ONTARIO COUNCIL FOR TECHNOLOGY EDUCATION

SKILLED TRADES AND APPRENTICESHIP CURRICULUM CONSORTIUM RESOURCE

Fire Piston Project
TMJ3C/4C

SKILLED TRADES & APPRENTICESHIP RESOURCE

takeTECH

Table of Contents

Introduction

Course Code: TMJ3C
Broad base Technology: Manufacturing Technology
Destination: TMJ4C / TMJ4M
Grade Level: Grade 11
Prerequisite: None
Resource/Project Name: Fire Piston

Project Outline

This project is designed as a grade 11 beginner project. The purpose of this practical assignment is to teach metal lathe basics such as end facing, parallel turning, drilling, threading, turning grooves, and turning angles on a manual metal lathe. This project can be used as a refresher project for a student moving from TMJ20 to TMJ3C or as a way of introducing the above skills to a student new to Manufacturing Technology.

Prior Knowledge

Students should prior knowledge and training before attempting this assignment. Several concepts, techniques, shop practices, including shop safety, that students should be aware of are,

- Machine and Shop Safety
- Basic Blueprint reading
- Band saw operation
- Order of operations
- Lathe operation
- Bandsaw Passport (if required by school board)
- Lathe Passport (if required by school board)
- Knowledge of lathe components and tooling
- How to select proper RPM and feeds

Student Activities

To successfully complete this project, **students** will require access to the following resources:

- A computer, smart phone, or tablet
- Internet access
- OCTE Metal Lathe hand out
- OCTE ToolSAFE Engine Lathe
- Access to a metal lathe
- Access to lathe tooling
- Access to material
- Access to Fire Piston blueprints
- Access to a tap drill chart

In this project, students will:

- Set up RPM correctly for selected material.
- Use proper techniques for setting up tooling and materials for; end facing, parallel turning, drilling, reaming, cutting a taper and threading.
- Demonstrate knowledge of machine and shop safety.
- Machine mating components to and accurate tolerance for the correct fit.

Teacher Resources

To successfully complete this project, **teachers** will require access to the following resources:

- A computer, smart phone, or tablet
- Internet access
- OCTE Metal Lathe hand out
- OCTE ToolSAFE Engine Lathe
- Access to a metal lathe
- Access to lathe tooling
- Access to material
- Access to Fire Piston blueprints
- Form tool or grooving tool for O-Ring groove
- O-rings for the piston
- Access to a tap drill chart
- Manufacturing Project Rubric

Activity 1 – Machining the Fire Piston Cylinder

The goal for this activity is for students to learn / demonstrate the proper setup of tooling and the workpiece. Students will demonstrate how to select proper RPM for the material type and size as well as select the correct order of operations. Students will learn how to read a tap drill chart and learn the importance of selecting the correct drill size for the tapped hole. Students will also learn about different fits and how to properly ream a hole.

- Students will manufacture the Fire Piston Cylinder using the bandsaw, metal lathe, hand file, and various other hand tools and tooling.
- This component of the project will introduce/refresh students on manufacturing techniques used when operating a Bandsaw, Metal Lathe and other hand tools.

Time Required: 2+hrs

Activity 2 – Machining the Fire Piston

The goal for this activity is for students to practice and build on the skills learned during activity 1. Students will use the form tools for cutting the groove and select the proper drill for the tapped hole using the tap drill chart and knowledge learned from activity.

- Students continue to manufacture the Fire Piston Cylinder with use of a Bandsaw, Metal Lathe, Hand File and various other hand tools and tooling.
- This component of the project will introduce students to the manufacturing process of cutting an O-ring groove.

Time Required: 1.5+hrs

Activity 3 – Machining the .3125 End Cap

The goal for this activity is for students to practice and build on the skills learned during activities 1 and 2. Students will learn the correct way to thread using a die and die set. Students will use a grooving tool and knowledge from activity 2 to cut the groove at the base of the thread.

- Students continue to manufacture the Fire Piston Cylinder using a bandsaw, metal lathe, hand file, and various other hand tools and tooling.
- This component of the project will introduce/refresh students on the manufacturing process of cutting a thread with a die and diestock. Students will have the opportunity to practice cutting a groove using the lathe.

Time Required: 1.5+hrs

Activity 4 – Machining the .375 End Cap

The goal for this activity is for students to practice and build on the skills learned during activity 1, 2, and 3. The last component gives students the opportunity to practice the skills learned in the previous activities.

Time Required: 1.5+hrs

Planning Notes

The following are suggestions when planning to perform this project:

- It is critical that students have an understanding of machine and shop safety
- Students will need to know how to identify the different lathe tooling and how to select the correct tool for specific processes.
- Students must know how to set up tooling and the workpiece correctly in the metal lathe.
- Students will need an understanding of RPM selection.
- Ensure all materials are on hand.
- Ensure all tooling is available e.g. tap drills, clearance drill for reamed hole, reamer, tap and tap handles, die and die stock, O-rings.

Skilled Trades and Apprenticeship Opportunities

The skills and knowledge gained by completing this project will benefit students who are considering pursuing a career in the Industrial sector. The following is a list of trades within the Industrial sector where students can directly apply this knowledge:

- Tool and Die Maker 430A
- Machine and Tool Builder and Integrator 430M
- General Machinist 429A, 430A, 431A, 443A, 430M, 630T
- Industrial Mechanic / Millwright 433A, 426A
- Mould Maker 431A
- Pattern Maker 443A
- Tool / Tooling Maker 630T

It is recommended that the instructor utilize the Canadian Apprenticeship Forum for up to date resources on that include,

- Apprentice Attitudes Towards Learning and Examinations
- The Quality of Workplace Training
- Communication and Inclusion in Apprenticeship
- Apprentice Well Being
- Career Entry, Training and Completion in the Skilled Trades
- The Impact of COVID-19 on Apprenticeship

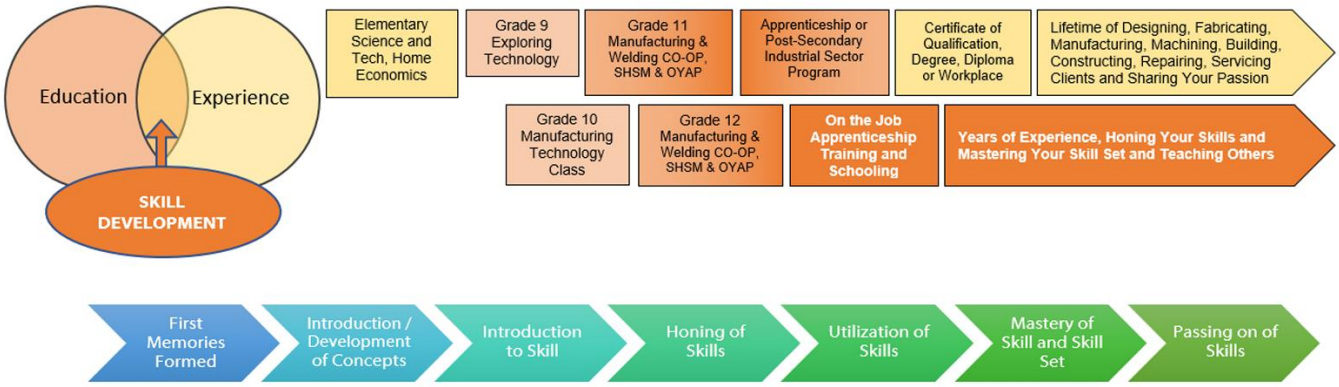
Career and Industry Extensions

The skills and knowledge gained by completing this project will be of great benefit to students when pursuing a career in multiple areas in the Industrial sector as well as other industries. Some additional examples of careers in other related industries are listed below:

- Metal Fabricator
- Mechanical Engineer
- Custom car / motorcycle / boat builder
- CNC lathe operator
- Heavy Equipment / Truck and Coach Service Technician
- Tool and Die Maker
- Machine Tool Builder and Integrator
- General Machinist
- CNC machine operator
- Mechanical engineering
- Manufacturing Engineering Technologist

Continuum of Influence

We all have different moments in our lives where we are affected by an experience. This can include learning a new concept or skill, experiencing something for the first time, taking a new course, developing a talent through practice and hard work, or even calling upon a skilled tradesperson to fix, repair, design, construct, maintain, build, bake, and create innovative solutions. The continuum of influence is a graphic representation of how those experiences can lead to developing a passion and talents in areas like Machine, Tool, Die, Mould & Automation (MTDMA) sectors.



