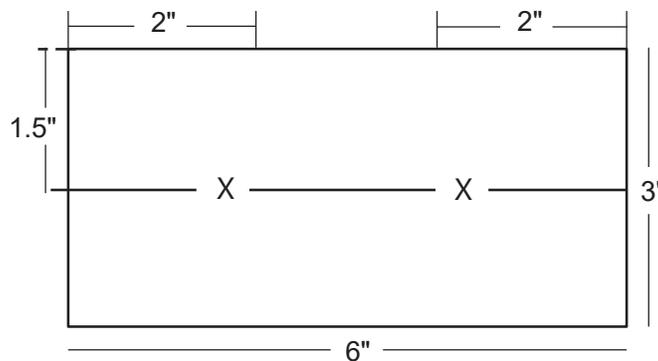
1. Measure and lay out a 12" section on the bottom of the channel and scribe a line.
2. Using the horizontal band saw, cut the body of the hibachi.
3. File and grind all edges on the body. Ensure there are no burrs or sharp edges. Put to the side to begin the next part.



4. Lay out two 6" sections on the 3" flat bar and scribe a line. These will be the end caps for your hibachi.
5. Cut the end caps using the abrasive chop saw or horizontal band saw.
6. File and/or grind all edges and surfaces of the end caps until smooth and burr-free.



7. Measure and lay out two holes using a tape measure and scribe according to the diagram below.



- Centre-punch the middle of the layout to make sure the drill bit will go through the material in the correct location.



- Clamp the flat bar to the drill press with a piece of scrap wood underneath. Before turning the drill press on, confirm that the drill bit will not pass through into the drill press table.
- Drill holes in both end caps using a HSS $\frac{3}{8}$ " drill bit.
- On both sides file out the holes or use a countersink bit or a de-burring tool to make sure there are no burrs or sharp edges. Set the pieces aside.



- Lay out and measure two 4" pieces of $\frac{3}{4}$ " square bar stock. Scribe the line for cutting. These will be the legs. You could substitute square tube for this part.
- Cut the bar stock using the abrasive chop saw or vertical band-saw.

14. File all edges to remove burrs and sharp corners.



15. File all flat surfaces of the bar stock for the legs. This will make sure there are good contacts for welding at the assembly stage. Set the pieces aside.

16. Measure and lay out two lengths of $\frac{3}{8}$ " bar stock at 11". These will become the grill ledge.

17. Cut the lengths using the abrasive chop saw or hacksaw.

18. File the ends to remove burrs and sharp corners. Set the pieces aside.



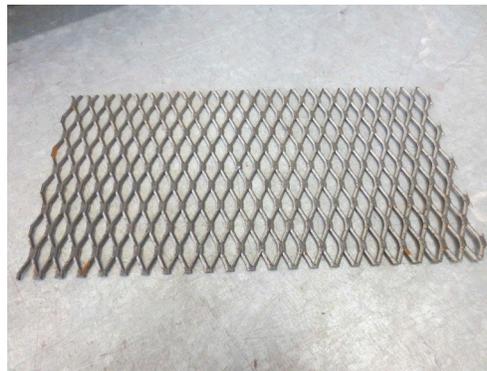
19. Measure and lay out two lengths of $\frac{3}{16}$ " bar stock $5\frac{3}{4}$ " in length. These pieces will eventually be welded to the grill for reinforcement.

20. Cut on the Beverly shear or use the hacksaw.

21. File the ends to remove all sharp edges. Set the pieces aside.



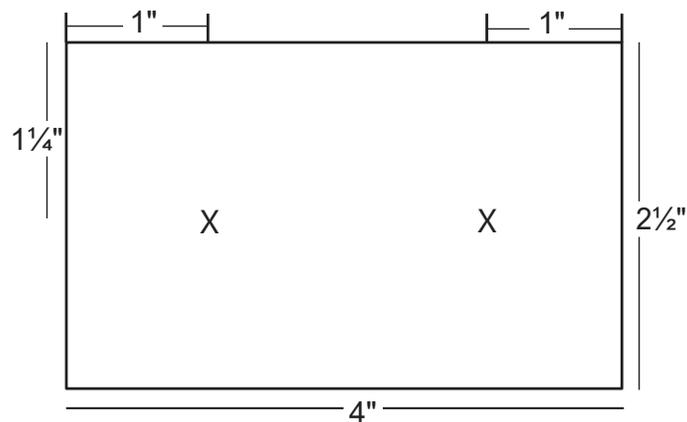
22. Measure and lay out the expanded sheet metal to 12" × 5 $\frac{7}{8}$ ".
23. Cut out on the foot shear. Handle very carefully as the edges will be very sharp. Set the grill piece aside.



Part 2: Handle Construction: Woodshop

This is only one option for handles. Students could design their own.

1. Gather material: two pieces of 4" × 2" × 1" thick hard wood. Oak or maple would work nicely.
2. Sand and file all edges to create a small chamfer.
3. Measure and lay out two holes as per the drawing below.



4. Clamp each piece onto the drill press table with a scrap piece underneath.
5. Before turning the equipment on, test the set-up to confirm the drill will not go through the table.
6. Drill two holes $\frac{3}{8}$ " in size in both handles in the laid-out positions.
7. Countersink each hole to fit a $\frac{3}{8}$ " hexagon bolt head.
8. Sand holes and remove any sharp edges.
9. Oil the handles with Danish oil or another similar finish. Set aside to dry.



Note: Countersink procedure has not been completed in this image.

Part 3: Assembly of Parts

Warning! All safe working procedures should be followed when using the MIG welder. Ensure students have had adequate practice time using the welders before beginning the assembly process. All safety gear (PPE) must be worn when operating the welding equipment.

Warning! If substitutions are made with materials, be sure to confirm that the heat of the welds will not adversely affect the overall project. Thin materials will also be impacted when used as a BBQ once the project is complete.

1. Using the MIG welder, begin assembling the grill ledge pieces onto the inside of the body (Figure 1). The ledge should be tack welded into place at either end and in the middle. The bar should sit 1" down from the top edge of the body wall. Complete this step for both ledges.



- Turn the body over and place the feet onto the bottom as in the photo below. Use magnetic clamps to hold the feet in place (1" from either side of the top, and 2" in on either end).



- Weld the feet into place. Use tack welds to hold them and then add short beads to ensure they are secure. The legs should have welds on either side to safeguard against warping once the hibachi is in use.



- Rotate the body so that the end caps can be placed inside the ends. Use a magnetic clamp on the inside of the body to hold the end cap for welding on the outside edge.



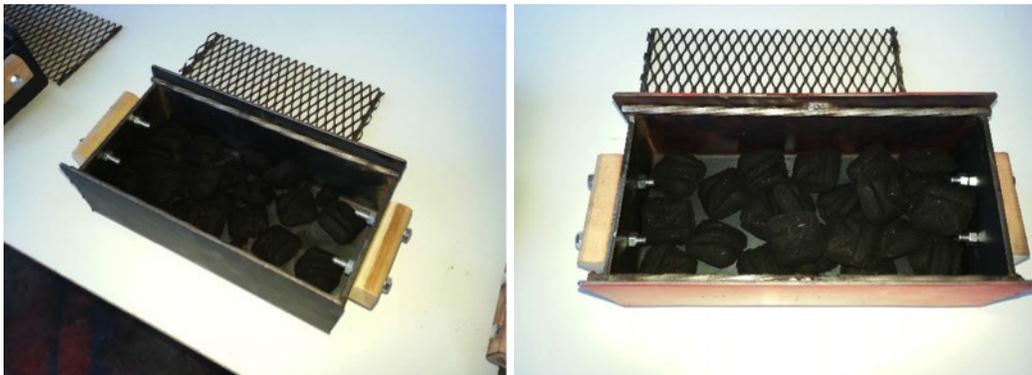
- If the body is placed on end it will be easier to weld the end caps in position with a horizontal weld. If the body is sitting on its feet, the weld becomes vertical and may be more difficult for beginning welders. Complete a welded bead on either side and along the bottom of the body. Once finished, set the body aside to cool.



- Lay the expanded sheet metal on the welding table and add the reinforcement bars to either end, aligned with the short ends of the grill. Tack weld in place.



- Grind, file, and sand all edges, surfaces, and welds to remove rough spots and burrs. Ensure the project is free of any welding splatter. Once filing is complete, wipe down the project with a dry cloth to ensure no dust or debris remains.
- Paint the outside of the body of the hibachi using high-heat engine/BBQ paint. Be careful not to overspray onto the grill. Make sure the body has two coats of paint before use. Each layer of paint will need to set/cure before the next coat can be applied.
- Assemble the handles onto the end caps in the following order:
Hex bolt > Handle > Nut > Wall of the end cap > Washer > 2nd Nut



Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

- Safe working procedures at all times
- Personal and project management: good use of time, attitude, effort
- Accurate measurements and layout
- Appropriate tools use
- All burrs and sharp edges are removed
- Welds have good penetration and contact, no pitting or splatter.
- Project fits well together, no missing pieces.

Make a Safe

Description

Welding is a vast area in the metalworking field and a widely used joining process for metal. In this activity plan students will learn how to MIG weld (GMAW). Students will cut and weld pieces together to fabricate a safe according to drawings and specifications. Further extensions to this activity could be to introduce other types of joints or welding processes.

Lesson Objectives

The student will be able to:

- Identify common metals
- Demonstrate appropriate shop behaviour
- Demonstrate safe and appropriate use of shop equipment
- Demonstrate proficient welding technique
- Demonstrate a variety of cutting processes

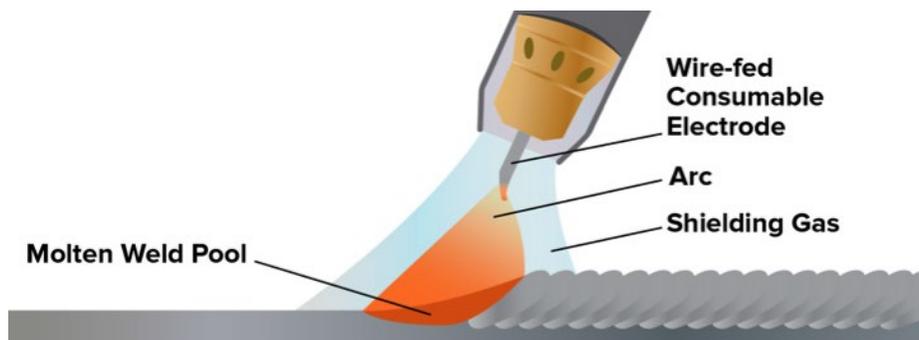
Assumptions

The student:

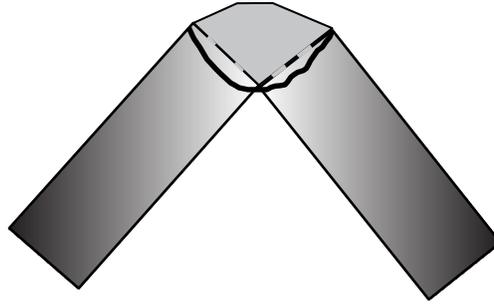
- Knows basic metallurgy
- Knows basic measurement
- Know various cutting processes
- Understands basic layout techniques
- Understands basic welding concepts

Terminology

MIG welding (GMAW): a welding method in which electric current flows through the filler metal wire to maintain the arc. An inert or semi-inert gas shields the arc from outside air. MIG is an abbreviation of “metal gas welding,” and GMAW is an abbreviation of “gas metal arc welding.”



Outside corner joint: a welding orientation where outside edges of two plates butt up to each other, leaving a groove to weld.



Tap drill chart: a chart used to determine the size of drill bit required for the specified size and thread of bolt you want to use. The chart is read by first determining what size of bolt and thread pitch you want to use. Next, look to the left to see the decimal equivalent of the drill bit size to use. Looking to the left once more, you will see the alphabetical, numerical, or standard drill bit size to use. Once the hole has been drilled to the correct size, a tap of the size required for the bolt will fit inside to create threads.

Estimated Time

5–10 hours

The time for this activity will depend on the familiarity of students with tools and the scope of the project (how much teachers prepare for students ahead of time, or how far they take the finishing portion of the project), and the availability of tools/equipment.

Recommended Number of Students

20, based on *BC Technology Educators' Best Practices Guide*

Facilities

Secondary school metal shop or equivalently equipped technology education shop

Personal Protective Equipment

- Welding coat
- Welding gloves
- Welding helmet

Equipment/Machinery

- Angle grinder
- Horizontal band saw

- MIG welder
- Plasma cutter or cutting torch

Tools

- Ball peen hammer
- Files
- Steel scale
- Square
- Tap handle
- Tap

Materials

Item	# of pieces	Material	Thickness	Width	Length
Safe body	1	6" square tubing hot rolled steel	1/8" wall	6"	6"
Safe backing plate	1	1/8" hot rolled steel plate	1/8"	6"	6"
Safe door	1	1/8" hot rolled steel plate	1/8"	6"	6"
Handle	1	3/8" hot roller round	3/8"	3/8"	3/4"
Lock plates	2	1/8" hot rolled steel flat bar	1/8"	1"	1 1/4"
Hinge pin	1	3/8" hot rolled round	3/8"	3/8"	5 1/4"
Hinges	2	1/2" round tubing	100" wall	1/2"	1 1/2"
Hinges	1	1/2" round tubing	100" wall	1/2"	2"

4 – 1/4" UNC bolts

1 – 1/4" UNC tapered tap

1 – #7 drill bit

Resources

How to use an angle grinder

<https://www.youtube.com/watch?v=t08VRIFptKw>

How to use a horizontal band saw

<https://www.youtube.com/watch?v=CWbn7ZeNoV4>

How to MIG weld

<https://www.youtube.com/watch?v=ZqoFseN17DA>

How to thread with a tap

https://www.youtube.com/watch?v=U5QU_3qUigk

Teacher-led Activity

Demonstrate the following steps to fabricate a metal safe. Students will then replicate the processes to create their own safes.

Body of Safe

1. Obtain 6" square tubing for safe body.
2. Teacher demonstrates how to use horizontal band saw.
3. Measure and lay out a 6" length and use the band saw to cut.
4. Use a rough file to remove all sharp edges from both sides of tubing.
5. Choose a side to create the bottom and lay out drill holes as per drawing.
6. Centre-punch four drill marks.
7. Teacher demonstrates how to use a drill press and read a tap drill chart.
8. Set up drill press with a #7 drill bit, and drill four marks.
9. Clamp body of safe in a vise with drill holes facing up.
10. Acquire a ¼" UNC tap, tap handle, and threading fluid.
11. Teacher demonstrates how to thread a hole with a tap.
12. Tap four drill holes with ¼" tap.
13. Thread four bolts into holes.

Back and Door for Safe

1. Obtain a piece of ⅛" plate for backing plate and door of safe.
2. Lay out two 6" squares.
3. Teacher demonstrates a plasma cutter or cutting torch to students.
4. Cut out squares using a plasma cutter or cutting torch.
5. Teacher demonstrates the bench grinder. If a bench grinder is not available, use an angle grinder or files.
6. Grind and file edges of plates to match tubing outer profile.
7. File all edges with a smooth file to remove burrs and sharp edges.

Door Hinge

1. Obtain a piece $\frac{3}{16}$ " round stock.
2. Lay out and cut a $5\frac{1}{4}$ " length of $\frac{3}{16}$ " round stock using a hacksaw.
3. Obtain a piece of $\frac{1}{2}$ " tubing.
4. Cut a 2" length and two $1\frac{1}{2}$ " lengths of $\frac{1}{2}$ " tubing using a hacksaw.
5. File ends of all pieces flat and smooth.
6. Teacher demonstrates the hammering process for the hinge.
7. Clamp round stock vertically in a vise.
8. Use a ball peen hammer to hammer around one outer edge of round stock.
9. Turn over round stock so hammered end is on the bottom and place tubing pieces over round stock, ensuring the 2" piece is in between the shorter pieces.
10. Carefully clamp hinge vertically in a vise, and hammer outer edge of round stock to capture tubing pieces.

