Project Final Report for

5-Axis Penta CNC Setup

in the partial fulfillment of

TECH 7991

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Executive Summary

During this project, a Penta Pocket NC V2-10 was set up and brought into calibration. Additionally, student labs were developed to be run on the machine. The intention was to use Siemens NX for CAM and post processing, but this did not work out. Instead, Fusion 360 was selected. Unexpected accuracy issues with the CNC machine caused delays to other aspects of the project, but were remedied.

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Introduction

I was tasked with making the university's Penta Pocket NC V2-10 5-axis CNC machine operational and developing a series of student labs for it. This involved making test cuts, learning the machine's CAD/CAM requirements, and troubleshooting any issues that arose. Initially, the machine suffered from accuracy problems. I worked with the manufacturer to resolve these issues and calibrate the machine. After the machine was functional, I created a model and lab guides for multi-axis machining.

The project was broadly successful except for technical difficulties that resulted in Siemens NX not being used. Fusion 360 was selected for CAD/CAM instead.

Review of Objectives

The main objectives for this project were to make the University's Pocket NC V2-10 5-axis CNC mill fully operational, prepare Siemens NX for use with the machine, document a workflow for students to use the NX post processor, and to develop a 3D CAD model for future students to program CAM with. I was also asked to accommodate requests that professor Hewitt and professor Hale had for the machine. Professor Hewitt requested that I develop 3, 4, and 5-axis labs for the machine along with lab guides for each.

Review of Deliverables

The deliverables for this project were:

- An operational Penta Pocket NC V2-10 CNC machine
- A post processor for Siemens NX that works with the Pocket NC
- Documentation on how to use the NX post processor
- A CAD model for students to learn how to use the machine with
- 3, 4, and 5-axis labs
- Lab guides

Review of Evaluation Methods

The machine was evaluated by verifying that the parts it produces were within the machine's claimed accuracy. The post processor for Siemens NX, post processor documentation, the CAD model, labs, and lab guides will all be evaluated by a pass/fail system.

Technical Implementation

I began the project by attempting to install the machine tool kit for the Pocket NC in Siemens NX. This led me to discover that machine tool kits can only be added to NX if the user has admin privileges. Due to the fact that NX is only available through the university's computers, this meant that I had to create a work order for the machine tool kit to be installed by the university's IT department.

Because a work order could take several weeks to complete, I wanted to ensure my instructions did not miss any important steps or features that were required to make the post processor work. To gain experience with creating and post processing programs for the Penta, I decided to find an alternative to NX. Autodesk Fusion 360 was selected as a substitute for NX because it is widely supported and is free for educational purposes.

After learning the basics of Fusion, I began running practice programs on the machine. At this point, I discovered that parts were not being cut to the programmed height. Instead, the first machining pass was significantly deeper than programmed. I determined that the machine's B-table offset was not set to the value written in the documentation that was shipped with the machine. I contacted Penta, obtained the correct value, and updated the value in the machine. This did not fully resolve the issue, however. After researching the issue further, I determined that the automatic tool setter was likely the cause. I found instructions and a spreadsheet from Penta on how to recalibrate the tool setter and followed the process. After the tool setter recalibration, the machine cut parts to the correct depth.

Troubleshooting the B-table offset and tool setter gave me enough experience that I felt confident in completing the NX work order. I finished writing the work order for NX and submitted it, and waited for the change to take place.

While waiting on the work order, I developed and machined more complicated models. When machined, these models showed irregularities in their surface finish and gouges in some areas. I worked extensively in Fusion 360 to identify any possible toolpath or CAM issues. No issues were found, but the machine continued to produce gouged parts.

Development of labs began at this point and, after meeting with professor Hewitt, I determined several design goals for the labs. The stock used in lab needed to be made of prototyping wax, cycle times for each lab needed to be under 10 minutes, and no tool changes should be required during a lab. Since prototyping wax is typically recycled and reused, the lab parts must be able to be produced with stock from standard sized molds. I selected a three inch diameter cylindrical candle mold to test producing stock in and determined that it was suitable.

The Penta is not very rigid, fast, or powerful. This meant that tool selection was critical in reducing lab times. I researched and acquired suitable tooling to experiment with while I continued to develop labs.