For a full size picture of the Continuum of Influence, see Appendix A

Continuum of Skills

As students pursue their careers in the manufacturing industry, and specifically the Machine, Tool, Die, Mould & Automation (MTDMA) sectors, they will have opportunities to build on the skills learned during this project. The Apprenticeship Training Standards have a common core curriculum for level 1 that covers many Industrial sector trades including, Tool and Die Maker 430A, Machine and Tool Builder and Integrator 430M, General Machinist 429A, 430A, 431A, 443A, 430M, 630T, Industrial Mechanic / Millwright 433A, 426A, Mould Maker 431A, Pattern Maker 443A, and Tool / Tooling Maker 630T.

The curriculum expectations met during this project are aligned with the Level 1 Common Core Apprenticeship Training Standard for all of the previously mentioned trades as follows:

A2.1 Describe and demonstrate the correct use of a variety of processes for joining materials (e.g., welding, bonding, fastening);

Alignment with Apprenticeship Training Standards:

- Aligned with: 6.1 Select bench or hand tools for bench working, operations. 6.3 Perform bench working metal removal procedures. 7.1 Demonstrate safe working procedures when setting up and operating metal cutting saws. 7.2 Describe functions and operating principles of vertical and horizontal bandsaws. 9.6 Perform turning. 9.5 Develop a plan for turning operations.

A2.4 Describe material conversions such as the separation process (e.g., converting a material's size and shape by removing excess material); the addition process (e.g., combining materials to achieve enhanced qualities, as in alloys); the process of making changes to contours (e.g., assembling materials by such means as gluing, mixing, fastening, bonding, welding); and the process of changing the properties (e.g., thermal, chemical, mechanical, physical) of solid materials;

Alignment with Apprenticeship Training Standards:

- Aligned with: 9.1 Demonstrate safe working procedures when setting up and operating a lathe. , 9.2 Set up lathe machine components, controls, and coolant requirements., 9.2 Set up lathe machine components, controls, and coolant requirements., 9.5 Develop a plan for turning operations

A4.1 Demonstrate a working knowledge of various mathematical formulas (e.g., Pythagorean theorem, formulas for calculating volume and surface area) and applications (e.g., tap drill sizing, calculation of machine speeds and feeds, weight calculations) that are commonly used in manufacturing;

Alignment with Apprenticeship Training Standards:

- Aligned with: 2.7 Calculate part features and machining parameters using formulae to determine: • drill sizes • thread size • cutting speeds • feed rate • tapers • angles • depths of cut • cutter locations

B2.3 Use the proper procedures to prepare materials for production (e.g., measuring, marking, cutting to rough length, grinding, cleaning, deburring)

.Alignment with Apprenticeship Training Standards:

- Aligned with: 5.1 Describe fundamentals of dimensional metrology, 6.1 Select bench or hand tools for bench working operations, 6.3 Perform bench working metal removal procedures.

B3.1 Demonstrate the correct use of various measuring instruments (e.g., scales, vernier calipers, micrometers, gauges) to make measurements in both metric and US customary/British imperial units;

Alignment with Apprenticeship Training Standards:

- Aligned with: 5.2 Describe the operational principles of measuring, checking, and gauging equipment. 5.3 Demonstrate measuring techniques using direct/indirect reading linear measuring equipment.

B3.2 apply principles of dimensional metrology (e.g., precision measurement, tolerancing for interchangeable manufacturing) to manufacturing processes when producing a product.

Alignment with Apprenticeship Training Standards:

- Aligned with: 5.1 Describe fundamentals of dimensional metrology, 5.2 Describe the operational principles of measuring, checking, and gauging equipment.

Resources

Blueprints

Fire Piston Cylinder Blueprints (see Appendix C)

Fire Piston_Blueprints (see Appendix C)

.3125 End Cap Blueprints (see Appendix C)

.375” End Cap Blueprints (see Appendix C)

Pictures

Completed Fire Piston Picture (see Appendix B)

Lesson Plan

Lesson Plan (see Appendix H)

Handouts

Fire Piston Cylinder Blueprint (see Appendix C)
Fire Piston Blueprint (see Appendix C)
.3125” End Cap Blueprint (see Appendix C)
.375” End Cap Blueprint (see Appendix C)
OCTE Metal Lathe Handout (see Appendix D
Metal Lathe Quiz (see Appendix E)
Tap Drill Chart (see Appendix F)
Fire Piston Rubric (see Appendix G)

Materials

1” diameter Brass or Aluminum
O-rings
Char Cloth

Exemplars

Completed Fire Piston Picture (see Appendix B)

Websites for Teachers

American Fastener Tap Drill Chart
Starrett Inch/Metric Tap Drill Sizes & Decimal Equivalents Chart

Tools/Equipment

The following tools and equipment will be required to complete this project:

- Metal lathe
- Turning tool
- Drill chuck
- Parting tool
- 5/16-18 tap and die
- 3/8-16 tap and die
- “F” drill,
- 5/16 drill
- HSS form tool ground to approximately 0.063” wide
- (for O-ring groove)
- 23/64” drill
- 3/8” reamer
- 1/2” x 90 deg. countersink
- Center drill

Videos

OCTE ToolSAFE TMJ Engine Lathe https://www.octe.ca/en/resources/resource-folder/toolsafe/toolsafe-tmj-engine-lathe-turning (4:44 minutes)	
DIY Survival: Fire-Starting with a Fire Piston | Dual Survival https://www.youtube.com/watch?v=1xbAVWBkGgI (3:05 minutes)	

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- 23/64” drill
- 3/8” reamer
- 1/2” x 90 deg. countersink
- Center drill

Instructional Strategies

Teachers may use any of the following instructional strategies; 3-Part lesson, lecture, storyboard, word wall, think-pair-share, placemat activity, rapid write, K-W-L, anticipation chart, ABC taxonomy, think aloud, analyzing text, Cornell note taking, exit ticket/ticket out the door, plus/minus/delta, etc.

The Hook / Motivational Strategies

Leading Question / Scenario: “You are on a hike with your friends when you get separated and lost in the wilderness. What are some essentials you would need to survive overnight in the wilderness?”

Have a class discussion on what would be needed and how they would obtain those “needs.” Write all student ideas on the board and expand on them. Students should identify the need to start a fire.

Show the DIY Survival: Fire-Starting with a Fire Piston | Dual Survival YouTube video.

Learning Goals and Success Criteria

Learning goals and success criteria are the foundation on which students base their ability to monitor their learning and determine next steps**.** Applicable learning goals will include the following:

- Students will learn basic lathe operation.

- Students will understand tap drill sizes and how to read the tap drill chart.
- Students will learn/review the process of cutting threads using taps and dies.
- Students will learn the process of reaming a hole.
- Students will learn the process of reaming cutting a groove.

Success criteria may include any of the following:

- Students will be able to identify the parts of the metal lathe.
- Students will be able to select the correct RPM for the material specified.
- Students will be able to select the correct tooling for the process required.
- Students will be able to complete basic metal processes e.g. end facing, drilling, parallel turning.
- Students will be able to accurately cut internal threads using a tap.
- Students will be able to cut external threads using a die.
- Students will understand how to select the correct drill size when tapping a hole.
- Students will have a basic understanding of dimensional tolerance.