Assembling Safe

1. Teacher demonstrates MIG welding (GMAW) to students.
2. Place backing plate on tubing
3. Tack weld backing plate to safe body and check fit.
4. Weld outside corner joint around backing plate.
5. Grind or file any high spots of weld down to body of safe.
6. Prepare safe to attach hinge by sitting the safe on its backing plate and placing the door on top so it aligns with the body. Use a welding magnet to place hinge in correct position on the safe, making sure it is centred vertically along the door and centred between the door and body of the safe.
7. Tack the shorter pieces of tubing to body of safe.
8. Tack weld wider middle piece of tubing to door of safe.
9. Remove welding magnet and test hinge to ensure the door swings open and shut, and door is aligned.
10. Finish welding the hinge on to door and body of safe. Be sure to only weld on the side that the tack welds are, otherwise the safe will not open.

Door Handle

1. Obtain a piece of $\frac{3}{8}$ " round stock. Measure and cut a piece $\frac{3}{4}$ " long.
2. Round edges of one end to a small radius. This will be the front of the handle.
3. File other end flat.
4. Lay out position of handle on door.
5. Tack weld handle on door, ensuring the flat side sits on the door.
6. Fillet weld around base of handle to door.
7. File any sharp or uneven edges.

Lock Plates

1. Obtain a piece of $\frac{1}{8}$ " thick 1" flat bar. Measure and cut two $1\frac{1}{4}$ " long pieces.
2. File both ends of each piece flat and smooth.
3. Lay out and centre-punch a mark $\frac{1}{2}$ " down and in from one end on each piece.
4. Drill holes with a $\frac{1}{4}$ " drill bit.
5. Remove any burrs from drilled holes.
6. Tack weld one piece to side of the lid plate, in the centre, ensuring the hole is toward the outside.
7. Tack weld the second piece to the side of the safe, directly below the piece attached to the lid so that the drill holes match up.
8. Weld the two lock plates in place once they match up.
9. Use a padlock or combination lock to protect the contents of your safe.

Finishing

1. Clean any grease, dirt, or scratches off metal using emery cloth.
2. Choose an appropriate method of finishing (painting, powder coating, etc.).

Evaluation

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

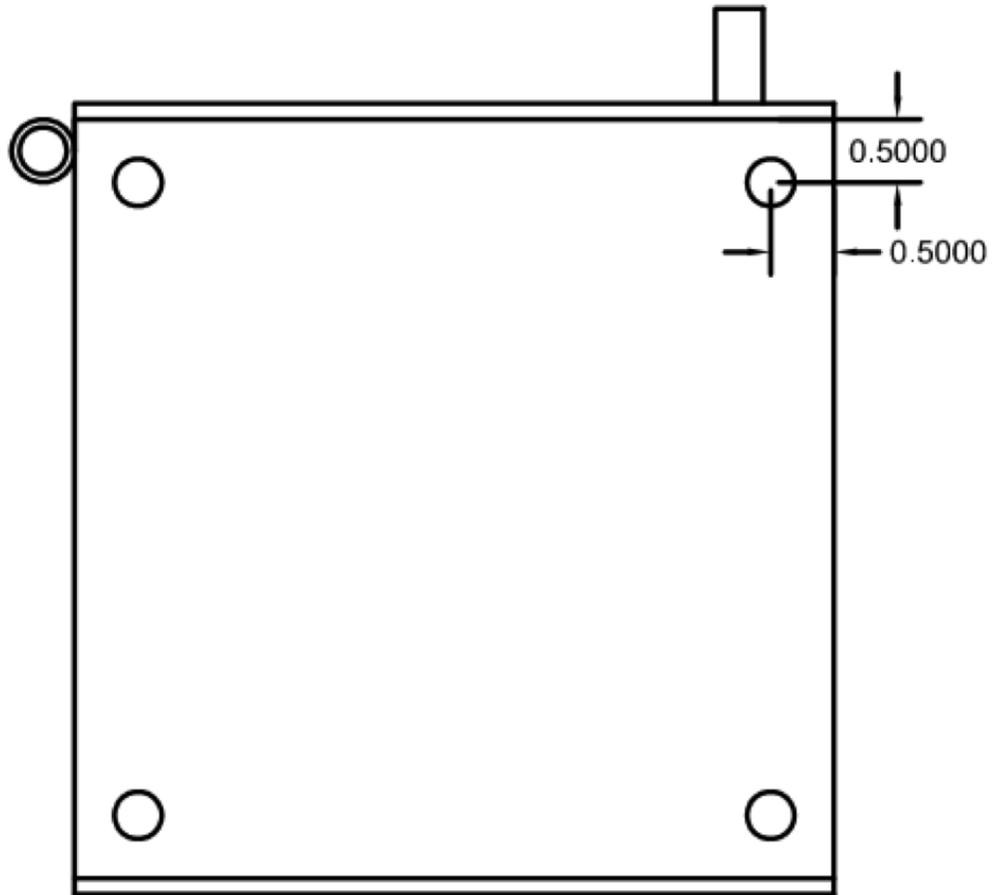
- Safe is square on both sides and within $\frac{1}{16}$ " of length
- Backing plate is within $\frac{1}{16}$ " on all sides, and four corners match the profile of safe body
- Backing plate welds have consistent penetrating bead on all four sides, with uniform width and thickness on all sides

- Hinge size is within $\frac{1}{16}$ " of length
- Hinge closes without squeaking or catching
- Hinge is welded correctly to allow door to open, and welds are secure and consistent in width and length
- Door lies flat against safe body
- Door size is within $\frac{1}{16}$ " on all sides, and four corners match profile of safe body
- All four feet thread in and out easily
- All four feet are within $\frac{1}{16}$ " of layout spots
- Door handle is within $\frac{1}{16}$ " of length, and is welded square and securely
- Both locking plates are welded square and securely, and lock holes line up
- Finish: all welds are ground down to blend into safe body; sanding is uniform on all sides; no deep file marks or holes left

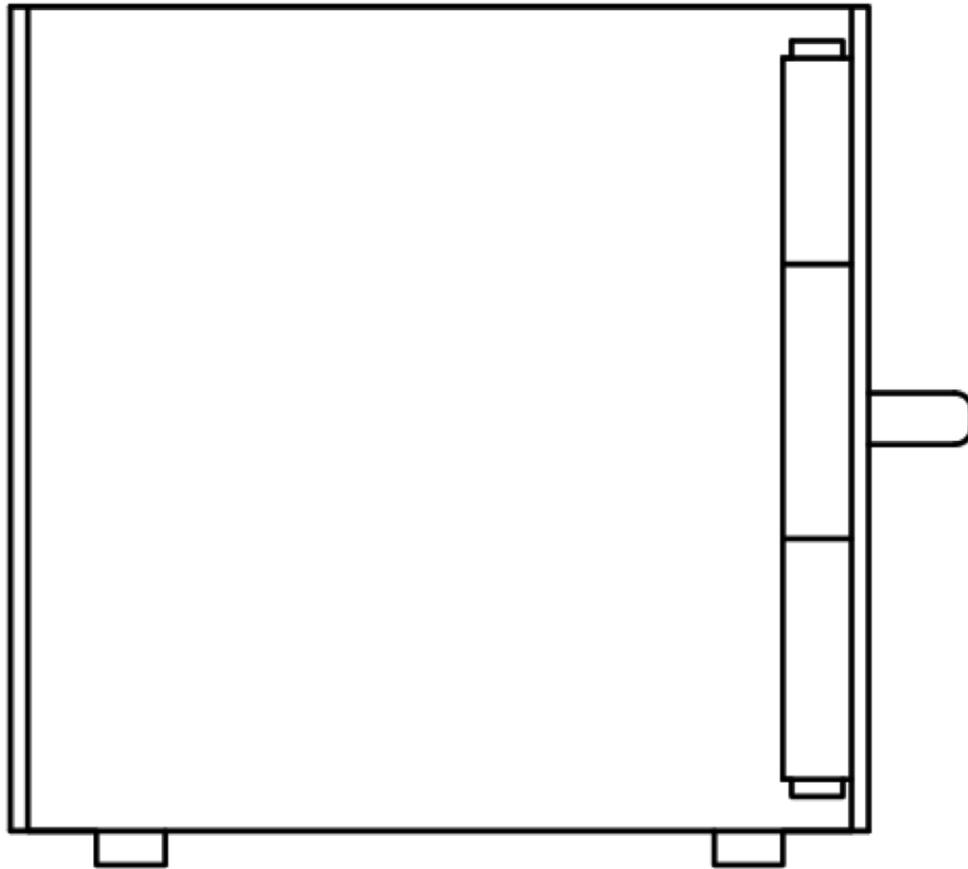
Optional Extension Activity

If time permits and the required equipment is available, students could be introduced to other types of joints or welding processes.

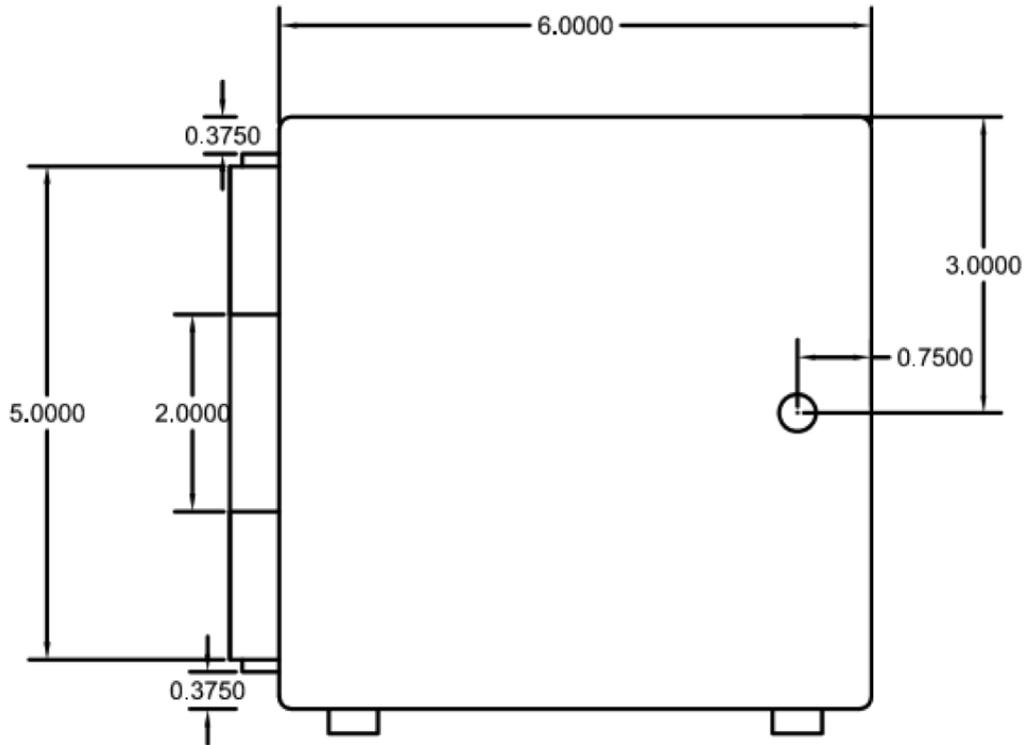
Safe bottom view – drill layout



Safe side view



Safe front view



Introduction to Machining

Description

Machining is the process of using cutting tools to remove some amount of a piece of material (metal, wood, plastics, ceramic, etc.) to precisely shape it for an intended use. This use of the physical action of cutting tools is also known as *subtractive manufacturing*.

The primary machines used in machining are the engine lathe (metal lathe), milling machine (both horizontal and, most typically, vertical), drill press, and abrasive grinders. These and other machines can be either manual or automated. Most automated machines have CNC (computer numerical control) and are capable of producing very intricate, precise, and complex parts with a high degree of repeatable accuracy for any number of applications.

Machinists are people trained in the operation of such machinery and processes. Machinists work in prototyping new parts, on production lines, and in repair and maintenance facilities. Machinists provide a necessary and vital service to all industries, from very large organizations such as Bombardier, NASA, and Boeing Corporation, to small, independent shops.

In this activity plan, students will learn what is meant by the term machining, be exposed to several machines and their uses and to trades related to machining.

Lesson Objectives

Students will be able to:

- Briefly describe the meaning of *machining*
- List and describe several machining-related trades
- Identify basic machining equipment by name and list some of the operations done on those pieces of equipment

Assumptions

The student will:

- Have an understanding of metals, forms and shapes of metals, and metallurgy
- Have at least a grade 9 numeracy level
- Know how to measure both in ISO and SAE systems using scales, Vernier calipers, height gauges, and micrometers
- Know the basic principles and methods of layout

Estimated Time

1–2 hours



Facilities

Senior secondary metal shop as per BC Technology Educators' Best Practices Guide

Recommended Number of Students

20, based on *BC Technology Educators' Best Practices Guide*

Personal Protective Equipment

- Welding coat
- Welding gloves
- Welding helmet

Tools

- Machine lathe with 3- and 4-jaw chucks
- Vertical milling machine
- Milling vise
- Horizontal mill*
- Gear head drill press
- Drill press vise
- Belt grinder
- Surface grinder*
- Indexing head*
- Rotary table*
- CNC mill/router/lathe*
- CNC plasma table*
- Tool post grinder*
- Boring head*
- Broaching kit*
- Taping head*
- Layout tools
- Measuring tools

* optional

Tooling

- Twist drills: straight, stepped, and MT shank; centre drills
- Mill bits: face mill, end mill, roughing mill, chamfer mill, fillet mill, radius mill, bullnose mill, taper mill, ball nose mill, woodruff/keying mill, planing mill, slotting mill, forming cutter, gear hob cutters
- Broaching kit
- Boring bars
- Hole saws

Terminology

Machine Lathe

Boring, reaming
Turning to a diameter
Facing off
Center drilling
Knurling
Parting off
Tapering
Filing, Sanding, Polishing
Threading (likely optional)

Vertical Milling Machine

Face milling
End milling
Slot milling
Boring head
Indexing head

Drill Press

Twist drills; fractional, metric, number, letter
Hole saws
Indexable carbide insert
Boring head
Boring
Reaming
Countersinking
Threading
Internal
External
Tap
Die

- Split die
- Button die
- Dienut
- Plug tap
- Taper tap
- Bottoming tap
- Tandem tap

Carbide tooling: tooling made of tungsten and carbide initially in a powdered form that is pressed into the desired shape and then sintered to fuse it together. Tungsten carbide tooling is much more heat resistant and much longer wearing than HSS and is formed into various cutting tool shapes such as endmills, drill bits, brazed lathe tool bits, and mountable inserts of many shapes for milling, drilling, and turning operations. The cost tends to be higher than equivalent HSS tooling. Such tooling may be coated in ceramics such as titanium nitride to improve wear and speed abilities.

Centre drill: a short, rigid drill used to locate holes for later drilling or holding on a centre in a lathe.

Face off: a process performed on a lathe in which irregularities on the face of an object are removed so that the face is at a 90-degree angle (right angle) to the object's sides.

Gear head drill press: a drill press in which rotational and downward forces cause the attached tooling to cut into the material being processed. The gear head allows for high-torque drilling operations with a variety of rotational speeds useful for cutting metals and other materials. The table may be slotted for holding materials and fixtures and movable in the x, y, and z planes.

HSS tooling: tooling made of carbon tool steel, often with alloying of tungsten and vanadium that resists tool edge breakdown due to heat caused by rapid motion. Found in endmills, drill bits, lathe tool bits, etc. Such tooling may be coated in ceramics such as titanium nitride to improve wear and speed abilities.

Machine lathe: a machine tool used to rotate and remove/shape material.

Surface grinder: a machine used for precision grinding of materials to accuracies up to about 0.0001". A horizontal spindle holds an abrasive wheel and a magnetic chuck holds the work piece.

Tap: hand tool used to create screw threads in metal. A tap makes an internal thread inside a hole (for example, a nut).

Die: hand tool used to create screw threads in metal. A die makes an external thread on a round rod (for example, a bolt).

Knurl: a process where a pattern of straight, crossed, or angled lines is cut or rolled into a metal surface, resulting in a series of small ridges or beads that aid in gripping

Chamfer: to cut away the (usually right-angled) corner or edge to make a sloping edge.

Vertical milling machine: a machine that uses rotating cutters to remove precise amounts of material as the material is fed into the cutter.

Materials

Mild steel and/or aluminum and/or bronze bar stock or heavy plate for machine demonstration purposes

Resources

Facing off on a lathe

<https://www.youtube.com/watch?v=5tXpKS3lfy0&noredirect=1>

Teacher-led Activity

The teacher will pre-set the machinery with tooling and stock to do a brief demonstration of a few processes on each machine. Carbide and HSS tooling, aluminum, and mild steel could be used to demonstrate material properties and tooling characteristics. Machining and related trades could be described during these demonstrations.