After developing a lab part that could be used for a 3-axis lab, I noticed that the machine created parts with significant, but consistent, errors. To help rule out a software issue, I updated the machine to the latest software version, but there was no change. At this point, I developed multiple test parts to help identify the issue and initiated contact with Penta with the results. As part of troubleshooting I measured the backlash of the X and Y axes, measured the positional accuracy of the B-table, and performed an X/Y origin point test. The origin point test showed that the X-axis had a significant error. I received instructions on how to recalibrate all the axes of the machine and this ultimately resolved the issue.

At this point I had a better understanding of what the features the lab parts would have, so I researched tooling to recommend to the university. The list of tooling was submitted, and the university acquired it promptly.

The work order for NX still had not been completed by this point. Upon inquiring, I discovered that, due issues within Outlook and a miscommunication on my part, the work order had not been sent to the IT department. I resubmitted the work order and received word that the university had lost its NX license. This prevented the machine tool kit being installed. Due this, I was unable to meet this deliverable of the project.

After meeting with professor Hewitt, it was determined that Fusion could be used in place of NX without issue. With this decision, I created labs and determined that the recycled stock was too large to easily orient the part such that the machine could reach all of the features. Furthermore, the vise on the Penta does not hold the stock in-line with the B-table's axis of rotation. This offset caused issues with some simultaneous toolpath types in Fusion. I felt that the simultaneous tool paths had educational value, so I developed and machined an extension for the vise that holds the recycled stock correctly.

Evaluation Results

The Pocket NC V2-10 has a claimed accuracy of 0.005 inches. However, the machine was miscalibrated from the factory and could not achieve these results. The tool setter was measured to be off by 0.0494 inches (see Figure 1) at the start of the calibration process. After recalibration, the error was successfully brought down to 0.0002 inches (see Figure 2). Measurements taken during the linear axis recalibration process showed that the X-axis had an error of 0.026 inches and the Y-axis had an error of 0.0029 inches when the machine was received (see Figure 10). After recalibration, the X-axis error was under 0.0005 inches and the Y-axis error was under 0.001 inches (see Figure 10). The updated B-table offset value in Figure 6 indicates that the Z-axis had an error of 0.0009 inches. Subsequent testing after recalibration showed that the machine was fully operational after the linear axis calibration with errors at or below Penta's accuracy claim of 0.005 inches.

Conclusions

Overall, the project was successful and the machine performs to its specifications. All deliverables were met except for the two related to NX. While it is unfortunate that the machine does not currently work with NX, Fusion is a satisfactory alternative with a large amount of support. I gained valuable experience with CNC setup and calibration procedures due to this project. In the process of developing lab guides, I gained significant experience in Fusion 360, which will be helpful as I work towards the completion of my degree and after I graduate.

Appendix A – Detailed Testing Results

Tool Setter Calibration

B-table offset	0.8322					
Z touch-off position	-0.9770					
1-2-3 dimension	3.0000					
Manually measured tool length offset	-3.1448					
Tool Probe						
Probe X	1.45					
Probe Y	-2.34					
123_Offset Initial	-0.3168	-0.3613	-0.3655	-0.3664	-0.3664	-0.3664
Tool Probe TLO	-3.1942	-3.1495	-3.1458	-3.1446	-3.1446	-3.1446
Error	-0.0494	-0.0047	-0.0010	0.0002	0.0002	0.0002
Probe_Sensor_123_Offset New	-0.3613	-0.3655	-0.3664	-0.3662	-0.3662	-0.3662

Figure 1 - Tool Setter Recalibration Attempt One

B-table offset	0.8366					
Z touch-off position	-1.9750					
1-2-3 dimension	2.0000					
Manually measured tool length offset	-3.1384					
Tool Probe						
Probe X	1.45					
Probe Y	-2.34					
123_Offset Initial	-0.3168	-0.3220	-0.3625	-0.3657	-0.3667	-0.3667	-0.3667
Tool Probe TLO	-3.1442	-3.1834	-3.1419	-3.1395	-3.1386	-3.1386	-3.1386
Error	-0.0058	-0.0450	-0.0035	-0.0011	-0.0002	-0.0002	-0.0002
Probe_Sensor_123_Offset New	-0.3220	-0.3625	-0.3657	-0.3667	-0.3669	-0.3669	-0.3669