Overall and Specific Expectations in Support of Ontario Curriculum Grades 9 - 12 Technological Education

Overall Expectations

- A2. Demonstrate an understanding of material conversion processes;
- A3. Demonstrate an understanding of various types of control systems used in manufacturing;
- A4. Apply relevant mathematical and scientific concepts and use appropriate forms of technical communication in the study of manufacturing technology;
- B1. Demonstrate the ability to interpret and prepare technical drawings and develop process plans;
- B2. Demonstrate a working knowledge of the characteristics of various materials and the proper selection of materials for the manufacture of a product;
- B3. Demonstrate a working knowledge of various metrology tools used to measure, lay out, and inspect products;
- B4. Use tools, equipment, and machine processes safely and correctly in the manufacture of a product.

Specific Expectations

- A2.1 Describe and demonstrate the correct use of a variety of processes for joining materials (e.g., welding, bonding, fastening);
- A2.4 Describe material conversions such as the separation process (e.g., converting a material's size and shape by removing excess material); the addition process (e.g., combining materials to achieve enhanced qualities, as in alloys); the process of making changes to contours (e.g., assembling materials by such means as gluing, mixing, fastening, bonding, welding); and the process of changing the properties (e.g., thermal, chemical, mechanical, physical) of solid materials;
- A4.1 Demonstrate a working knowledge of various mathematical formulas (e.g., Pythagorean theorem, formulas for calculating volume and surface area) and applications (e.g., tap drill sizing, calculation of machine speeds and feeds, weight calculations) that are commonly used in manufacturing;
- A4.2 Apply mathematical concepts (e.g., linear systems; integers; decimals and fractions; order of operations) and skills in performing a variety of tasks required within the context of manufacturing design and production (e.g., angle calculations; calculation of perimeter, volume, and area; percent/decimal/fraction conversions; US customary/ British imperial and metric unit conversions);

- A4.6 Describe how the physical and mechanical properties of solid materials (e.g., physical: density, appearance, porosity, surface texture; mechanical: hardness, ductility, elasticity, brittleness, compression, fatigue, shear, tensility) create advantages or disadvantages that affect their suitability for use in manufacturing;
- A4.7 Use technical language correctly and appropriately (e.g., in reports and presentations) to communicate information related to manufacturing technology;
- A4.8 Use appropriate forms of communication (e.g., oral and written reports) and supporting documentation (e.g., statistical graphing; sketches; scale drawings; perspectives; orthographic, isometric, and oblique views; pattern and development projections; shop, assembly, and detail drawings) to convey ideas and processes and to show materials and specifications;
- B1.3 Convert drawing dimensions (e.g., US customary/British imperial units to metric units, fractions to decimals) using the appropriate chart, table, or formula;
- B2.2 Select appropriate materials for a project based on their properties and characteristics (e.g., physical, mechanical, thermal, chemical, electrical, magnetic, optical, acoustical) and the project's design criteria (e.g., strength, finish, customer specifications, quality control processes, working environment);
- B2.3 Use the proper procedures to prepare materials for production (e.g., measuring, marking, cutting to rough length, grinding, cleaning, deburring);
- B3.1 Demonstrate the correct use of various measuring instruments (e.g., scales, vernier calipers, micrometers, gauges) to make measurements in both metric and US customary/British imperial units;
- B3.2 Apply principles of dimensional metrology (e.g., precision measurement, tolerancing for interchangeable manufacturing) to manufacturing processes when producing a product;
- B3.3 Demonstrate a working knowledge of the proper tools required to lay out a product precisely (e.g., height gauge, surface gauge, trammel points, protractor, scribe, straight edge);
- B3.4 Use metrology tools to inspect and evaluate products for quality control purposes (e.g., for inspection reports, destructive and non-destructive testing).
- B4.1 Demonstrate the use of appropriate bench work techniques to lay out, fit, and assemble workpieces;
- B4.2 Use appropriate procedures (e.g., correct machine set-up, operational safety procedures) when setting up, maintaining, using, and storing tools and equipment used in manufacturing and production processes;
- B4.3 Demonstrate the correct selection and use of appropriate tools and equipment (e.g., wrenches, electric drills, grinders, engine lathe, milling machine) for specific manufacturing tasks.

Safety Concerns

Students must follow instructions on machine safety while operating the band saw and metal lathe. Safety passports or equipment instruction, testing and demonstration sign offs may be used to track student training on pieces of equipment. Students must also wear all required PPE including:

- Safety Glasses
- Proper footwear
- Proper clothing ie. no lanyards or baggy clothing

Applicable SAFEDocs and ToolSAFE videos

Please refer to the OCTE SAFEDocs for Manufacturing Technology for safety documents in order to properly address and instruct this project.

- OCTE ToolSAFE TMJ Engine Lathe
- OCTE Metal Lathe Handout (see Appendix D)
- Metal Lathe Quiz (see Appendix E)
- Tap Drill Chart (see Appendix F)

Project Challenges

Some challenges that may occur during this project are:

First time students may not fully grasp lathe operation.

- Consider spending more time one on one to help support students' needs.
- Consider having students work with a partner.
- Use demonstration videos.

Students may have trouble reading the blueprints

- Consider working through the first blueprint step by step with students.
- Consider having students work with a partner.
- Consider providing extra worksheets for practice.

There may not be enough machines available for every student.

- Consider having students partner up on machines.
- Have students take turns on machines.

Students may break tooling.

- Use as a teachable moment to show class how to change tooling.
- Have extra tools ready.

Differentiation of the Project / Activity

This project can be differentiated by:

- Using different types of materials
- Using different sizes of material (make sure to scale all components)
- Working in groups, have students make specific components
- Lathe quiz could be made into a Google Form
- Students could complete the project online by doing a write up on the step-by-step procedures they would use to complete each component.

Teachers can also refer to the Differentiation Scrapbook to take into account for learner ability, multiple intelligences, exceptional students, and ESL learners.

Assessment and Evaluation

Assessment For Learning

- Ask students about wilderness survival as outlined in The Hook / Motivational Strategies.
- Provide students with a brief outline of the project and ask them how they would go about building it.
- Ask students what tools they think they might need to build the project.
- Identify particular learning needs of students.

Assessment As Learning

- Ask questions and make suggestions based on daily observation.
- Assess students' cognition about their learning (asking them "why" and "how" they are completing a certain operation.
- Students monitor their own learning and ask questions as needed.

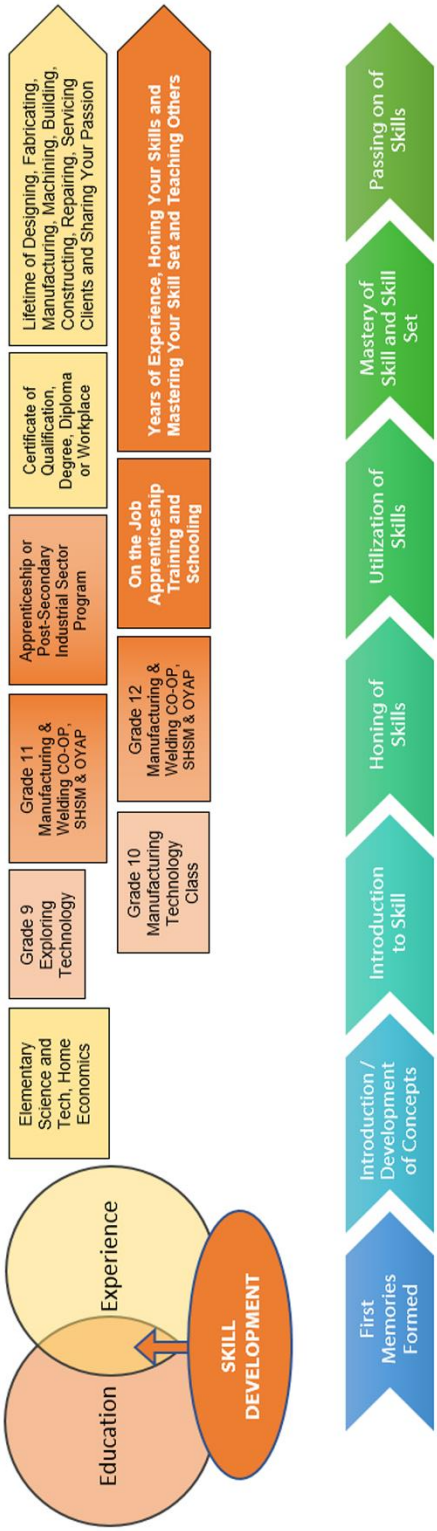
Assessment Of Learning

- Students will complete a quiz to assess their understanding of the lessons
- Evaluate each project according to the rubric