Students are to take notes. Key terminologies under a heading for each machine could be included in fill-in-the-blank formatted note sheets. Safety features and procedures should be stressed at each of these teaching stations.

Evaluation

Consider co-creating the evaluation criteria with your students at the beginning of the activity.

A short written quiz at the start of the second period could be used to evaluate student understanding, to review main ideas, and to maintain student focus on the subject. Students will have the opportunity to study and assimilate the material covered.

Have students build a study sheet from their notes (one side of one sheet of paper only, handwritten) and use this when writing their quiz.

Optional Extension Activity

The teacher could integrate the demonstrations with a pre-demonstration of the processes necessary to complete a future mandatory project.

Build a Cross Peen Hammer

Introduction

In this activity plan students will develop various machining and metalworking skills by building a two-piece steel hammer. This project will introduce basic operations for initial familiarization with lathe use, layout procedures, drill press operations, edge and face milling, and an oil or chemical blackening finish process.



Lesson Objectives

The student will be able to:

- Use a machine lathe to form tool cut, face off, centre drill, knurl, and file in a scrolling 3-jaw chuck, and facing in an independent 4-jaw chuck
- Lay out hole locations for drilling
- Use a drill press with a drill press vise to pilot drill and bore to a given nominal size
- Cut stock steel using a band saw
- Perform milling operations: face milling, edge milling, chamfer milling
- Perform an oil or chemical blackening finish process

Assumptions

The student will already know:

- Hand tool safety
- Measurement
- Basic layout techniques
- Names and usages of layout and hand tools



Terminology

End mill: a type of cutting tool different from a drill bit in that it can generally cut in all directions. An end mill creates a flat surface on the sides along the same axis as the spindle.

Face off: a process performed on a lathe in which irregularities on the face of an object are removed so that the face is at a 90-degree angle (right angle) to the object's sides.

Face mill: a cutting tool with blades along the bottom or sides; used to shape the face of an object.

HRMS: Hot rolled mild steel made by a process which involves rolling the steel at a high temperature (typically at a temperature over 1700° F), which is above the steel's recrystallization temperature.

HSS tooling: High-speed steel tooling made of carbon tool steel, often with alloying of tungsten and vanadium, that resists tool edge breakdown due to heat caused by rapid motion. It is found in endmills, drill bits, lathe tool bits, etc. Such tooling may be coated in ceramics such as titanium nitride to improve wear and speed abilities.

Knurl: small ridges or bumps on a metal surface to help grip the object. Also used to describe the act of cutting knurls.

Live centre: a part of a lathe that holds and revolves with the work piece. Usually refers to the headstock centre.

Tailstock: the movable part of a lathe that supports the dead centre.

Estimated Time

7 hours

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Metal shop as per the *BC Technology Educators' Best Practices Guide*

Tools and Equipment

- Drill bits: bell end centre drills with $\frac{5}{16}$ " body, $\frac{1}{8}$ " tip
- HSS twist drills: $\frac{3}{16}$ ", $\frac{13}{32}$ ", $\frac{27}{64}$ "
- Taper or plug tap: $\frac{1}{2}$ -13NC
- Split die: $\frac{1}{2}$ -13NC
- Layout tools, including height gauge, centre punch, scribe, dividers, layout dye, layout hammer

- Hacksaw, bench vise, flat file, mill file, de-burring tool
- Drill press
- Machine lathe, knurling head, LH tool holder/bit, 3- and 4-jaw chuck
- Belt machine with 60 g and 120 g belts
- Vertical milling machine with tooling: 2"+ facing mill, $\frac{3}{4}$ "+ end mill, chamfering mill (optional)
- T-slot clamping kit for milling machine

Materials

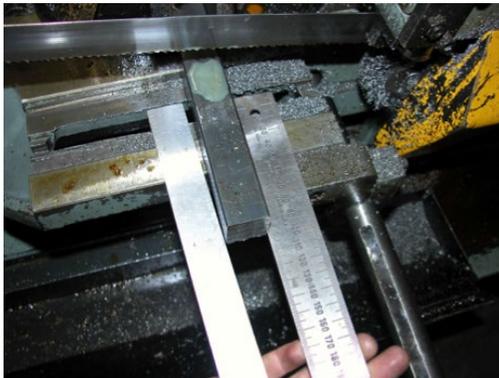
- Head: 1" × 1" square 1018 HRMS, 100 mm (4") long piece per hammerhead
- Handle: $\frac{7}{8}$ " diameter 1018 HRMS, 250 mm (10½") long piece per hammer handle
- Securing pin: $\frac{3}{16}$ " × 1" roll pin
- Chemical blackening kit or oxy-fuel torch and used motor oil
- Tapping fluid, threading lubricant

Teacher-Led Activity

Demonstrate the following steps to fabricate a cross peen hammer. Students will then each make their own hammer.

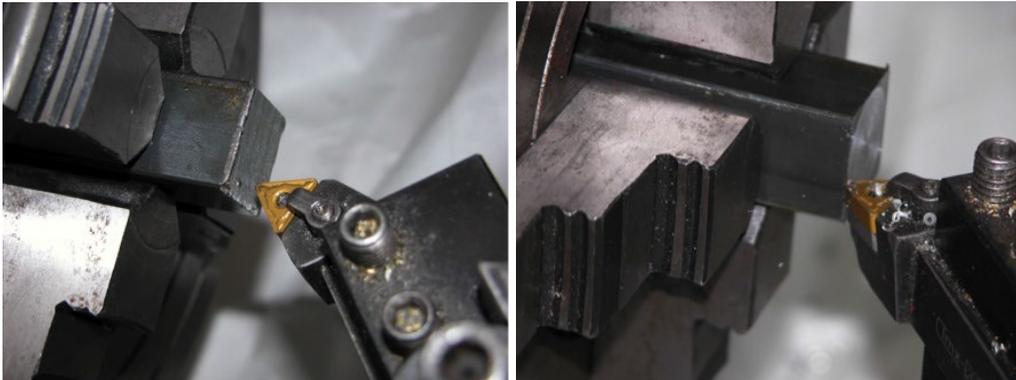
Hammerhead

1. Cut 1" × 1" square 1018 HRMS over length by 3 mm ($\frac{1}{8}$ ") to 103 mm or 4 $\frac{1}{8}$ " long on band saw.



2. Face one end flat on lathe. Tool bit should be on centre and 90 degrees to the direction of travel. Centre stock within 2 mm in a 4-jaw chuck.

Caution: Turn only at maximum manufacturer's recommended speed for their 4-jaw chuck. This is approximately 400 rpm if using HSS tooling or 900 rpm if using carbide tooling. Calculate rotational speed using the formula of $4 \times \text{cutting speed (100 for mild steel)}/\text{diameter}$ in inches of the cutting circle (outer diameter of the cutting tool).



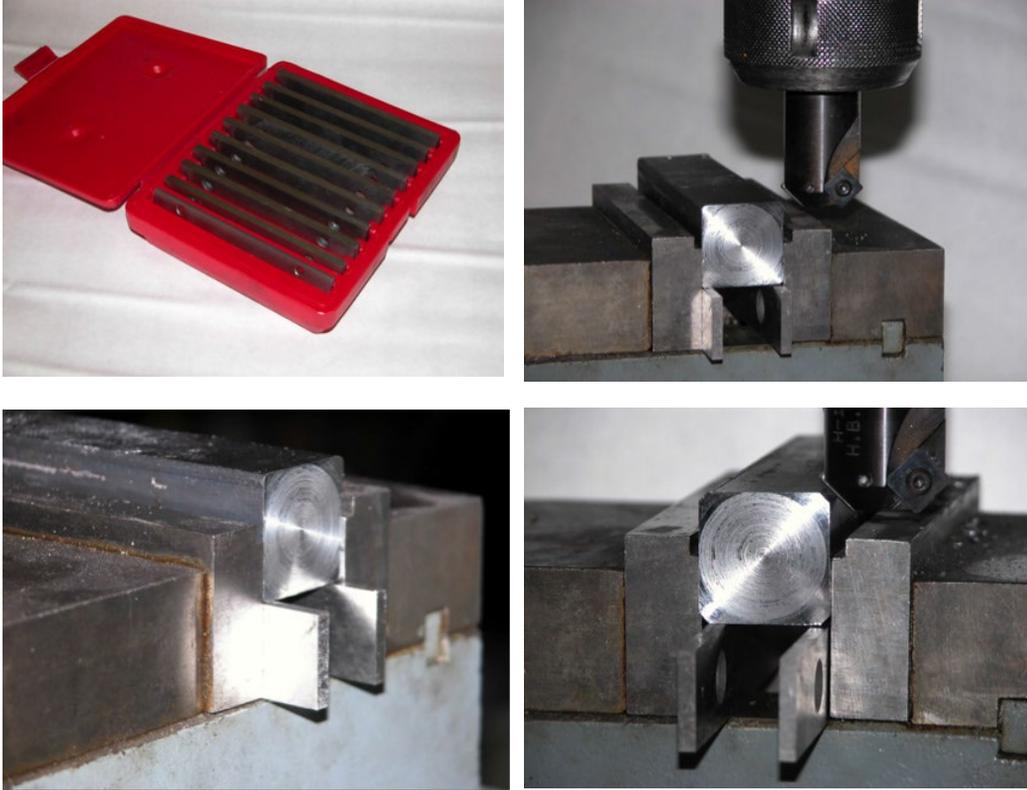
3. Measure and mark height at 100 mm or 4" on layout table using a height gauge.



Then face the opposite end to approximate final length using lathe.

4. Mount in a milling vise using parallels to support and place the block.

Chamfer, approximately 1 mm wide and 45 degrees, all four longitudinal edges of the block using a chamfering mill or a flat file.



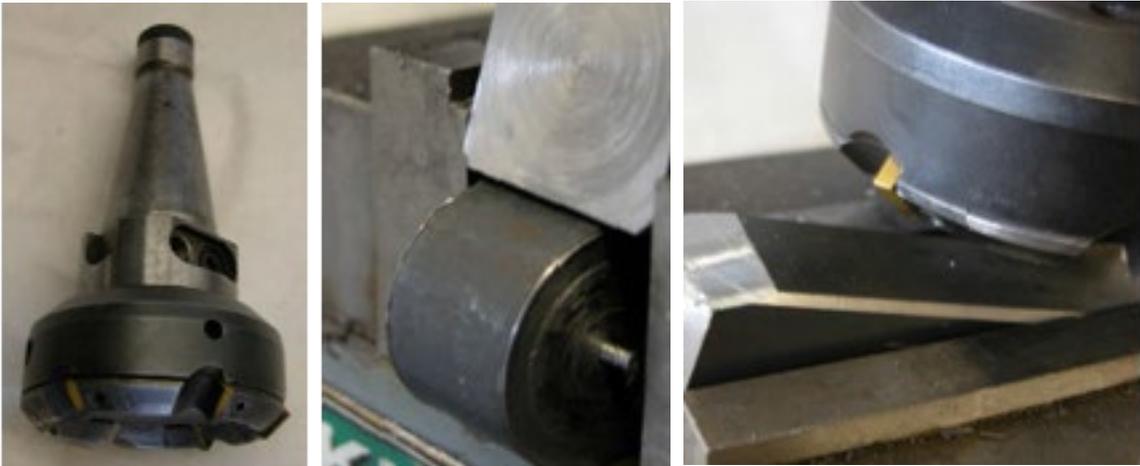
Then chamfer **one end only** of the block, all four edges. Part may be held in stepped jaws as shown or set using parallels as above.



- 5. Re-mount hammerhead in a milling vise using a 1" jacking block to set a taper of 1:4 ratio or about 14.5 degrees. Change tooling to a facing mill. Reset spindle speed to suit tooling size and type of cutting material (HSS or carbide).

Calculate rotational speed using the formula of $4 \times \text{cutting speed (100 for mild steel)} / \text{diameter in inches of the cutting circle (outer diameter of the cutting tool)}$.

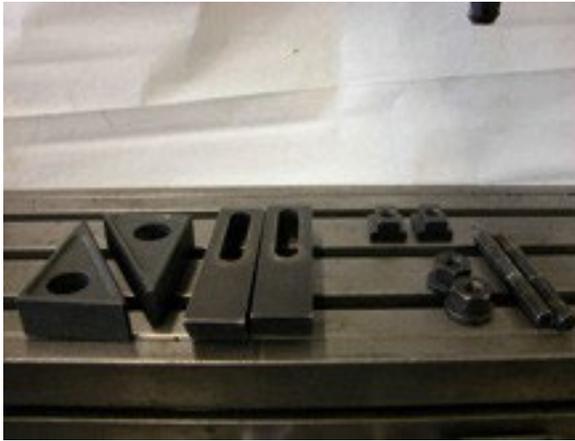
Take multiple cuts of 1–2 mm depth using a feed speed up to 200–250 mm/min., depending on facing mill. Calculate using $\text{rotational speed} \times \text{number of teeth} \times 0.025 \text{ mm} = \text{mm/minute feed rate}$.



- 6. Remove hammerhead from vise and de-burr edges using a flat file.



7. Side mill cross peen end to 30 degrees (option: grind and file to 30 degrees). Use a $\frac{3}{4}$ " or larger 4-flute end mill. Hold down hammerhead to bed using a clamp kit as shown.
Note: Set the mill's rotational speed appropriately to the end-mill diameter and material type being used.



Clamp kit including T nuts, flare nuts, studs, clamps, and jacks 1"



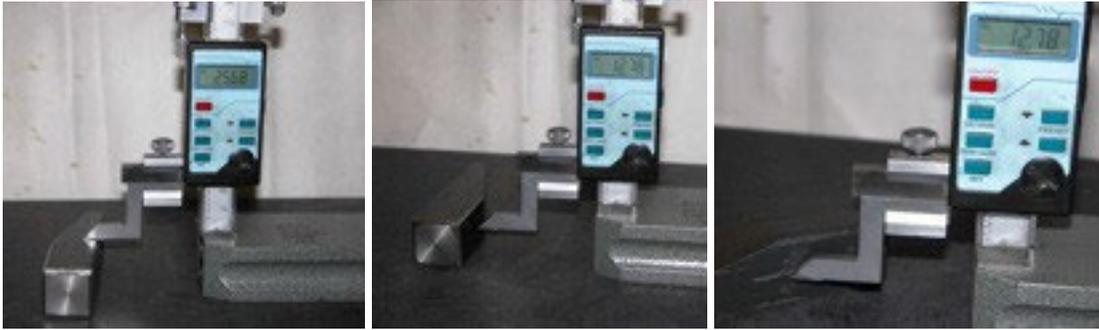
4-flute end mill



8. Zero cross y axis dial when material touches overhanging end of hammerhead. Cut 2 mm off of end at a 30-degree angle. Flip the head over and repeat on the other side.



9. Lay out head for drilling holes:



Measure height of block and then divide by 2 and mark centre lines down each side.

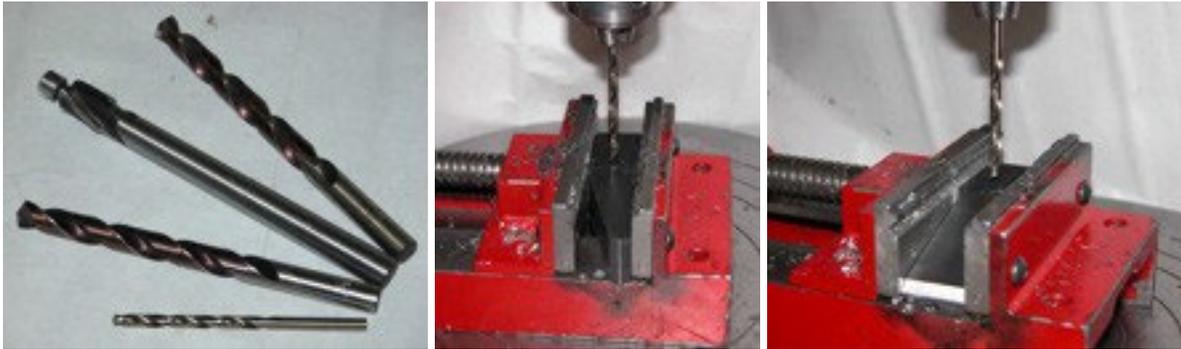


Measure 38 mm up from square end and mark, then an additional 6.5 mm up from there and mark again.