Figure 2 - Tool Setter Recalibration Attempt Two

Machine Accuracy Troubleshooting

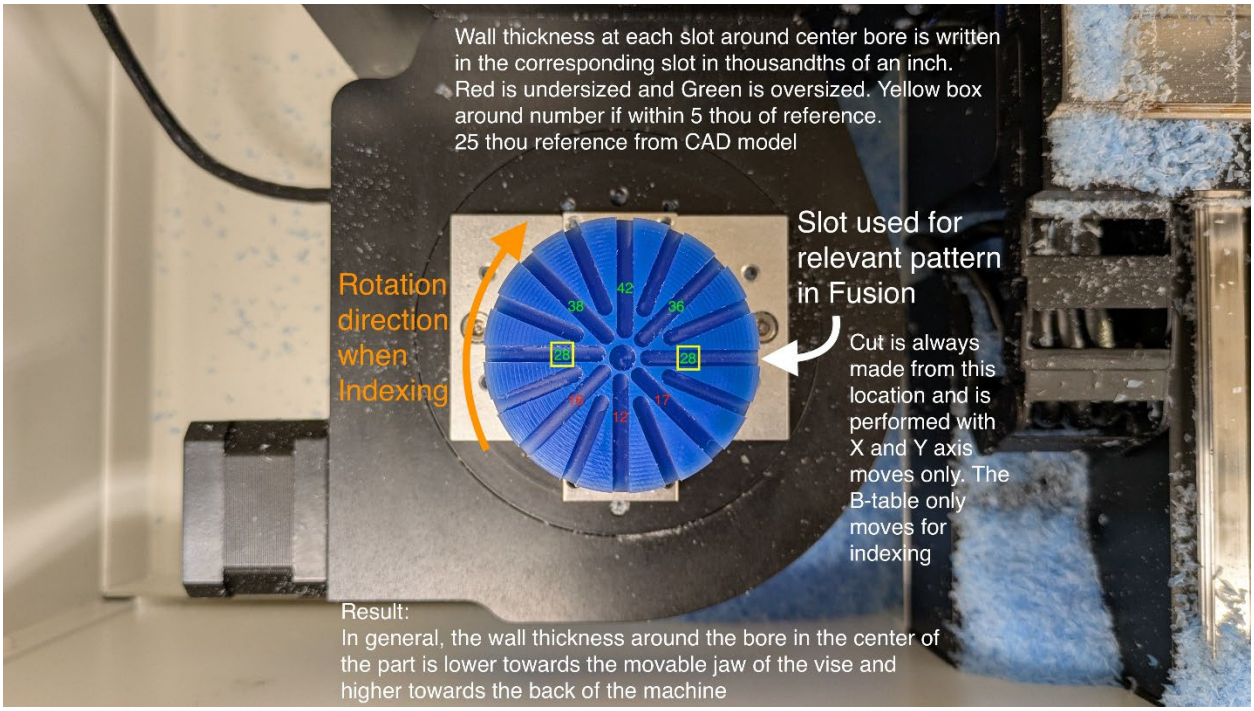

Figure 3 - Test Part One With B-Table Movement