Reflection or Design Report

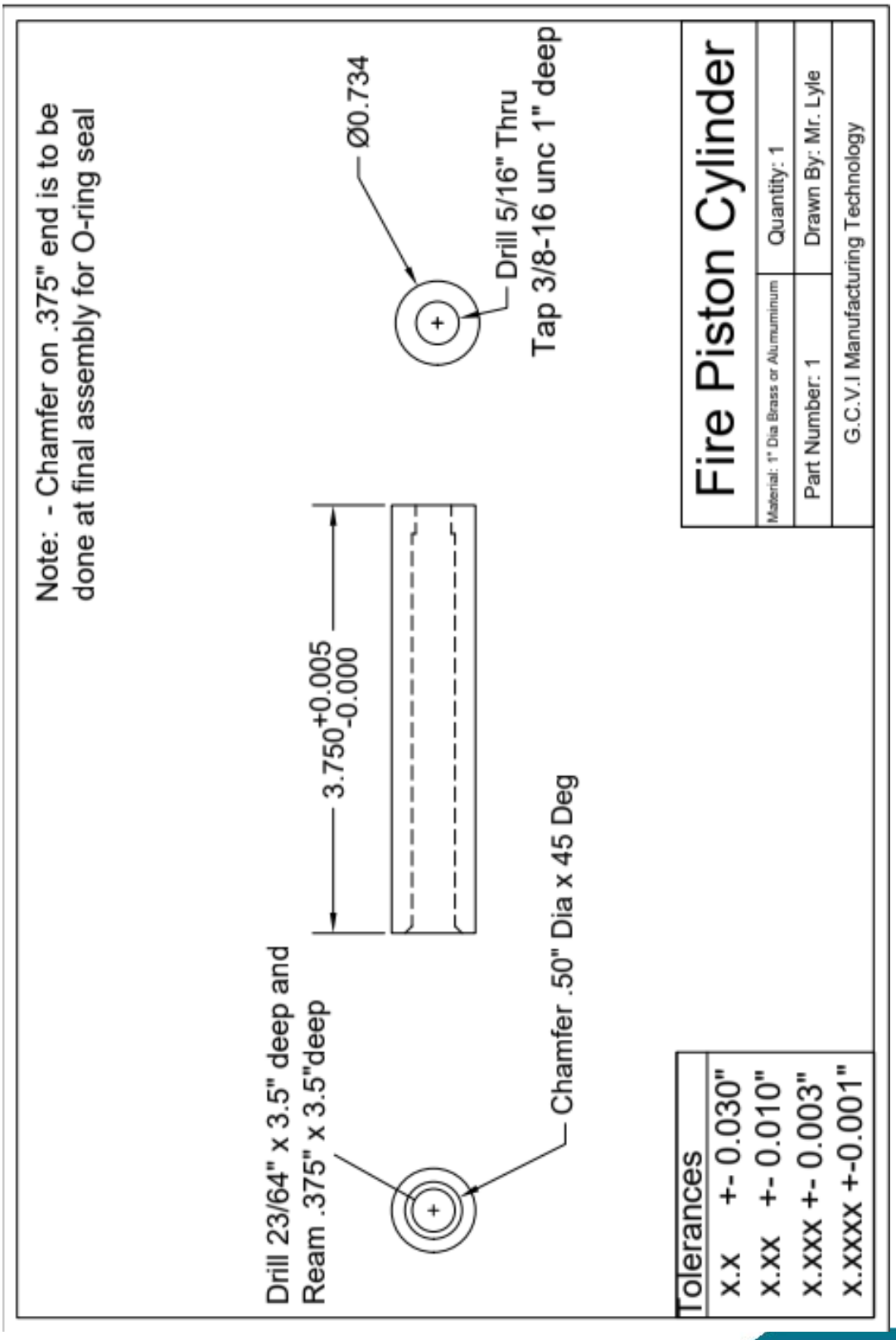
Teachers may wish to have the students complete a design report, reflection or create a foldable to consolidate their learning. This would be a nice way to capture the students' understanding in a summative format and be used in preparation for their examination, entering post-secondary education, or the workforce.