Centre-punch handle hole and retainer pin hole 6.5 mm offset from handle hole.

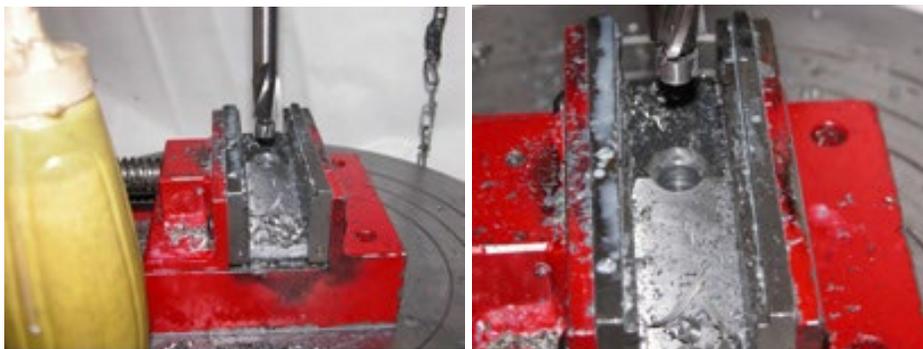
10. Pilot drill both the handle hole and retainer pin hole through, using a 3/16" twist drill.



11. Re-drill handle hole using a 13/32" twist drill through.



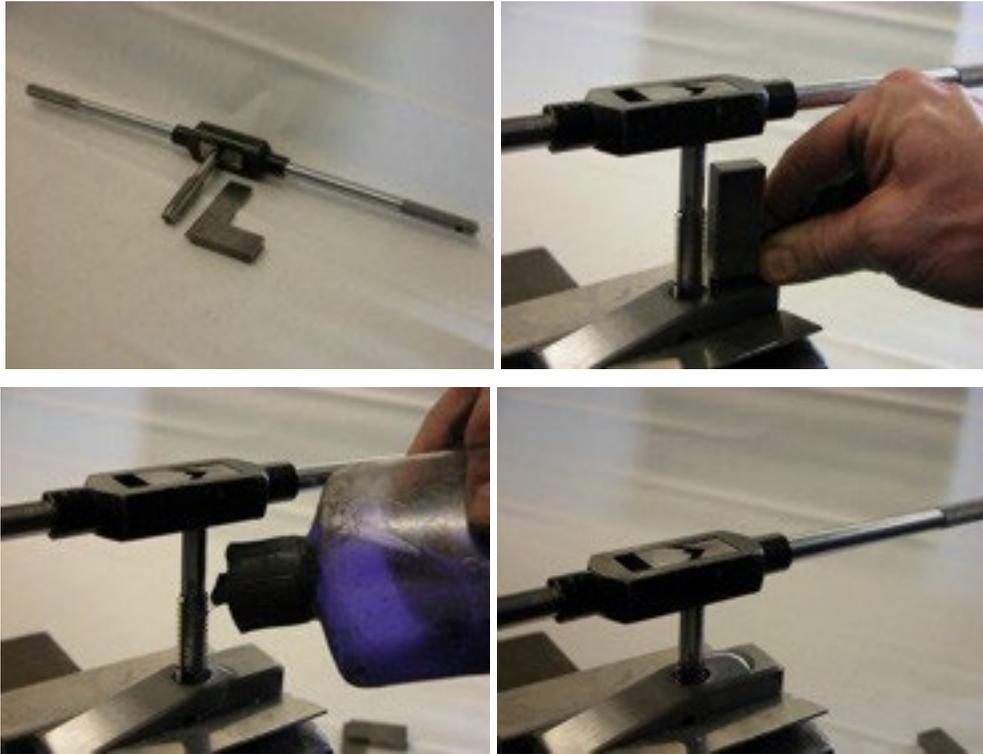
12. Counter-bore using a 3/8" CB, 3 mm deep.



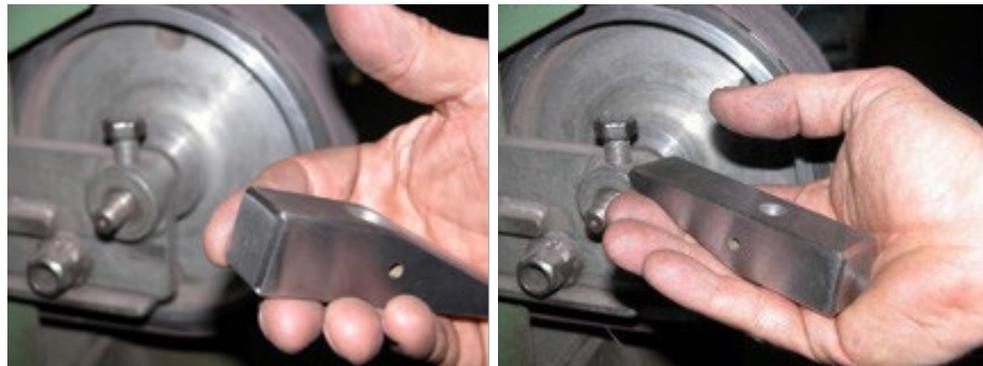
13. Re-drill handle hole to tap drill size for a 1/2-13NC internal thread (27/64").



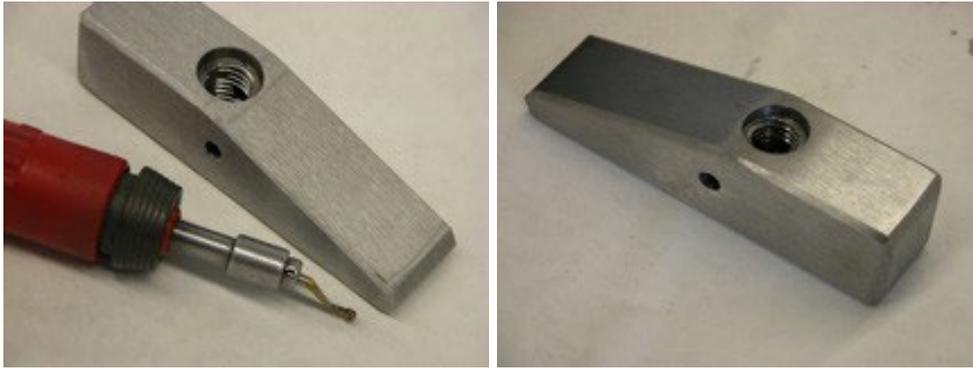
14. Using a 12-13NC tap, thread 27/64" hole through the head. Check to ensure that the tap is square to the hole throughout the process. Use appropriate tapping fluid.



15. Clean up faces then edges on a surface grinder or on a belt grinder using 120 g belt to finish all surfaces.



16. De-burr all holes using a countersink or a de-burring tool.



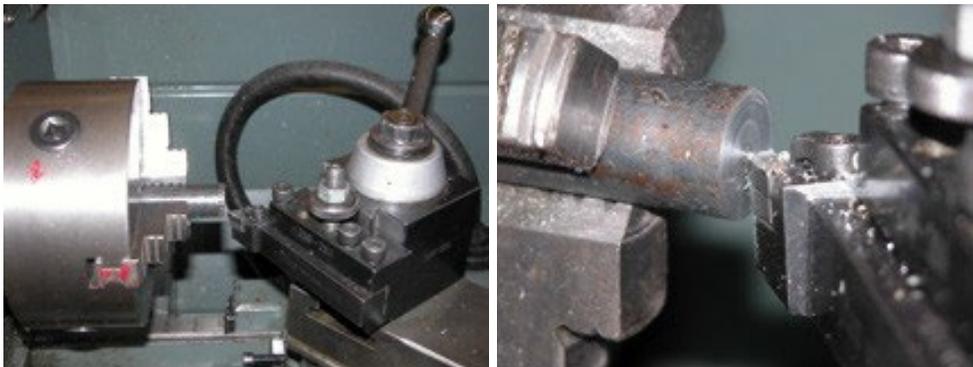
Hammer handle

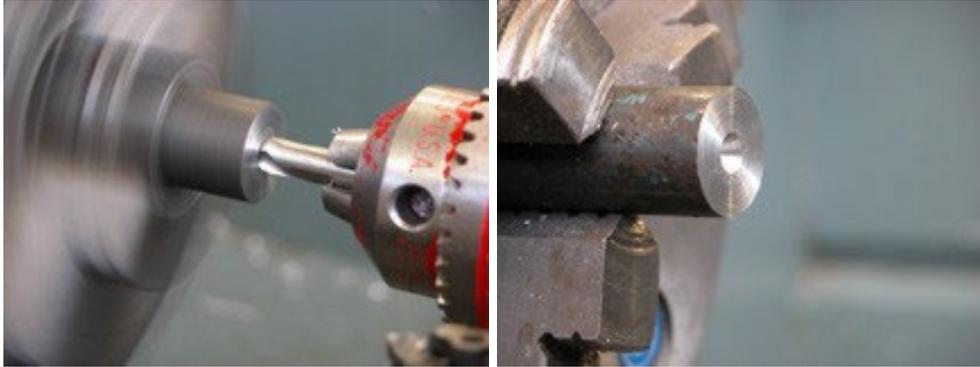
1. Cut $\frac{7}{8}$ diameter \times 245 mm piece of round stock on band saw.



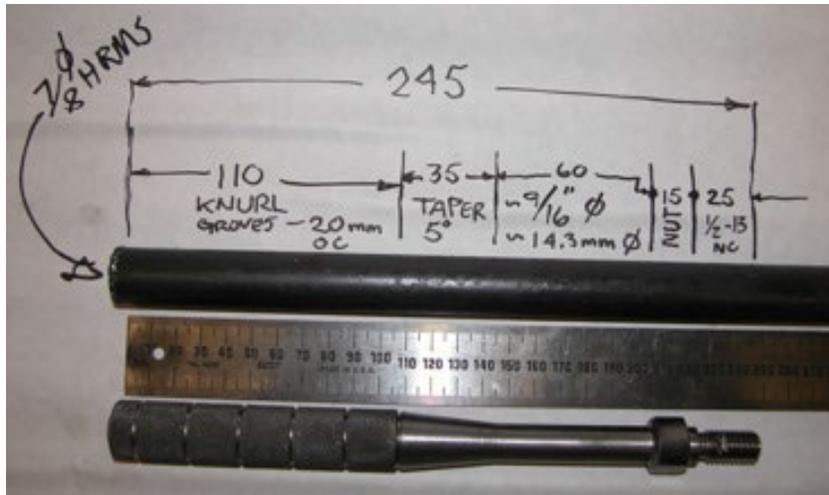
2. Using a lathe, calculate and set spindle speed to minimally face off both ends of the handle and then centre-drill to the base of the cone, but no deeper.

Lathe spindle speed should be calculated for a $\frac{5}{16}$ " bell centre-drill and be at least 1200 rpm.

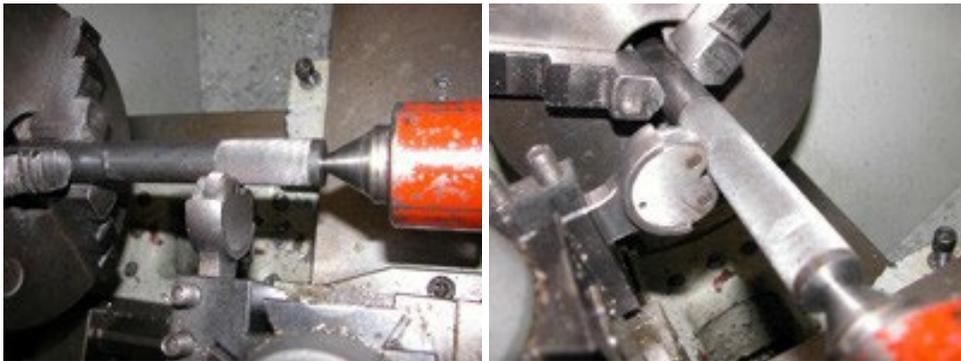


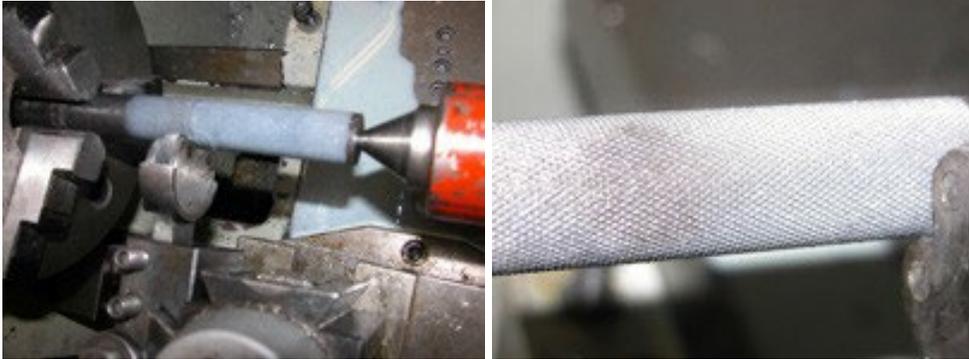


3. Lay out the lines on handle stock according to sketch. All transition points should be clearly marked on the handle.

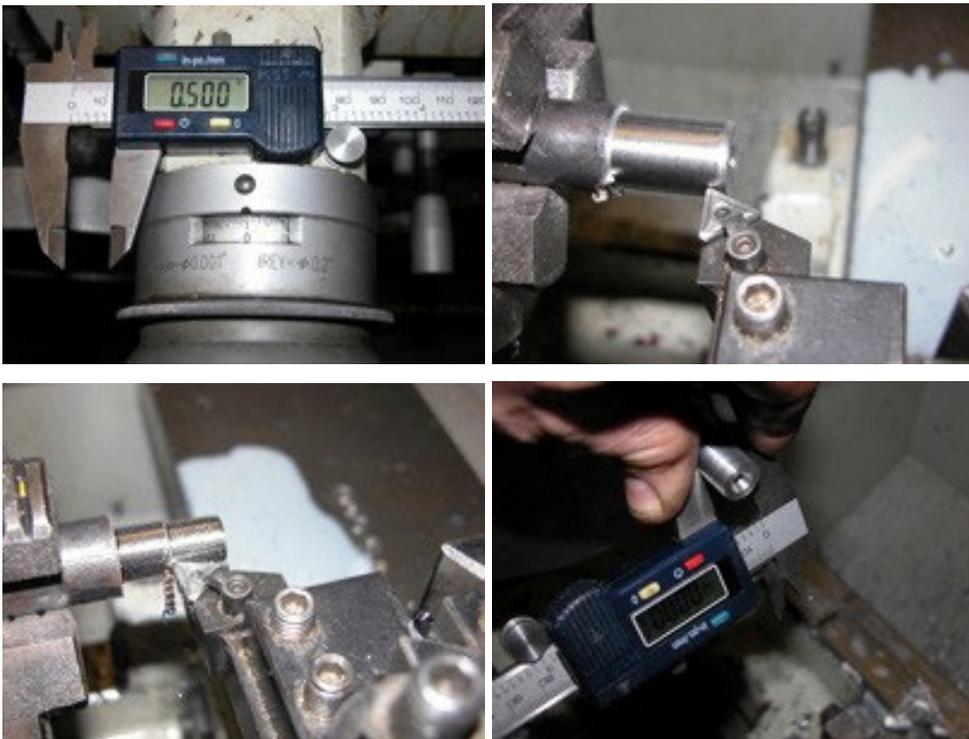


4. Knurl using a medium or coarse set of knurling wheels. Knurling head must be 90 degrees to the work and on centre. Use a coolant to clean, cool, and lubricate the knurling head.





5. Turn handle stock to 0.500 ± 0.005 " diameter \times 25 mm long.



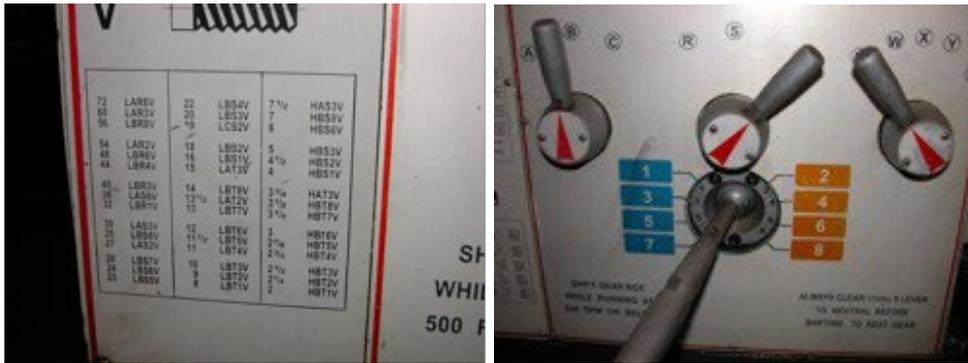
6. External threading of spindle

Machine cut process using a lathe:

a. Set compound slide to 60 degrees.