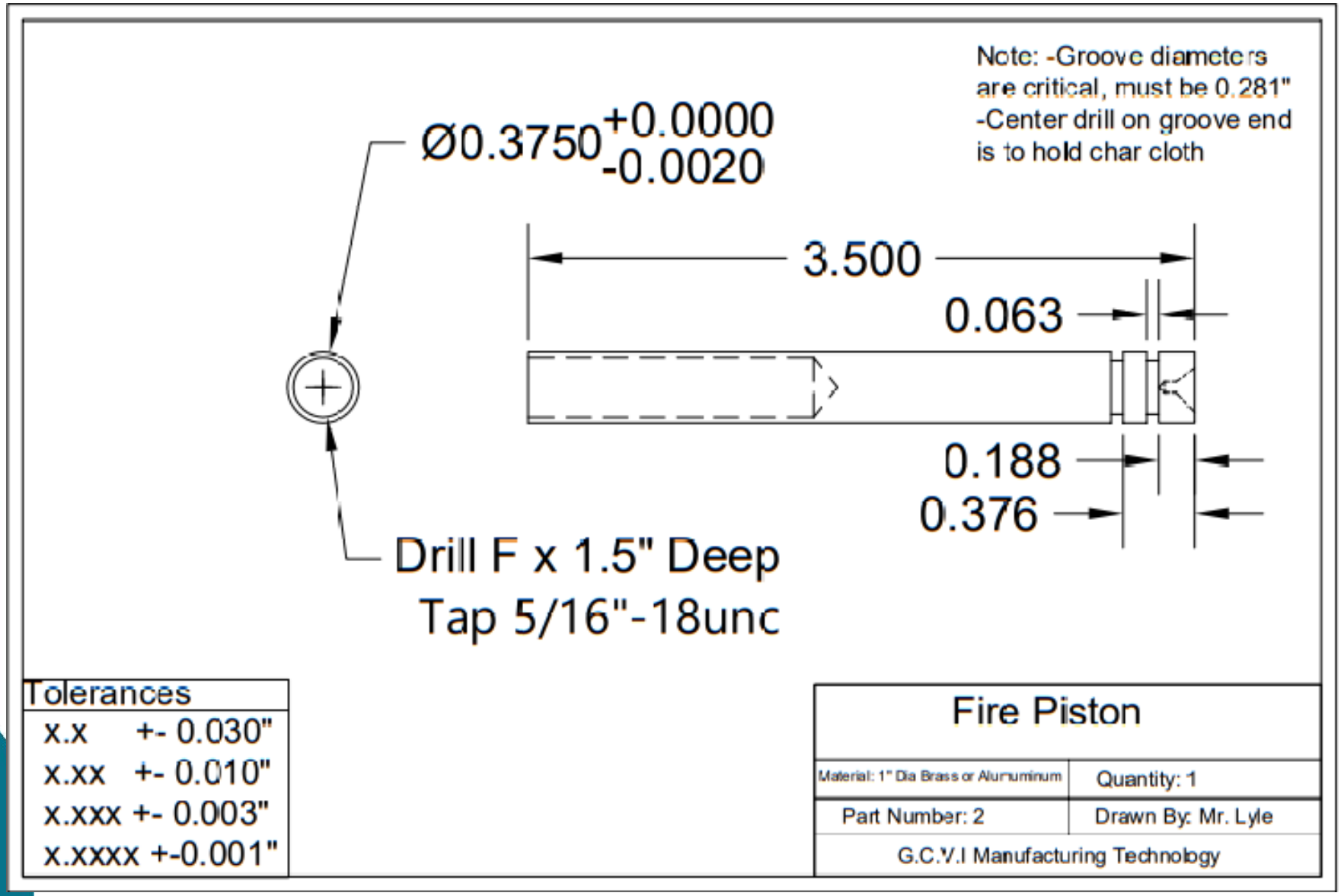
Appendix A –Continuum of Influence

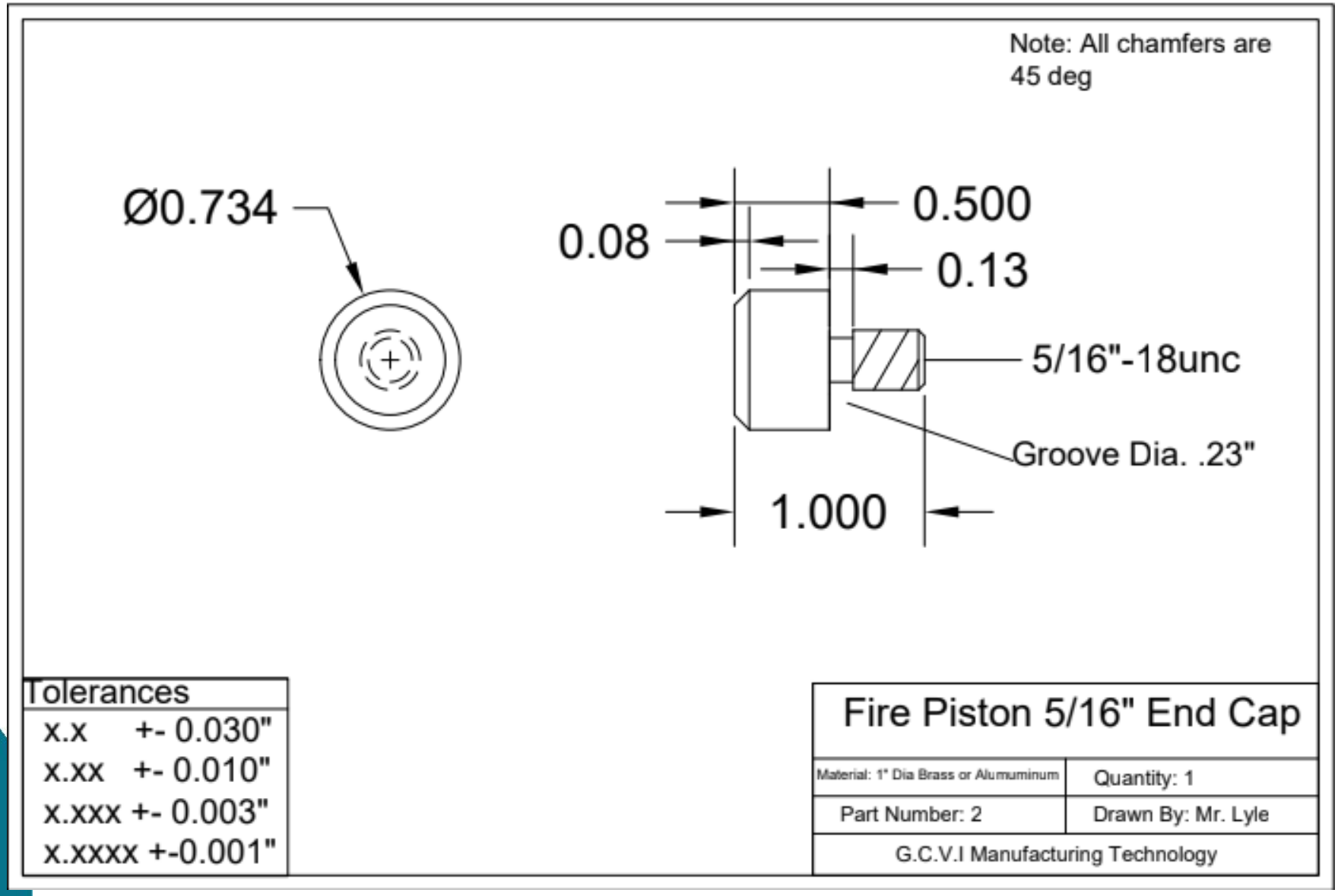


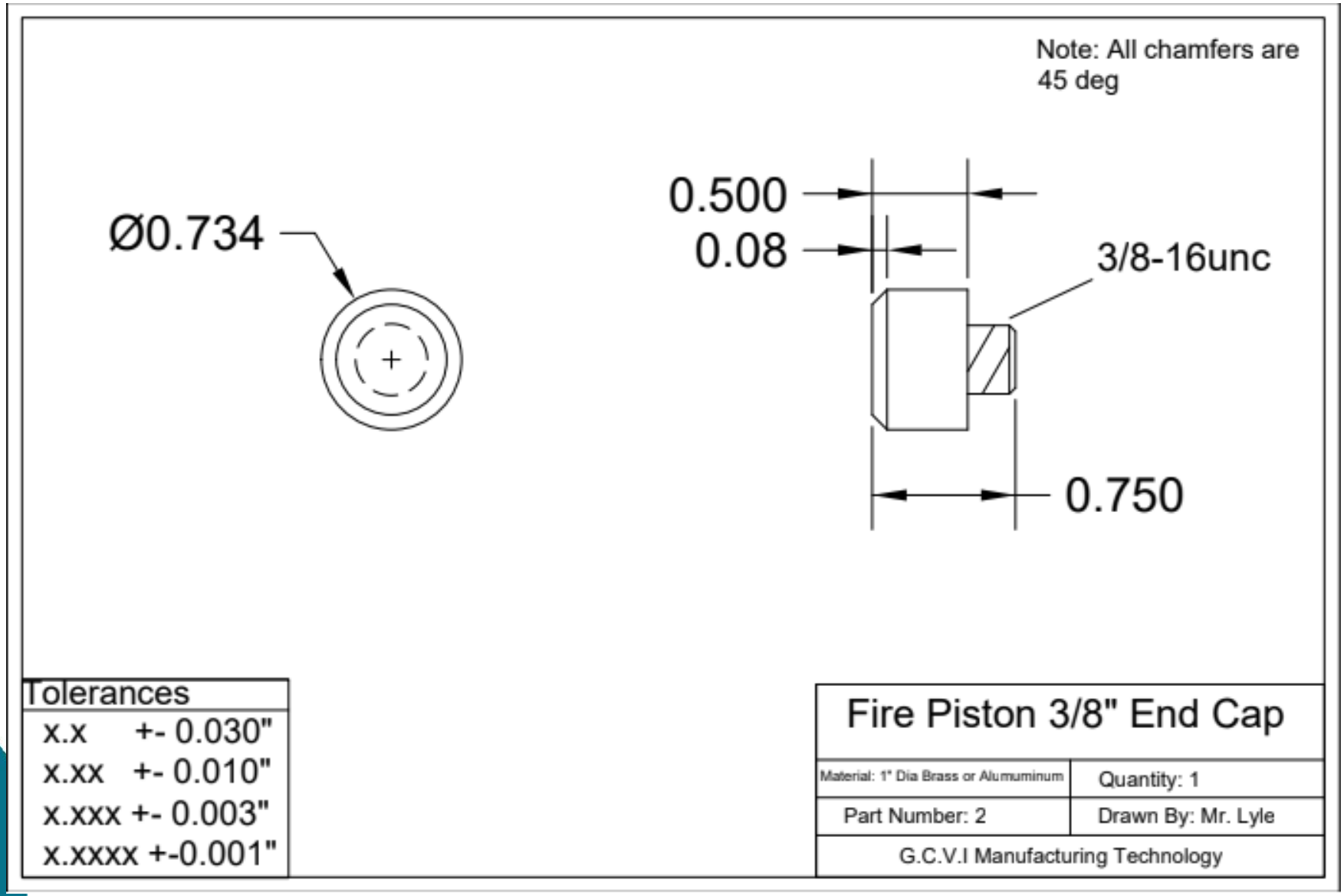
Appendix B - Fire Piston Picture

Appendix C - Fire Piston Blueprints




Note: -Groove diameters are critical, must be 0.281"
-Center drill on groove end is to hold char cloth
Ø0.3750 +0.0000 -0.0020
3.500
0.063
0.188
0.376
Drill F x 1.5" Deep
Tap 5/16"-18unc
Tolerances
x.x +- 0.030"
x.xx +- 0.010"
x.xxx +- 0.003"
x.xxxx +-0.001"
Fire Piston
Material: 1" Dia Brass or Alurnuminum
Quantity: 1
Part Number: 2
Drawn By: Mr. Lyle
G.C.V.I Manufacturing Technology


Note: All chamfers are 45 deg
Ø0.734
0.08
0.500
0.13
5/16"-18unc
Groove Dia. .23"
1.000
Tolerances
x.x +- 0.030"
x.xx +- 0.010"
x.xxx +- 0.003"
x.xxxx +-0.001"
Fire Piston 5/16" End Cap
Material: 1" Dia Brass or Alumuminum
Quantity: 1
Part Number: 2
Drawn By: Mr. Lyle
G.C.V.I Manufacturing Technology


Note: All chamfers are 45 deg
Ø0.734
0.500
0.08
3/8-16unc
0.750
Tolerances
x.x +- 0.030"
x.xx +- 0.010"
x.xxx +- 0.003"
x.xxxx +-0.001"
Fire Piston 3/8" End Cap
Material: 1" Dia Brass or Alumuminum
Quantity: 1
Part Number: 2
Drawn By: Mr. Lyle
G.C.V.I Manufacturing Technology

Appendix D - Metal Lathe SAFEDoc

Metal Lathe

1. Wear Personal Protective Equipment (PPE) such as safety glasses, safety goggles, face shields, gloves and proper clothing as appropriate. No loose clothing, long hair or jewelry is allowed in the shop.
2. Do not operate the lathe without the instructor's permission.
3. Be aware of the position of the on/off switches and emergency **STOP** button.
4. Make sure headstock, tailstock and tool rests are tight before operating.
5. Ensure your material is secure before starting motor.
6. Ensure all tool bits are sharp and without nicks. Show your instructor any problems with the tooling.
7. Do not operate lathe till you have established proper speeds, stops, tool heights and angles.
8. Make sure you have proper speeds and feeds for the type of material and tool bits, type of operation, and diameter of material. When in doubt, ask.
9. Assume a solid position with your body to the side of the tool. Be sure to have firm footing when operating the lathe.
10. Remove cut off material with a brush. Never use your hand.
11. Turn the lathe off immediately if it does not sound right or if there is excessive vibration.

AT ALL TIMES – IF IN DOUBT, SEE YOUR INSTRUCTOR

Appendix E - Lathe Safety Test

Lathe Safety Test

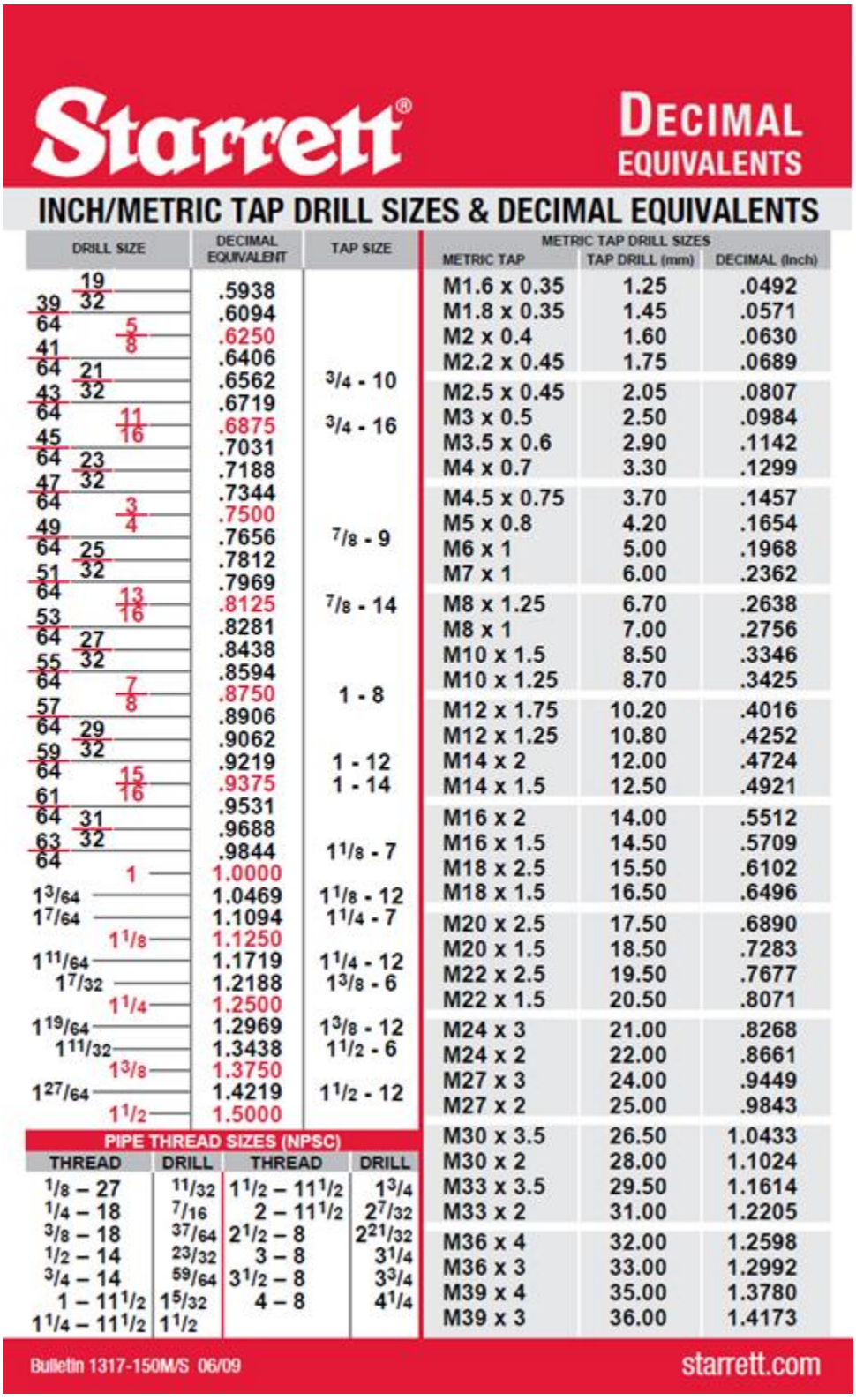
Student Name: _____

1. Always wear _____ when operating the lathe.
2. Be aware of the _____ and emergency stop buttons.
3. Always remove _____ with a brush not your _____.
4. Turn the lathe off if it does not _____right.
5. Ensure your _____ is secure before _____ the machine.
6. Make sure the chuck is _____before starting the lathe.
7. Always remove the _____before starting the machine.
8. Ensure you have the correct _____ speed before beginning to machine your workpiece.
9. Always let the Lathe _____ by itself.