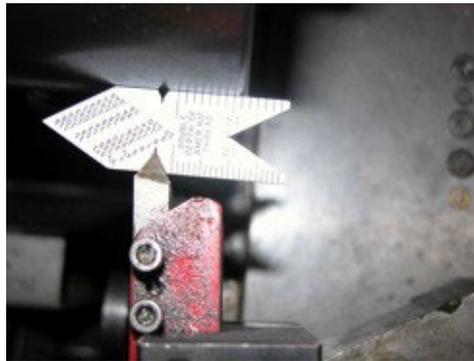
b. Set quick change gear box to 13 threads per inch (TPI). LBT7V is the setting below.



c. Set spindle speed to 200 or lower.

d. Secure work piece in the lathe. Allow about 50 mm protrusion from the 3-jaw chuck.

e. Set a 60-degree threading bit on centre and correctly angled to the work piece.



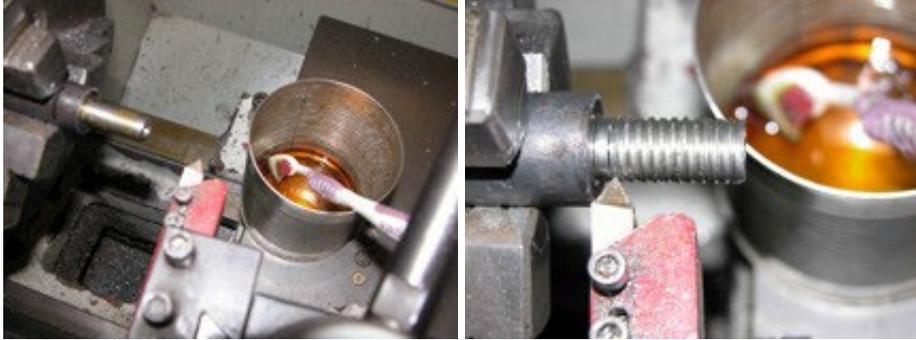
f. Test cut to confirm 13 TPI settings.

g. Zero both cross feed dial and compound slide dial with tip of bit touching the work piece.



h. Make cuts engaging threading dial only at No. 1 position for a 13 TPI cut or according to the lathe manufacturer's instructions.

- i. Apply a heavy duty cutting fluid to work piece. Make successive cuts beginning with a 0.020" depth and advancing with 0.005" depth of cuts, always advancing only with the compound slide.



- j. Continue successive cuts until to double depth calculation of approximately 0.100" is obtained.
- k. A clean-up pass using a ½-13NC split die with threading lubricant can be used to obtain a final fit. Check that the head threads onto the handle with minimal interference.



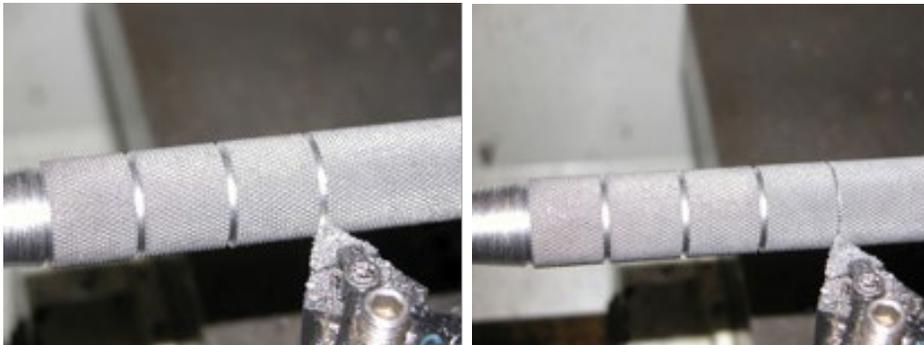
7. Turn a shoulder to $0.600" \pm 0.005"$ × 3 mm wide at end of thread so that the hammer handle threads into the counter bore.



- Cutting the taper at the knurl termination point: Set compound slide at -5 degrees. Support the handle with a live centre mounted in the tailstock. Calculate and set the turning speed appropriately. Cut the taper down until the minor diameter is about 0.570 ". Finish turning the remaining handle section from end of taper to the nut boss at 0.563 " \pm 0.005 ".



- Lay out with dividers or using the lathe carriage wheel dial. Cut 0.020 " deep grooves at 20 mm centres beginning at the top of the taper and moving toward the lathe's tailstock. Set the tool bit symmetrically so that the angle is the same on either side of the bit.



10. Chamfer end of handle at 45–60-degree angle.



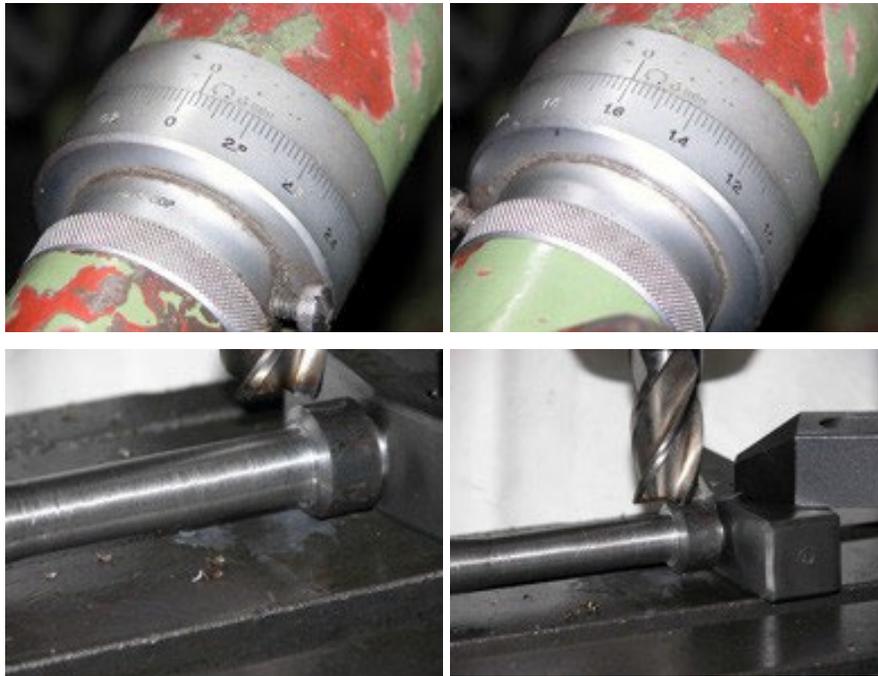
11. Chamfer each side of the nut boss. Support part using tailstock and live centre.



12. Tightly attach hammerhead to handle stock and clamp 90 degrees to edge of mill bed. Use a scrap of 0.060 (16 g) aluminum sheet to shim the underside of the handle and to pad the clamp on the knurl.

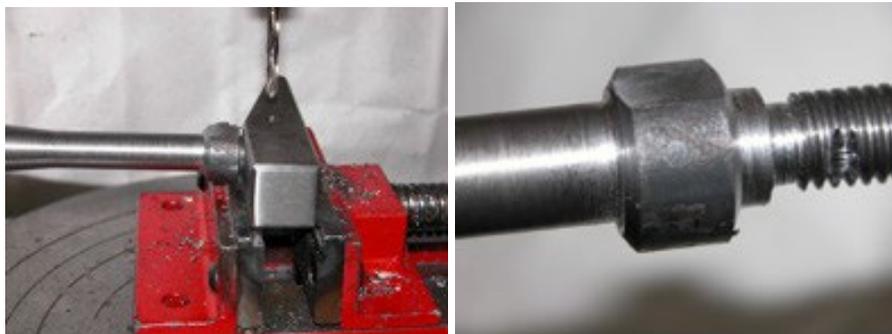


13. Touch the end mill to the top of the nut boss, then zero the knee height adjusting dial. Lock the x axis of the mill bed, provide clearance between the end mill and the nut boss, and raise the knee by 1.6 mm.



14. Flip head over and repeat milling operation to form a nut that measures $\frac{3}{4}$ " across the flats.

15. Clamp in drill press and drill $\frac{3}{16}$ " hole through the head with handle in place for the retaining roll pin ($\frac{3}{16} \times 1.00$).



16. De-burr edges of nut and check fit with $\frac{3}{4}$ " wrench.



17. Wire wheel or bead blast all parts clean in preparation for finishing.



18. Parts may be oil blackened or chemically blackened (blueing).

- a. Oil process: Heat parts to black hot (very dull cherry red) using an oxyacetylene torch, then quench in used diesel engine oil, drip dry, wipe off residue, and wash with detergent soap.



- b. Chemical blueing: Follow manufacturer's recommended application process. Brush on solution, wait one or two minutes, rinse, dry off parts, apply sealer coats as specified.



Assembly

1. Thread head together with handle and tighten as before. Nut flats should parallel the sides of the head.
2. Insert roll pin and tap in place using a layout hammer.

Evaluation

Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Overall size and shape
- Hole placement, sizing, and alignment
- Head taper and 30-degree bevels
- Knurl quality: consistent diamond pattern
- Handle taper and finished diameters
- Handle groove spacing and depth
- Nut alignment, shape, finish quality
- Prefinish: filing and sanding removal of all tool marks
- Finishing: even lustre

Build an Aluminum Whistle

Description

In this activity plan the students will further develop their machining and metalworking skills by fabricating a two-piece aluminum whistle. The project will cover basic lathe operations, layout procedures, drill press operations, and a polished finish process.



Lesson Objectives

The student will be able to:

- Use a machine lathe to form, tool cut, face off, centre-drill, bore, ream, knurl, file, and sand aluminum in a scrolling 3-jaw chuck
- Lay out hole locations for drilling
- Use a drill press with a drill press vise to pilot drill and bore to a given nominal size
- Cut stock aluminum longitudinally in a bench vise and cross cut in a vise
- Use a vise to press-fit parts together
- File, sand, and buff the whistle to a polished finish

Assumptions

The student will already know:

- Hand tool safety
- Measurement
- Basic layout techniques
- Names and usages of layout and hand tools



Terminology

Knurl: small ridges or bumps on a metal surface to help grip the object. Also used to describe the act of cutting knurls.

Peck cycle drilling: a method of drilling in which the bit is periodically retracted a short distance to clear chips from its flutes.

Reamer: a rotary cutting tool used to enlarge a previously cut hole to a high precision.

Estimated Time

2.5 5 hours

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Metal shop as per the *BC Technology Educators' Best Practices Guide*

Tools and Equipment

- Drill bits: bell end centre drills, $\frac{5}{16}$ " body, $\frac{1}{8}$ " tip
- HSS twist drills: $\frac{1}{8}$ ", $\frac{1}{4}$ ", $1\frac{1}{32}$ "
- $\frac{3}{8}$ " chucking reamer
- HSS blank to grind forming tool
- Layout tools, including height gauge, centre punch, scribe, dividers, layout dye, layout hammer
- Hacksaw
- Bench vise
- Flat file and mill file
- De-burring tool
- Drill press
- Machine lathe with knurling head and custom HSS forming tool, LH tool holder/bit
- Belt machine with 60 g and 220 g belts
- Buffing machine and black or brown buffing compound

Materials

Note: Materials are sourced in SAE dimensions for ease and economy.

- Body: $\frac{1}{2}$ " diameter 6061 T6 aluminum or similar alloy, 75 mm (3") long piece per whistle
- Fipple (reed): $\frac{3}{8}$ " diameter 6061 T6 aluminum or similar alloy, 18 mm ($\frac{3}{4}$ ") long piece per whistle

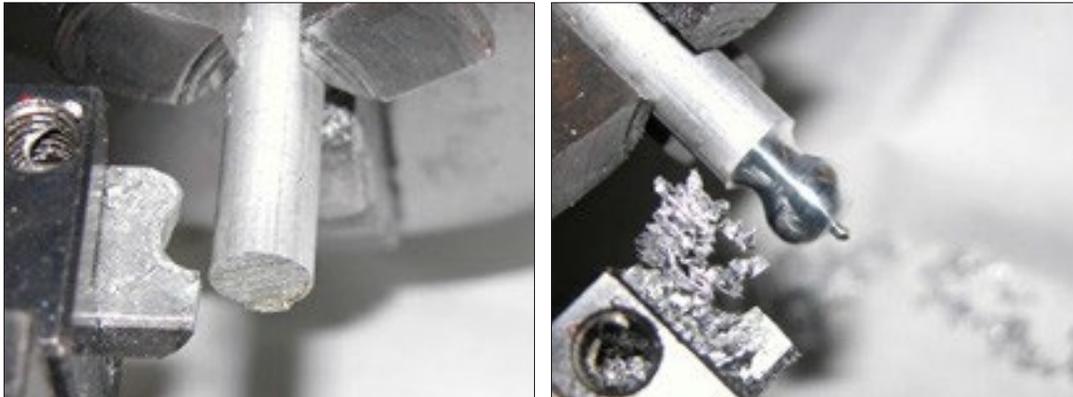
Teacher-Led Activity

Whistle Body

1. Cut body to 75 mm length using hacksaw or band saw.



2. Form one end round in lathe using HSS forming tool.



3. Centre-drill end opposite ball end.



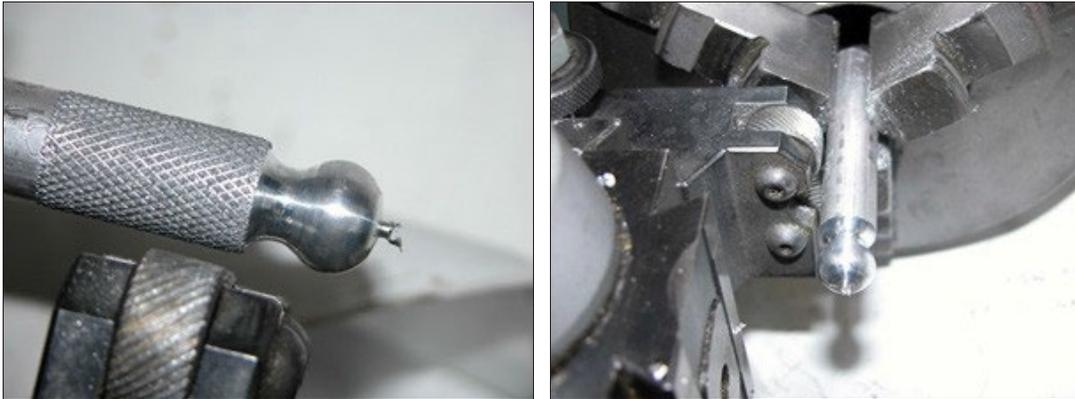
Then peck cycle drill $1\frac{1}{32}$ " x 50 mm (2") deep @ approx. 1200 rpm.



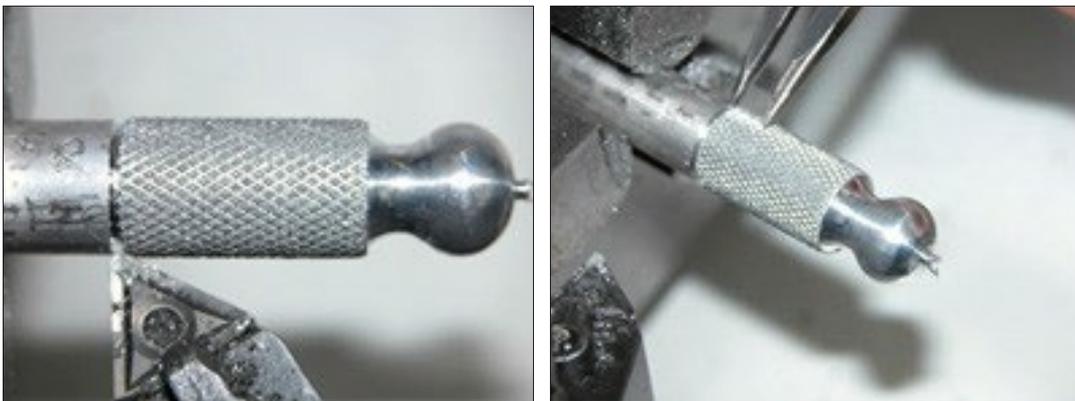
4. Ream $\frac{3}{8}$ " x 25 mm (1") deep @ approx. 300 rpm.