Word Bank:

Safety Glasses Cutting Sound On-Off Starting Chips
Hands Material Tight Stop Chuck Key

Appendix F - Tap Drill Charts



Starrett®

DECIMAL EQUIVALENTS

INCH/METRIC TAP DRILL SIZES & DECIMAL EQUIVALENTS

DRILL SIZE	DECIMAL EQUIVALENT	TAP SIZE
19/64	.5938	
39/64	.6094	
5/8	.6250	
41/64	.6406	
21/32	.6562	3/4 - 10
43/64	.6719	
11/16	.6875	3/4 - 16
45/64	.7031	
23/32	.7188	
47/64	.7344	
3/4	.7500	
49/64	.7656	7/8 - 9
25/32	.7812	
51/64	.7969	
13/16	.8125	7/8 - 14
53/64	.8281	
27/32	.8438	
55/64	.8594	
7/8	.8750	1 - 8
57/64	.8906	
29/32	.9062	
59/64	.9219	1 - 12
15/16	.9375	1 - 14
61/64	.9531	
31/32	.9688	
63/64	.9844	1 1/8 - 7
1	1.0000	
1 3/64	1.0469	1 1/8 - 12
1 7/64	1.1094	1 1/4 - 7
1 1/8	1.1250	
1 11/64	1.1719	1 1/4 - 12
1 7/32	1.2188	1 3/8 - 6
1 1/4	1.2500	
1 19/64	1.2969	1 3/8 - 12
1 11/32	1.3438	1 1/2 - 6
1 3/8	1.3750	
1 27/64	1.4219	1 1/2 - 12
1 1/2	1.5000	

PIPE THREAD SIZES (NPSC)

THREAD	DRILL	THREAD	DRILL
1/8 – 27	11/32	1 1/2 – 11 1/2	1 3/4
1/4 – 18	7/16	2 – 11 1/2	2 7/32
3/8 – 18	37/64	2 1/2 – 8	2 21/32
1/2 – 14	23/32	3 – 8	3 1/4
3/4 – 14	59/64	3 1/2 – 8	3 3/4
1 – 11 1/2	1 5/32	4 – 8	4 1/4
1 1/4 – 11 1/2	1 1/2		

METRIC TAP DRILL SIZES

METRIC TAP	TAP DRILL (mm)	DECIMAL (Inch)
M1.6 x 0.35	1.25	.0492
M1.8 x 0.35	1.45	.0571
M2 x 0.4	1.60	.0630
M2.2 x 0.45	1.75	.0689
M2.5 x 0.45	2.05	.0807
M3 x 0.5	2.50	.0984
M3.5 x 0.6	2.90	.1142
M4 x 0.7	3.30	.1299
M4.5 x 0.75	3.70	.1457
M5 x 0.8	4.20	.1654
M6 x 1	5.00	.1968
M7 x 1	6.00	.2362
M8 x 1.25	6.70	.2638
M8 x 1	7.00	.2756
M10 x 1.5	8.50	.3346
M10 x 1.25	8.70	.3425
M12 x 1.75	10.20	.4016
M12 x 1.25	10.80	.4252
M14 x 2	12.00	.4724
M14 x 1.5	12.50	.4921
M16 x 2	14.00	.5512
M16 x 1.5	14.50	.5709
M18 x 2.5	15.50	.6102
M18 x 1.5	16.50	.6496
M20 x 2.5	17.50	.6890
M20 x 1.5	18.50	.7283
M22 x 2.5	19.50	.7677
M22 x 1.5	20.50	.8071
M24 x 3	21.00	.8268
M24 x 2	22.00	.8661
M27 x 3	24.00	.9449
M27 x 2	25.00	.9843
M30 x 3.5	26.50	1.0433
M30 x 2	28.00	1.1024
M33 x 3.5	29.50	1.1614
M33 x 2	31.00	1.2205
M36 x 4	32.00	1.2598
M36 x 3	33.00	1.2992
M39 x 4	35.00	1.3780
M39 x 3	36.00	1.4173

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DECIMAL EQUIVALENTS

INCH/METRIC TAP DRILL SIZES & DECIMAL EQUIVALENTS

DRILL SIZE	DECIMAL EQUIV.	TAP SIZE
80	.0135	
79	.0145	
1/64	.0156	
78	.0160	
77	.0180	
76	.0200	
75	.0210	
74	.0225	
73	.0240	
72	.0250	
71	.0260	
70	.0280	
69	.0292	
68	.0310	
1/32	.0312	
67	.0320	
66	.0330	
65	.0350	
64	.0360	
63	.0370	
62	.0380	
61	.0390	
60	.0400	
59	.0410	
58	.0420	
57	.0430	
56	.0465	
3/64	.0469	0 - 80
55	.0520	
54	.0550	
53	.0595	1 - 64, 72
1/16	.0625	
52	.0635	
51	.0670	
50	.0700	2 - 56, 64
49	.0730	
48	.0760	
5/64	.0781	
47	.0785	3 - 48
46	.0810	
45	.0820	3 - 56
44	.0860	
43	.0890	4 - 40
42	.0935	4 - 48
3/32	.0938	
41	.0960	
40	.0980	
39	.0995	
38	.1015	5 - 40
37	.1040	5 - 44
36	.1065	6 - 32
7/64	.1094	
35	.1100	
34	.1110	
33	.1130	6 - 40
32	.1160	
31	.1200	
1/8	.1250	
30	.1285	
29	.1360	8 - 32, 36
28	.1405	
9/64	.1406	
27	.1440	
26	.1470	
25	.1495	10 - 24
24	.1520	
23	.1540	
5/32	.1562	
22	.1570	
21	.1590	10 - 32
20	.1610	
19	.1660	
18	.1695	
11/64	.1719	
17	.1730	
16	.1770	12 - 24
15	.1800	
14	.1820	12 - 28
13	.1850	
3/16	.1875	
12	.1890	
11	.1910	
10	.1935	
9	.1960	
8	.1990	
7	.2010	1/4 - 20
13/64	.2031	
6	.2040	
5	.2055	
4	.2090	
3	.2130	1/4 - 28
7/32	.2188	
2	.2210	
1	.2280	
A	.2340	
15/64	.2344	
B	.2380	
C	.2420	
D	.2460	
1/4	.2500	
E	.2500	
F	.2570	5/16 - 18
G	.2610	
17/64	.2656	
H	.2660	
I	.2720	5/16 - 24
J	.2770	
K	.2810	
9/32	.2812	
L	.2900	
M	.2950	
19/64	.2969	
N	.3020	
5/16	.3125	3/8 - 16
O	.3160	
P	.3230	
21/64	.3281	
Q	.3320	3/8 - 24
R	.3390	
11/32	.3438	
S	.3480	
T	.3580	
23/64	.3594	
U	.3680	7/16 - 14
3/8	.3750	
V	.3770	
W	.3860	
25/64	.3906	7/16 - 20
X	.3970	
Y	.4040	
13/32	.4062	
Z	.4130	
27/64	.4219	1/2 - 13
7/16	.4375	
29/64	.4531	1/2 - 20
15/32	.4688	
31/64	.4844	9/16 - 12
1/2	.5000	
33/64	.5156	9/16 - 18
17/32	.5312	5/8 - 11
35/64	.5469	
9/16	.5625	
37/64	.5781	5/8 - 18

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THREAD SIZE	DRILL DIAMETER *Coarse Thread*	TAP DRILL SIZE
1-64	.0595	No. 53
2-56	.0700	No. 50
3-48	.0785	No. 47
4-40	.0890	No. 43
5-40	.1015	No. 38
6-32	.1065	No. 36
8-32	.1360	No. 29
10-24	.1495	No. 25
12-24	.1770	No. 16
1/4-20	.2010	No. 7
5/16-18	.2570	‘F’
3/8-16	.3125	5/16
7/16-14	.3680	‘U’
1/2-13	.4219	27/64
9/16-12	.4844	31/64
5/8-11	.5312	17/32
3/4-10	.6562	21/32
7/8-9	.7656	49/64
1″-8	.8750	7/8

THREAD SIZE	DRILL DIAMETER *Fine Thread*	TAP DRILL SIZE
0-80	.0469	3/64
1-72	.0595	No. 53
2-64	.0700	No. 50
3-56	.0820	No. 45
4-48	.0935	No. 42
5-44	.1040	No. 37
6-40	.1130	No. 33
8-36	.1360	No. 29
10-32	.1590	No. 21
12-28	.1820	No. 14
1/4-28	.2130	No. 3
5/16-24	.2720	‘I’
3/8-24	.3320	‘Q’
7/16-20	.3906	25/64
1/2-20	.4531	29/64
9/16-18	.5156	33/64
5/8-18	.5781	37/64
3/4-16	.6875	11/16
7/8-14	.8125	13/16
1″-14	.9375	59/64

Appendix G - Manufacturing Project Rubric

	Level 1 **50 - 65%**	**Level 2** **66 – 75%**	**Level 3** **76 – 85%**	**Level 4** **86 – 100%**
KNOWLEDGE\ UNDERSTANDING	DEMONSTRATES A LIMITED UNDERSTANDING OF IMPORTANT FEATURES ON THE BLUEPRINT	DEMONSTRATES SOME UNDERSTANDING OF IMPORTANT FEATURES ON THE BLUEPRINT	DEMONSTRATES A GOOD UNDERSTANDING OF IMPORTANT FEATURES ON THE BLUEPRINT	DEMONSTRATES A THOROUGH UNDERSTANDING OF IMPORTANT FEATURES ON THE BLUEPRINT
THINKING	USES CRITICAL/ CREATIVE THINKING SKILLS TO EXPLAIN PROJECT REQUIREMENTS WITH LIMITED EFFECTIVENESS	USES CRITICAL/ CREATIVE THINKING SKILLS TO EXPLAIN PROJECT REQUIREMENTS WITH SOME EFFECTIVENESS	USES CRITICAL/ CREATIVE THINKING SKILLS TO EXPLAIN PROJECT REQUIREMENTS WITH CONSIDERABLE EFFECTIVENESS	USES CRITICAL/ CREATIVE THINKING SKILLS TO EXPLAIN PROJECT REQUIREMENTS WITH A HIGH DEGREE OF EFFECTIVENESS
COMMUNICATION	COMMUNICATES ABOUT THE MACHINING PROCESS IN A LIMITED OR UNCLEAR WAY	COMMUNICATES ABOUT THE MACHINING PROCESS WITH SOME CLARITY	COMMUNICATES ABOUT THE MACHINING PROCESS WITH CONSIDERABLE CLARITY	COMMUNICATES ABOUT THE MACHINING PROCESS WITH A HIGH DEGREE OF CLARITY
APPLICATION	CREATES FINISHED PRODUCT OF LIMITED QUALITY WITH MANY FLAWS	CREATES FINISHED PRODUCT OF MODERATE QUALITY WITH SOME FLAWS	CREATES FINISHED PRODUCT OF CONSIDERABLE QUALITY WITH FEW FLAWS AND A GOOD LEVEL OF DETAIL	CREATES FINISHED PRODUCT OF HIGH DEGREE OF QUALITY WITH NO FLAWS AND A HIGH LEVEL OF DETAIL

Instructor Feedback:

_____

_____

_____

Final Grade: _____

Appendix H - Fire Piston Unit Plan

Apprenticeship Resource Lesson Plan

Topic: **Fire Piston Project**

Student Activity	Curr	Content	Teacher Activity
Students should already have these prerequisite skills prior to starting this project, ● Shop safety ● OCTE Metal Lathe Safety ● Measurement ● Lathe Components		Prior knowledge and skills	Teacher to assess prior knowledge and skill set of students **NOTE:** Because this is a practical assignment, timing and demonstrations that need to be taught will vary based on the skill level of the students.
Students are engaged with discussion and brainstorming ideas (10 - 15 minutes)		Lead in	Ask students the leading question "You are on a hike with your friends when you get separated and lost in the wilderness. What are some essentials you would need to survive overnight in the wilderness?" Then discuss with the class and write ideas on the board.
Students watch video (3 minutes)		Fire Piston Video	
Students engage in project introduction and demonstration (5 minutes)		Project introduction and demonstration	Show video on the fire piston
Students select small groups to work in and gather around the lathe for instruction, safety, and engine lathe demonstration (3-5 minutes)	**Activity #1**	Selection of groups	Have completed piston ready and demonstrate how it works to the students
Students demonstrate proper set up and operation of the lathe (15-20 min. /group)		Lathe setup, safety and demonstration	Split up students into small groups for the demo (if first time students, pair them with experienced students)
Students engaged in the machining process and layout of their project. If they are not using the lathe, they are watching		Layout and machining process	Demonstrate the setup of the machine for Specific

their partner or partners to make sure safe practices are being followed, correct set up and machine operation are adhered to. (5 -7 days, depending on number of lathes, size of groups, length of classes, materials for projects, etc.) ***Safety Concerns*** ● Students must follow all safety rules set by the school board, Technology department and the teacher ● Students must have safety passport or signed school board safety rules to enter shop ● Safety glasses must be worn ● No loose or baggy clothing ● Proper footwear is required ● Students must follow safe machine operating procedures ● Only one person uses a machine at any one time ● Do not distract others ● No running or horseplay in the shop	**Activity #2**	for the caps of the Fire Piston Project Layout and machining process for the barrel of the Fire Piston Project Safety	Processes and record student demonstrations Students set up and begin the machining process of their parts. Pause class periodically to demonstrate next steps and next process. Repeat steps from Activity #1 for Activity #2 where required ***Additional Teacher Notes*** ● Make sure material is prepped for the demo and shop power is on ● Ensure all machines have required tooling ● Ensure all tooling needed for threading is available ● Have demonstration material prepped ● Have a completed project ready to demonstrate to the students

Expected Outcomes	Assessment of Outcomes
The student will: ● Students will learn basic lathe operation ● Students will understand tap drill sizes and how to read the tap drill chart ● Students will learn/review the process of cutting threads using taps and dies ● Students will learn the process of reaming a hole ● Students will learn the process of reaming cutting a groove	● Students follow all shop safety rules ● Students come prepared to cut material (Safety Glasses, No loose clothing or jewelry) ● Students will be able to identify the parts of the metal lathe. ● Students will be able to select the correct RPM for the material specified ● Students will be able to select the correct tooling for the process required ● Students will be able to complete basic metal processes e.g. end facing, drilling, parallel turning ● Students will be able to accurately cut internal threads using a tap

	• Students will be able to cut external threads using a die • Students will understand how to select the correct drill size when tapping a hole • Students will have a basic understanding dimensional tolerance

Motivation	Curriculum Expectations
Student can manufacture their own useful tool	A2.1, A2.4, A4.1, A4.2, A4.7, A4.8, B2.2, B2.3, B3.1, B3.2 B3.3, B3.4, B4.1, B4.2, B4.3

Reflections	Instructional Materials
Ask the students leading questions regarding their prior knowledge on processes or best guesses	**Handouts** • Fire Piston Cylinder Blueprint • Fire Piston Blueprint • .3125 End Cap Blueprint • .375” End Cap Blueprint • OCTE Metal Lathe Handout • Metal Lathe Quiz • Fire Piston Rubric **Materials** • 1” diameter Brass or Aluminum • O-rings • Char Cloth **Exemplars** • Completed Fire Piston Picture **Websites for Teachers** • Tap Drill Chart Link: https://www.americanfastener.com/tap-and-drill-size-chart/ **Videos** • OCTE ToolSAFE video TMJ Engine Lathe • DIY Survival: Fire-Starting with a Fire Piston | Dual Survival

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