5. Knurl using medium or fine wheels approx. 25 mm along body from ball end.



6. Cut three grooves in knurl at even intervals.



7. File (use lathe file), then sand (320 g) non-knurled section of body.



8. Lay out for holes:

Spray with layout dye.



Establish centre line.





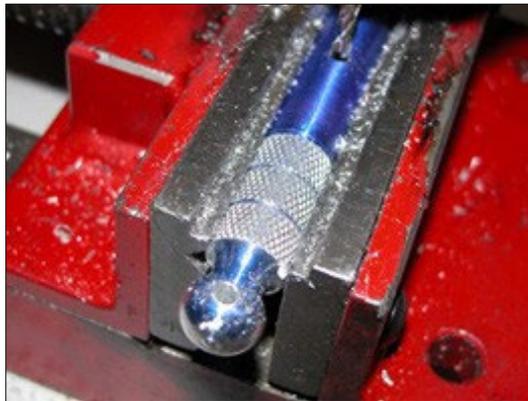
Mark off heights 18 mm from flat end and 6–7 mm from ball end.



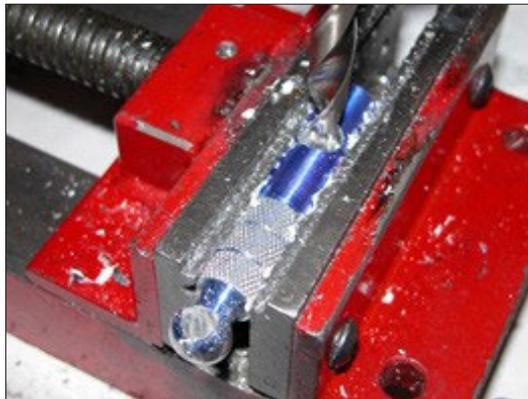
9. Centre-punch at the two scribe intersections.



10. Drill $\frac{1}{8}$ " pilot holes.

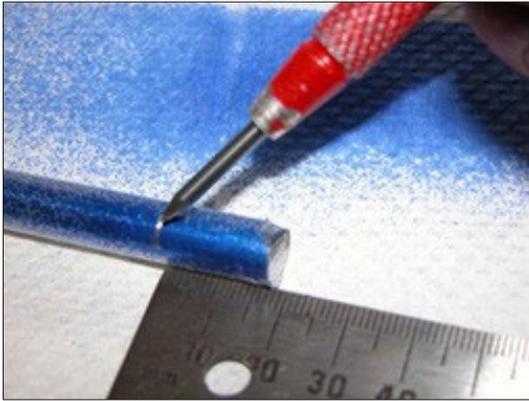


11. Drill ball end $\frac{1}{4}$ " through ball and $1\frac{1}{32}$ " through top side of body only.

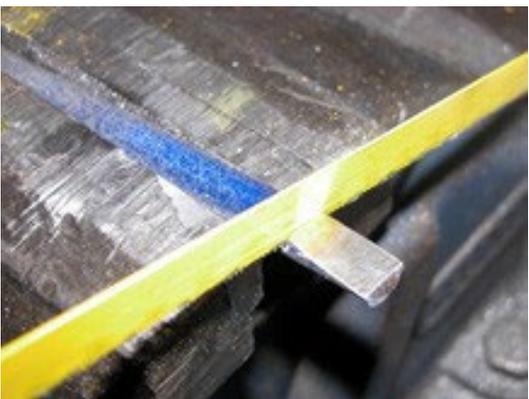


Reed/Fipple

1. Lay out dye 1/8" aluminum stock material and mark at 18 mm. Hold in vise and hacksaw angularly from 1/2 to 3/4 of its diameter over an 18 mm length, removing a wedge-shaped piece.

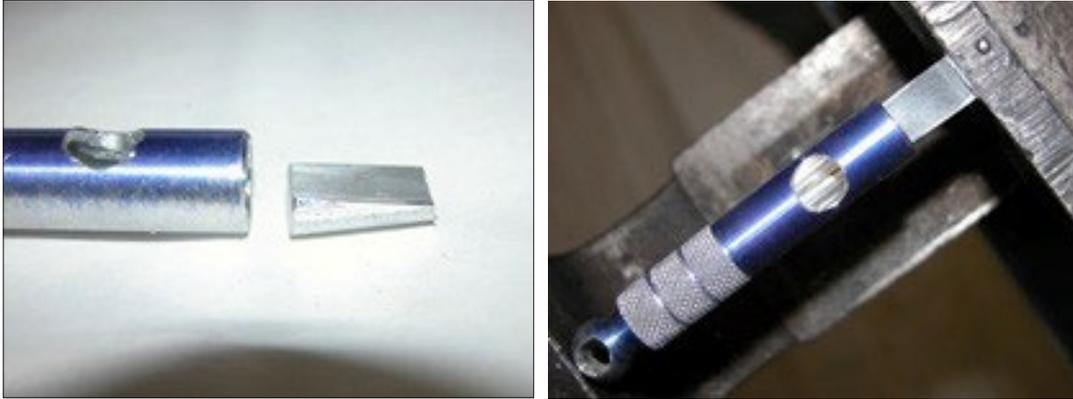


2. File smooth and flat. Cut off to length. File thicker end smooth with sharp edge and then slightly chamfer end.



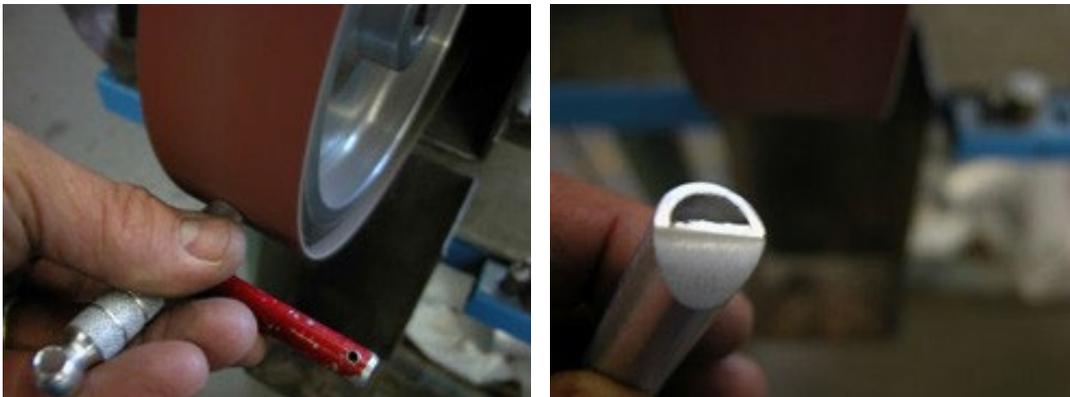
Assembly

1. Ensure that all holes in whistle body have been de-burred inside and out. Using a bench vise, press-fit thick end of fipple into body as far as edge of tone hole. Fipple is perpendicular to the drilled hole.

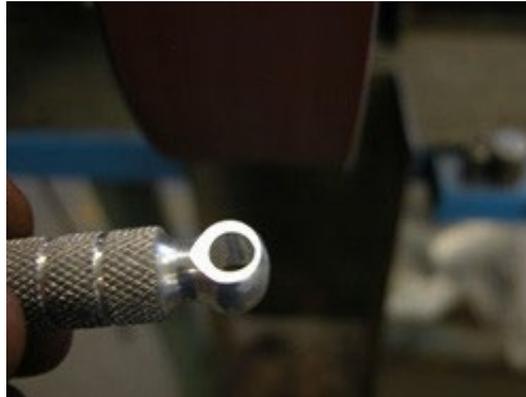


Finishing

1. Belt grind or file fipple flush with end and then taper end at about 45 degrees parallel with the flat of the fipple.



2. De-burr fipple end and lightly chamfer outer edges. Slightly grind ball end flat at hole ends and de-burr hole.



3. Buff all areas of body to high lustre except knurled section. Clean with toothbrush and solvent then with soapy hot water. Pat dry.



Finished whistle



Evaluation

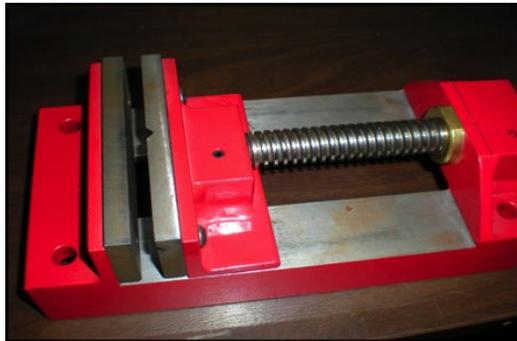
Consider co-creating the evaluation criteria with your students at the beginning of the activity/project. You may want to include the following:

- Overall size and shape
- Hole placement, sizing, and alignment
- Formed end size/shape
- Knurl quality
- Groove spacing and depth
- Fipple alignment, shape, finish quality
- Prefinish: filing and sanding, removal of all tool marks
- Buffing: all sanding marks removed; even lustre

Build a Drill Press Vice

Introduction

This activity plan will develop the student's machining and metalworking skills as they fabricate a multi-piece steel vise. The project will encompass basic lathe operations, layout procedures, drill press operations, slot milling and face milling, and oil or chemical blackening finish painting or powder-coat finishing process. The student will also perform GMAW welding.



Lesson Objectives

The student will be able to:

- Use a machine lathe to face off, centre drill, cut threads, knurl, turn to diameter, and file in a scrolling 3-jaw chuck, and do facing, boring, and reaming in an independent 4- jaw chuck
- Lay out hole locations for drilling
- Use a drill press with a drill press vise to pilot drill, bore, and ream to a given nominal size
- Cut stock steel using a band saw
- Use a milling machine to face mill, slot mill, and perform combined use of indexing head and end milling
- Complete oil or chemical blackening, painting, or powder coating finish processes
- V-groove, tack weld, and fillet weld the frame components using the GMAW process

Assumptions

The student will already know:

- Hand tool safety
- Measurement
- Basic layout techniques
- Names and usages of layout and hand tools
- Basic GMAW technique



Terminology

End mill: a type of cutting tool different from a drill bit in that it can generally cut in all directions. An end mill creates a flat surface on the sides along the same axis as the spindle.

Face off: a process performed on a lathe in which irregularities on the face of an object are removed so that the face is at a 90-degree angle (right angle) to the object's sides.

Face mill: a cutting tool with blades along the bottom or sides, used to shape the face of an object.

Knurl: a process where a pattern of straight, crossed, or angled lines is cut or rolled into a metal surface, resulting in a series of small ridges or beads that aid in gripping

Live centre: a part of a lathe that holds and revolves with the work piece. Usually refers to the headstock centre.

Reamer: a rotary cutting tool used to enlarge a previously cut hole to a high precision.

Swarf: metal debris left as a result of a machining operation.

Tailstock: the movable part of a lathe that supports the dead centre.

V-groove: a type of butt joint in which the edges of two pieces of metal are both cut at an angle and form a V-shaped groove when they are placed together.

Estimated Time

25 hours

Recommended Number of Students

20, based on the *BC Technology Educators' Best Practices Guide*

Facilities

Metal shop as per the *BC Technology Educators' Best Practices Guide*

Tools and Equipment

- Drill bits: bell end centre drills with $\frac{5}{16}$ " body, $\frac{1}{8}$ " tip
- HSS twist drills: $\frac{3}{16}$ ", $\frac{15}{32}$ ", $\frac{7}{32}$ ", $\frac{21}{32}$ ", $\frac{39}{64}$ "
- $\frac{1}{4}$ " transfer punch
- Taps: $\frac{1}{4}$ -28NF plug tap, $\frac{3}{4}$ "-6 Acme tandem tap or $\frac{3}{4}$ "-10NC plug tap
- Layout tools, including height gauge, centre punch, scribe, dividers, layout dye, layout hammer
- Hacksaw, bench vise, flat file, mill file, de-burring tool, cold chisel
- Drill press

- Chucking reamers: $\frac{1}{2}$ ", 1"
- Machine lathe, knurling head, LH tool holder/bit, 3- and 4-jaw chucks, $\frac{3}{8}$ " square tool bit
- Acme threading gauge
- Belt machine with 60 g and 120 g belts
- Vertical milling machine with tooling: 2"+facing mill, $\frac{3}{4}$ "+ end mill, indexing head
- T-slot clamping kit for milling machine
- Bench grinder, wire wheel
- Chemical blackening kit or oxy-fuel torch and used motor oil
- Paint or powder-coating equipment

Materials

Note: All parts can be pre-cut except the bronze bushing and jaw spacer plate.

Frame

- 2 – $1.5 \times 1.5 \times \frac{1}{4} \times 9$ " angle iron (rails)
- 3 – $1.5 \times 1.5 \times \frac{1}{4} \times 4.5$ " angle iron
- 1 – $1 \times 1 \times 2$ " solid (jaw block)
- 1 – $1.25 \times 1.25 \times 2$ " solid (nut block)
- 1 – $1.5 \times \frac{1}{4} \times 2.5$ " flat bar (jaw retainer)
- 1 – $1.5 \times \frac{1}{4} \times 1.6$ " approx. (jaw spacer)
- Spindle: 1 – $\frac{3}{4} \times 13$ " round
- Bronze nut: 1 – $1\frac{1}{4} \times 2$ " cast silicon bronze
- Jaws: 2 – $1\frac{1}{2} \times \frac{3}{8} \times 4\frac{5}{8}$ " flat bar – MS or aluminum

Fasteners

- 1 – $\frac{3}{16} \times \frac{3}{4}$ " RH plain rivet
- $\frac{3}{16} \times 1$ " split roll pin
- 2 – $\frac{1}{4}$ "-28 \times 1" socket head bolts with $\frac{1}{4}$ " lock washers
- 4 – $\frac{1}{4}$ "-28 \times $\frac{5}{8}$ " button head sockets

Teacher-led Activity

Demonstrate the following steps to fabricate a multi-piece steel vise. Students will then each make their own vise.

Bronze $\frac{3}{4}$ -6 Acme nut

1. Face off end. Turn bronze to 1.000 × 1.5 long, leave $\frac{3}{16}$ " × 1.2" diameter shoulder at top end, part off.



2. Reverse nut in lathe chuck, centre drill, pilot drill at $\frac{1}{4}$ ", bore through at $\frac{39}{64}$ ".



3. Set lathe feed to 6 TPI, remove tool post, set rpm to about 50, align tandem Acme $\frac{3}{4}$ -6 tap with live centre in tailstock, turn 3 revolutions by hand, keeping tap in contact with live centre while running through. Posi-drive with tap bar or wrench.





Completed bronze nut with chamfered edges

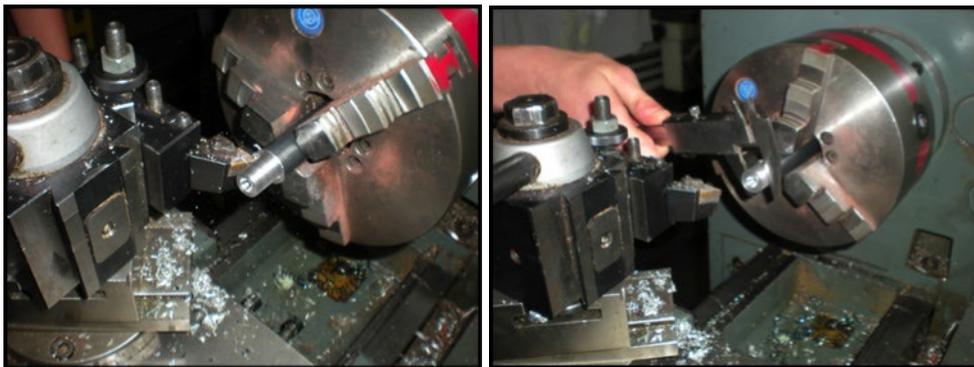
Spindle

1. 0.750 HRMS × 13"

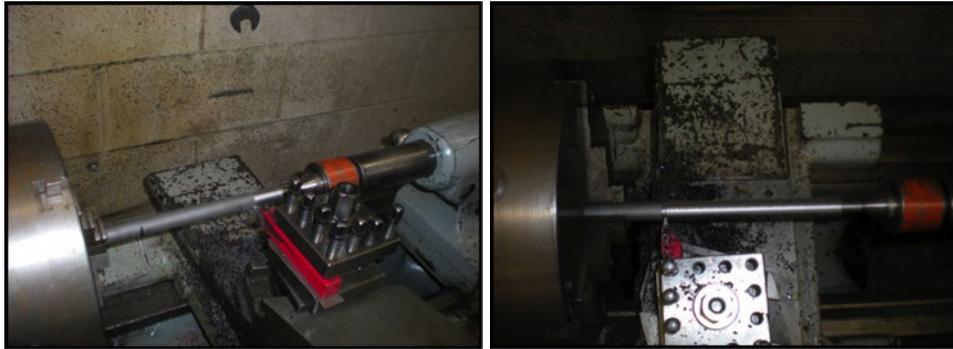
Faced and centre drilled both ends



2. One end turned to 0.500 D × $\frac{3}{4}$ long



3. Turn spindle to 0.740+/-0.002 diameter x 6.5³/₄ long. Beginning from the shoulder, cut relief groove 0.070" deep x 0.150" wide.



4. Cutting Acme ³/₄-6 x 6.5" long

Set lathe to about 150 rpm, gear box to 6 TPI, compound slide at 14.5 degrees.

First cut at 0.025" deep on compound engage threading dial at appropriate increment for a 6 TPI thread as per lathe make and model. Use Sulflo or equivalent heavy duty cutting fluid.



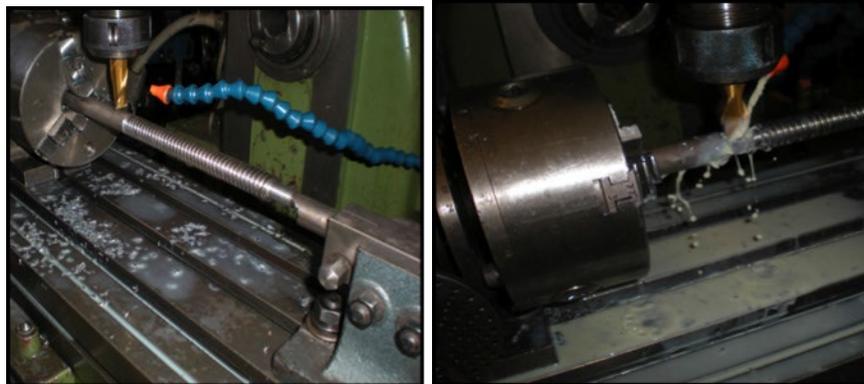
5. Subsequent cuts are made at these depths:

- 2nd: 0.012"
- 3rd-5th: 0.008"
- 6th-11th: 0.005"
- 12th and subsequent cuts: 0.002", until 0.095" is registered on the compound slide dial.

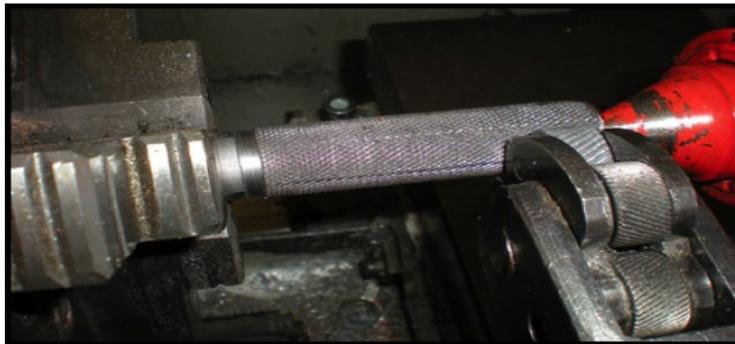
Test fit bronze nut only after filing, then cleaning spindle of all burrs and swarf. Final cut: Do not advance compound but rather recut, file, clean, and check fit with bronze nut. Do not remove from chuck until a final fit is established.

6. File threads to de-burr flats and edges. Fit Acme nut to threads.

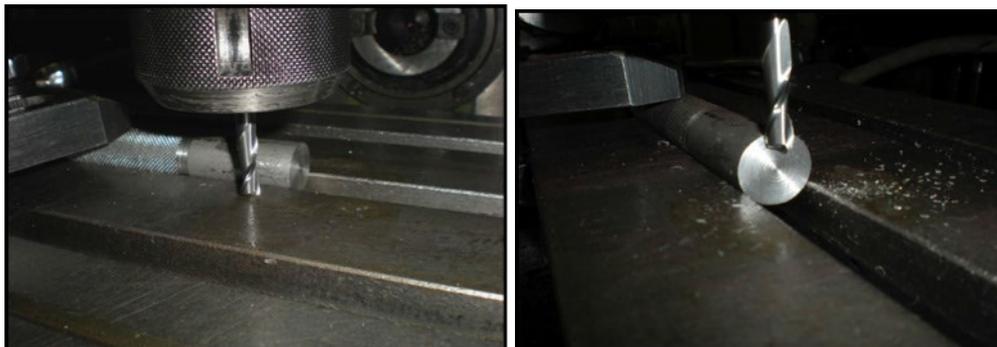
7. Mill $\frac{3}{4} \times 0.245$ deep in two stages $\frac{3}{16}$ " from end of threaded section. Use indexing head with tailstock for 180-degree rotation. Band-saw off handle section at handle end of flats.



8. Coarse knurl 3" of handle end, groove at termination of knurl, chamfer end.



9. Set handle on mill bed T-slot using a clamp. Insert and tighten a $\frac{1}{4}$ " carbide end mill into the collet chuck. Mark edge $\frac{3}{8}$ " from end with rotating $\frac{1}{4}$ " EM to form a shallow "football" mark. Zero the cross slide (y-axis dial) and raise and centre bit (0.500" y-axis motion), lock y-axis in place.



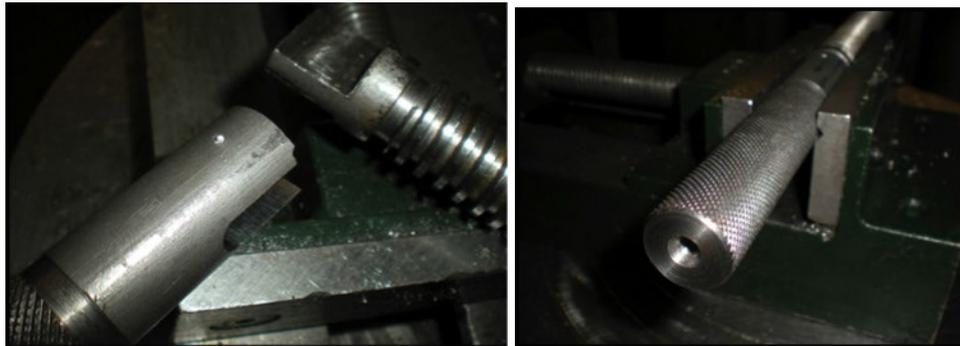
10. Make $\frac{3}{4}$ " long \times $\frac{1}{8}$ " depth cuts: set auto stop, and feed at 3–4 IPM. Flood-cool the end mill.



Make successive $\frac{1}{8}$ " passes until end mill is through the diameter of the handle.



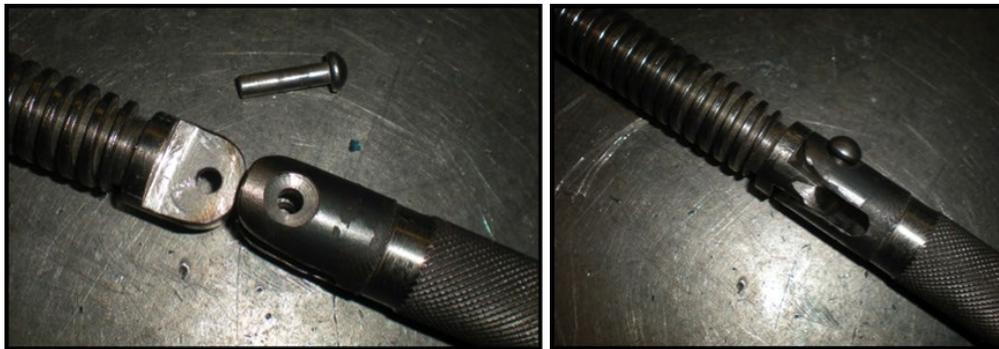
11. Centre-punch the spindle handle on the “football” mark. Align in vise V-jaw ensuring that tongue is level, then slid handle over spindle and clamp tightly.



12. Drill through $\frac{3}{16}$ ", counter-bore $\frac{3}{8}$ " diameter \times $\frac{1}{8}$ " depth on one side and counter sink on other.



13. Round off ends of spindle and handle to semi-circular. Test fit with a $\frac{3}{16}$ " \times $\frac{3}{4}$ " round head rivet so that 90-degree motion right and left is possible.



14. Fasten together with $\frac{3}{16}$ " \times $\frac{3}{4}$ " plain rivet: Slide through counter-bore side first,peen into countersunk area, then blend to radius using a mill file.



Vise Frame

1. Use band saw to cut $1.5 \times 1.5 \times 0.0250$ angle iron to 2@9", 3@4.5" lengths.



2. V-groove the corners for welding and belt-sand sliding surfaces.

V-grind two jaws on bench grinder; belt one jaw smooth on one outer face.



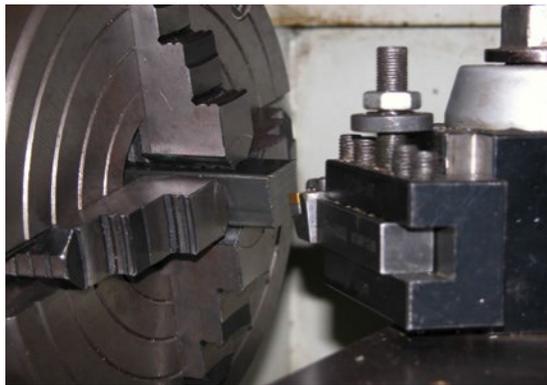
3. V-groove ends of side rails for welding; belt on top surface only.



- Clamp rails to mill bed using a clamp kit. Mill all longitudinal edges of rails at 650 rpm using 3" carbide facing mill, -1.5 mm cut. Power feed at about 8–10 IPM or 200 mm/min.



- Spindle blocks: cut one of each piece on the band saw: $1 \times 1 \times 2$ ", $1\frac{1}{4} \times 1\frac{1}{4} \times 2$ ".
- Face off on 4-jaw chucks.



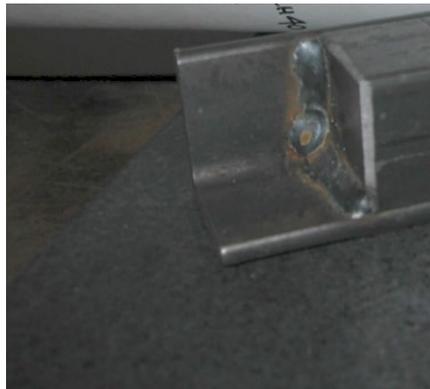
- Mark centre lines around each block using digital height gauge (measure height and divide by two).



8. Grind off one edge of both blocks to allow blocks to sit tightly against the angle iron. Chamfer ends of blocks using a flat file.



9. Clamp and weld blocks to 4.5" angle iron, centred with:
- 1¼" square to V-ground piece (spindle nut boss)
 - 1" square to sanded smooth piece (sliding jaw)
10. Set the welding unit for ⅜" thick stock corresponding to wire diameter and constitution of the shielding gas. Fillet weld ends of blocks only to angle iron.



11. Mark height line 0.750" from bottom of angle iron on face of both blocks (V-groove side down for spindle boss and sanded side down for sliding jaw).

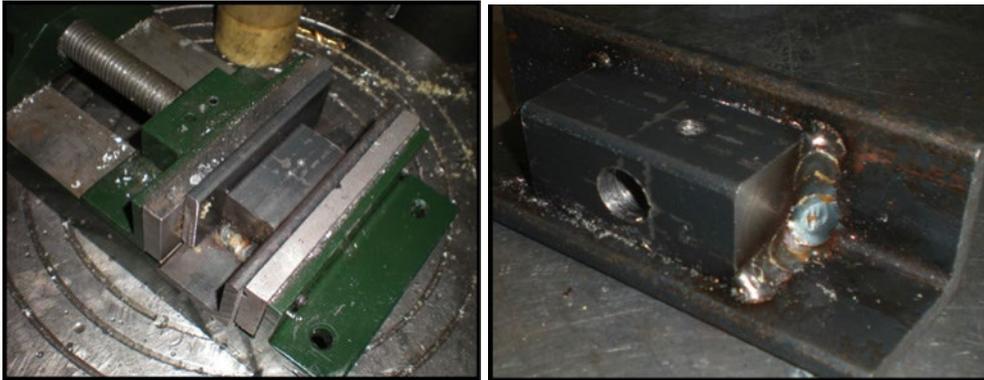


12. Centre-punch along centre line at intersections and at 0.270 offset from centre line for the sliding jaw retaining pin.



13. Drilling the sliding jaw:

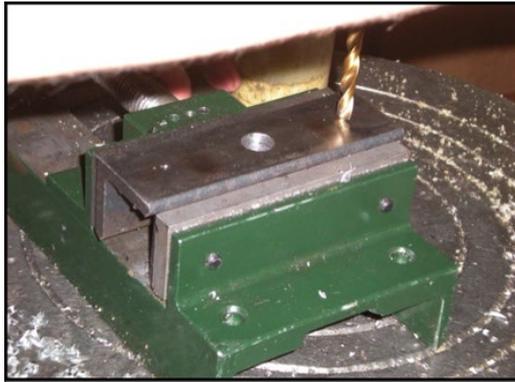
1. Pilot drill all holes $\frac{3}{16}$ " @ 1500 rpm, through.
2. Drill jaw offset hole first 0.270" from C-line (sanded side down). Drill centre spindle hole at $1\frac{5}{32}$ " @ 800 rpm, ream to $\frac{1}{2}$ " @ 400 rpm. **Note:** Jaw must be level in the drill press vise to ensure the hole is perpendicular to the jaw's smooth-ground side.



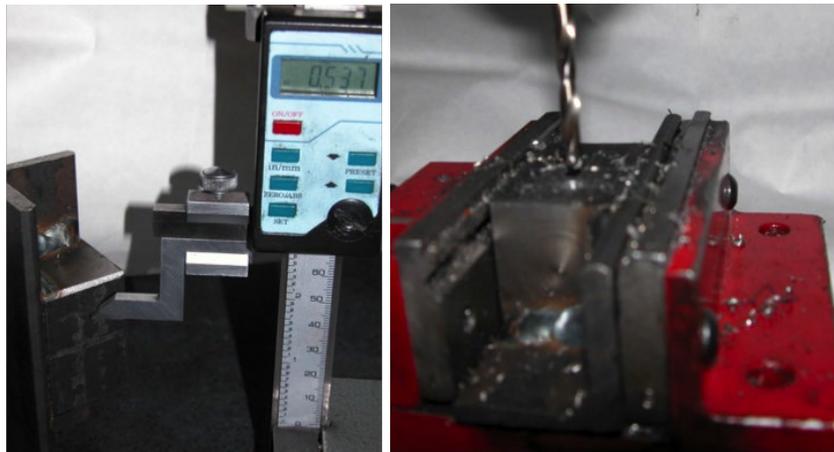
14. Lay out and centre-punch holes for jaw plates 0.625" from bottom and ends of the fixed and sliding jaws.



15. Drill both jaws $\frac{1}{4}$ " through for jaw plates.



16. Drill retaining pin hole in spindle nut holder. Offset by about 0.540" from centre line and drill through using a $\frac{3}{16}$ " bit. This hole is from opposite the V-grooved side of the piece.

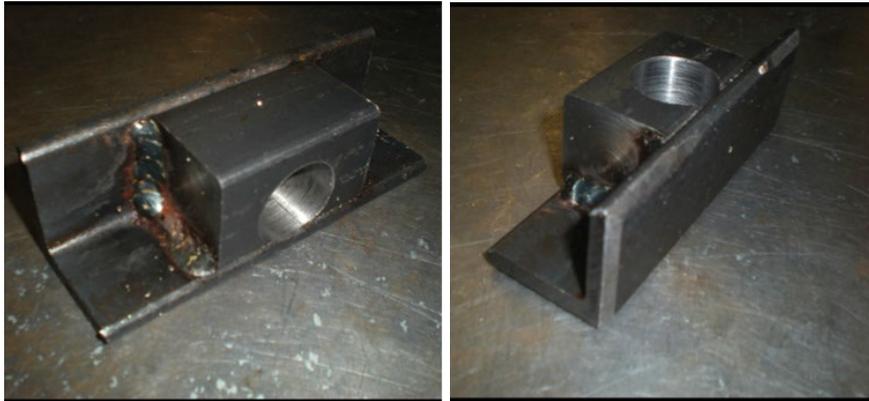


17. Align large block in a 4-jaw chuck at centre-punch mark using live centre. Centre drill, pilot drill through at $\frac{5}{16}$ ", drill out at $3\frac{1}{32}$ " at about 300 rpm, ream to 1" at about 150 rpm. **Note** the position of ground V-grooves.



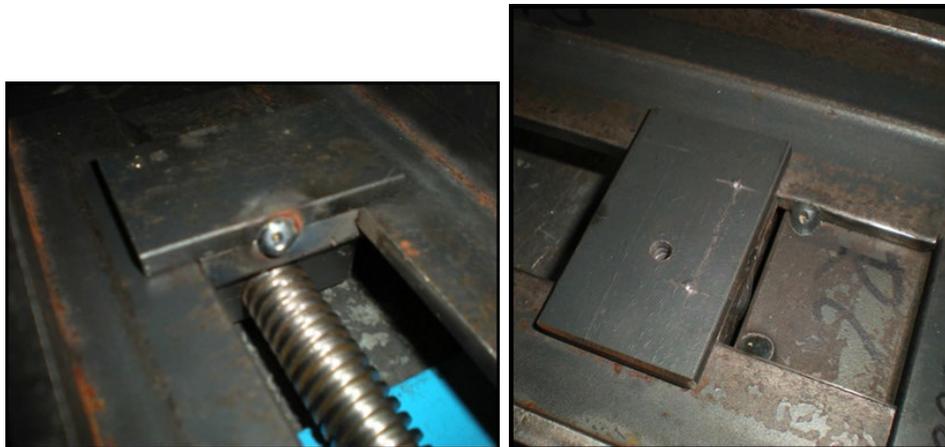
18. Spindle nut holder completed

Note that the weld V-grooved edge is **down!**



19. Frame assembly:

Ensure nut boss and fixed jaw are **square** and **flush** to the rails, then firmly hold in place with locking pliers. Tack weld at three locations of lap joint to one rail only.



20. Construct sliding jaw spacer and retainer from $\frac{1}{4}$ " \times 1.5 stock. Spacer to have parallel ground edges, about 1.6" long. Use spacer to position second rail, then clamp and tack weld rail in place.

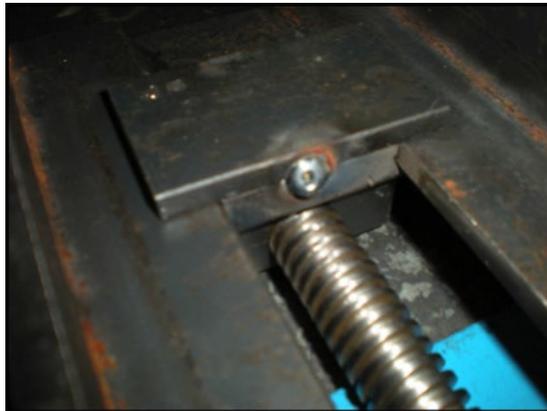


21. Grind spacer V-groove, position sliding jaw using spindle and nut, then tack weld spacer in position.

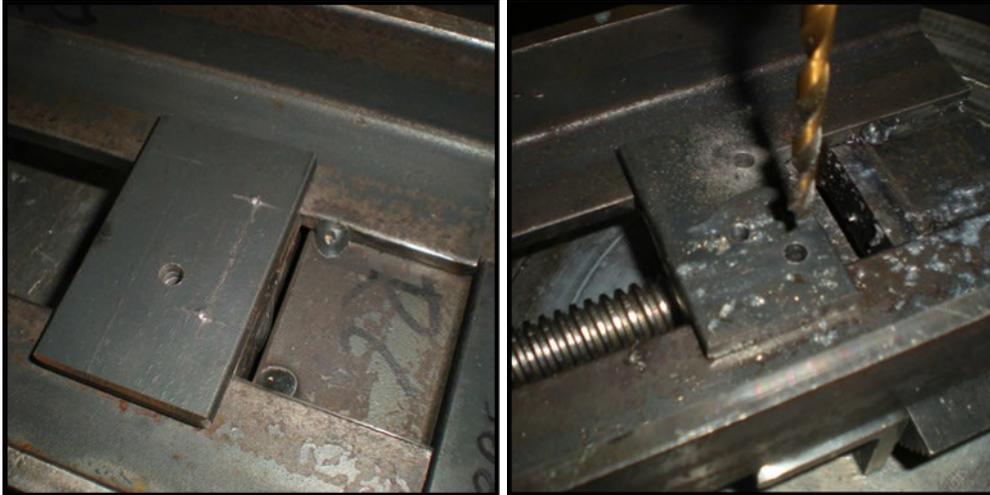


22. Remove sliding jaw from frame. Fill weld the V-groove and grind weld flush with edges.

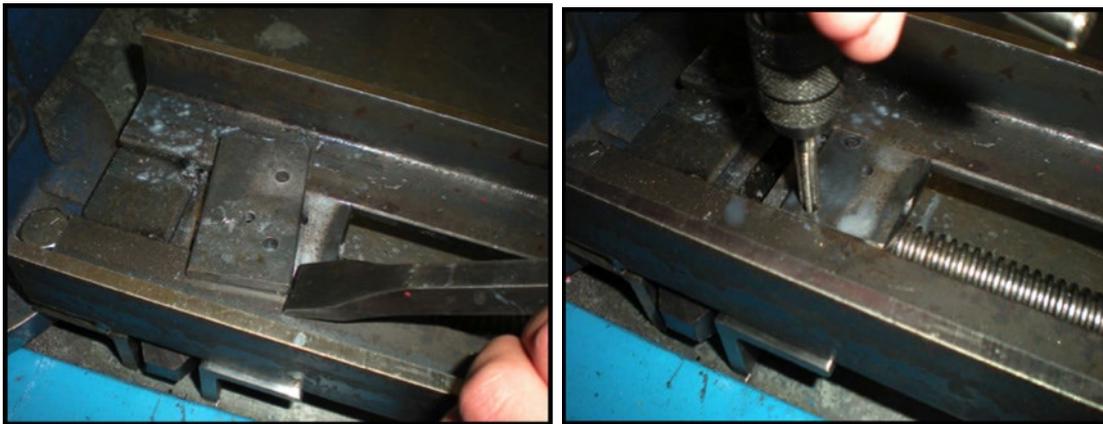
23. Retainer to be about 2.5" long. Temporarily tack weld to spacer. Cover spindle when welding.



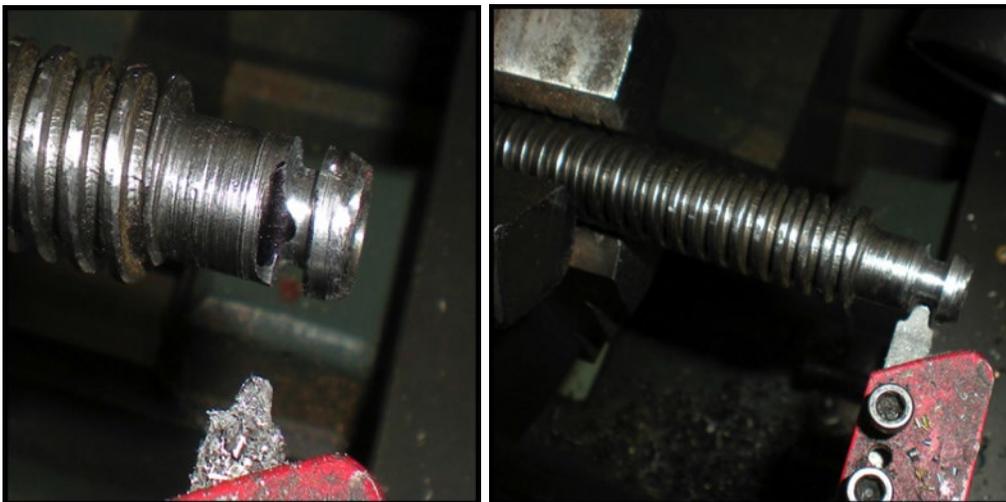
24. Drill retaining pin holes ($\frac{3}{16}$ ") through the entire assembly from top of sliding jaw while having the spindle tightly in place. Drill two holes $\frac{7}{32}$ " \times 1.5 deep for retaining plate bolts. These are located $\frac{3}{8}$ " from the front edge of the sliding jaw and $\frac{3}{16}$ " toward the centre from the inner edges of the sliding frame rails.



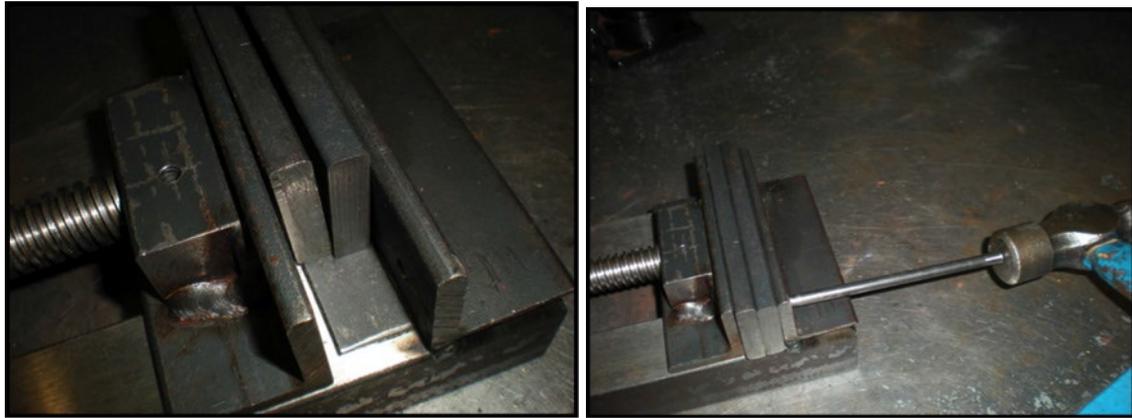
25. Remove retaining plate using a cold chisel and hammer. Drill out all holes in plate to $\frac{1}{4}$ ", tap two $\frac{7}{32}$ " holes only, $\frac{1}{4}$ -28NF \times $\frac{3}{4}$ " deep in the sliding jaw.



26. Remove spindle assembly and turn retaining groove at 0.500" end with forming tool only removing entire felt-penned drill mark.



27. . Jaw plates: $\frac{3}{8}$ " \times $\frac{1}{8}$ " longer than vise width, two pieces. Place $\frac{1}{8}$ " \times $\frac{3}{4}$ " \times 4" spacer under plates, position, and then tighten in place. Use a $\frac{1}{4}$ " transfer punch to mark hole placement.



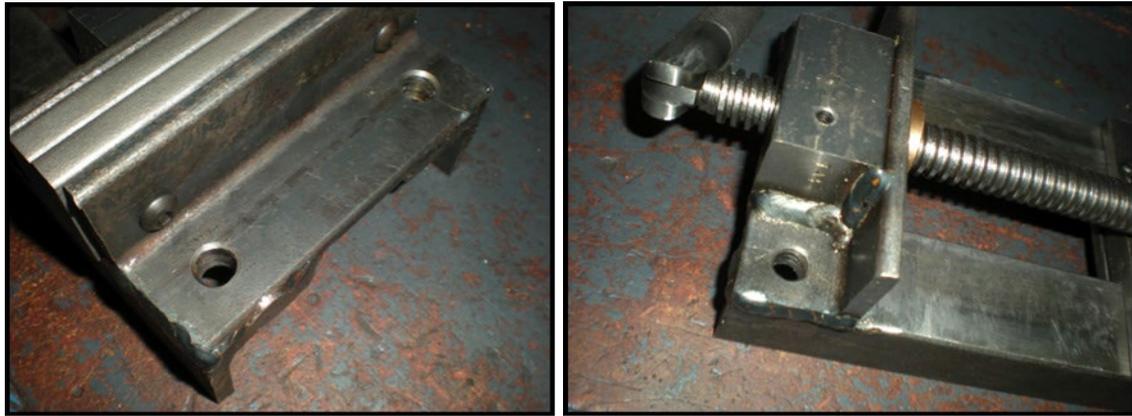
28. Drill plates $\frac{7}{32}$ " and tap $\frac{1}{4}$ -28 NF through.

29. Option: V-groove fixed jaw plate on milling machine: $\frac{3}{4}$ " end mill at 45 degrees, 4.0 mm deep.



30. Pulse weld frame; MIG set at 21.5 V and 425 wire feed or manufacturer's specification for $\frac{3}{8}$ " material. Alternate side to side filling in the V-grooves and fillets.

31. Drill $\frac{25}{64}$ " holes $\frac{5}{8}$ " in from edge and end, four corners. Countersink to de-burr holes top and bottom.



32. Face mill sides, ends, and top of jaw plates to square off frame.



33. . Mill the ends or grind and file flat.



Finishing

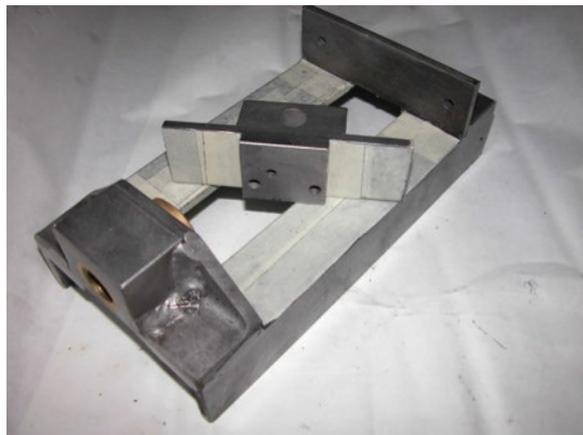
1. Cut off corners of frame at nut boss end using a hacksaw. De-burr and chamfer all edges using a file.



2. Bead blast all frame components clean.



3. Mask off contact areas on the sliding jaw and rails.



4. Paint or powder coat frame. If powder-coating, remember to remove tape while hot!

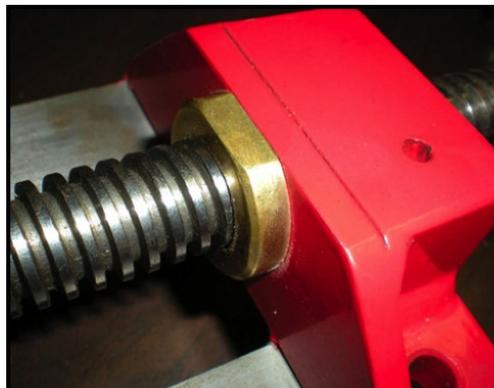


5. Handle may be painted or powder-coated rather than blackened. Do not paint or powder-coat past the handle.



Assembly

1. Secure jaw plates to both fixed and sliding jaws using $\frac{1}{4}$ NF \times $\frac{5}{8}$ " round socket head bolts.
2. Secure sliding jaw to frame with retaining plate using $\frac{1}{4}$ NF \times 1" socket head bolts with lock washers.
3. Thread spindle through nut and into sliding jaw. Insert $\frac{3}{16}$ " roll pin using a drift punch and hammer. Split side of roll pin should face away from the rotating end of the spindle.
4. Insert $\frac{3}{16}$ " roll pin through bushing block using a drift punch and hammer.
5. Apply a small amount of light lubricant on all moving parts.



Assessment

Consider co-creating the assessment criteria with your students at the beginning of the activity/project. You may want to include the following:

Spindle and nut:	threads fit and finish end fit and motion
Handle:	knurl and chamfer joint articulation, finish, fit
Frame:	squareness, finish preparation, applied finish
Sliding jaw:	fit, finish preparation, applied finish
Jaw plates:	alignment, finish preparation
Assembly:	vise smoothly functioning as a unit
Finish:	even, smooth