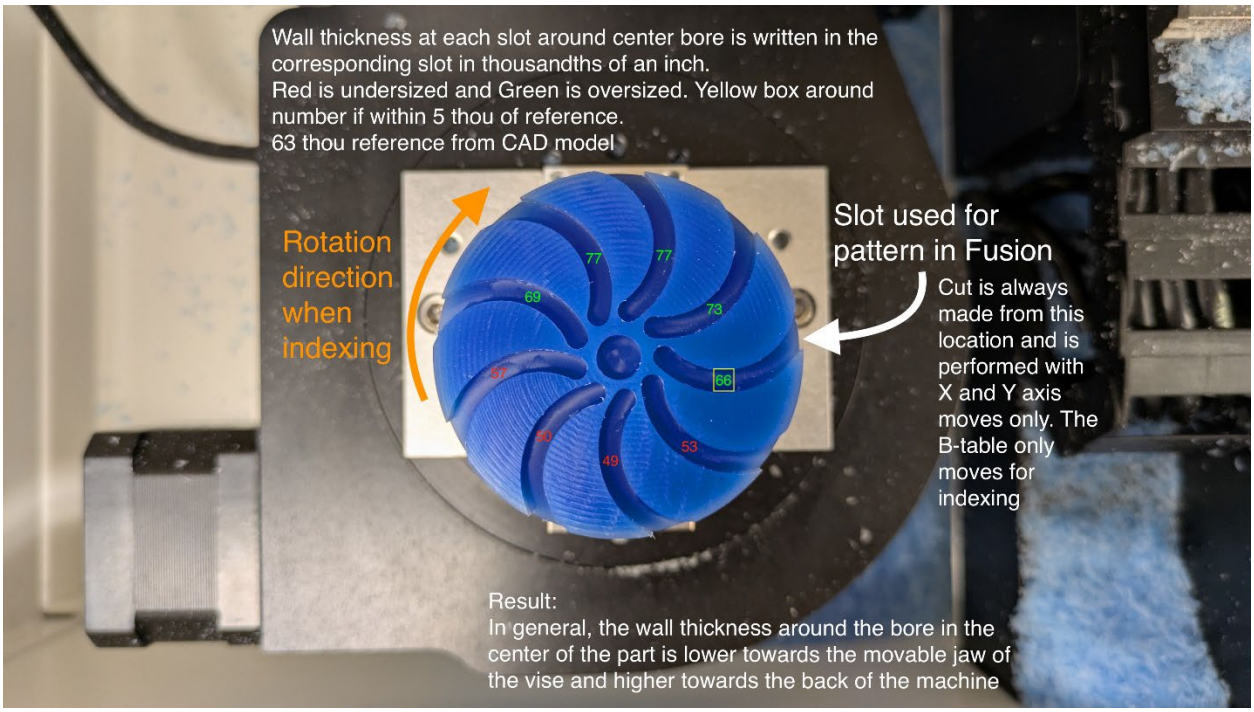

Figure 4 - Test Part Two With B-Table Movement

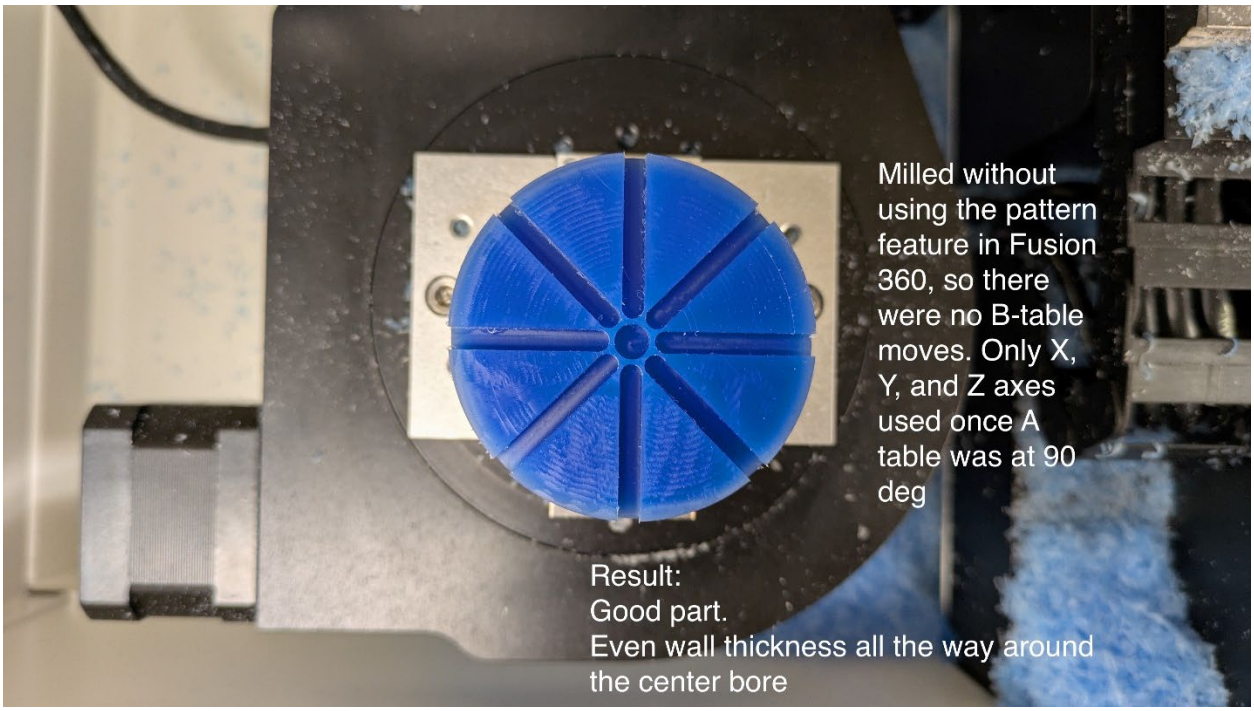

Figure 5 - Simplified Test Part One Without B-Table Movement

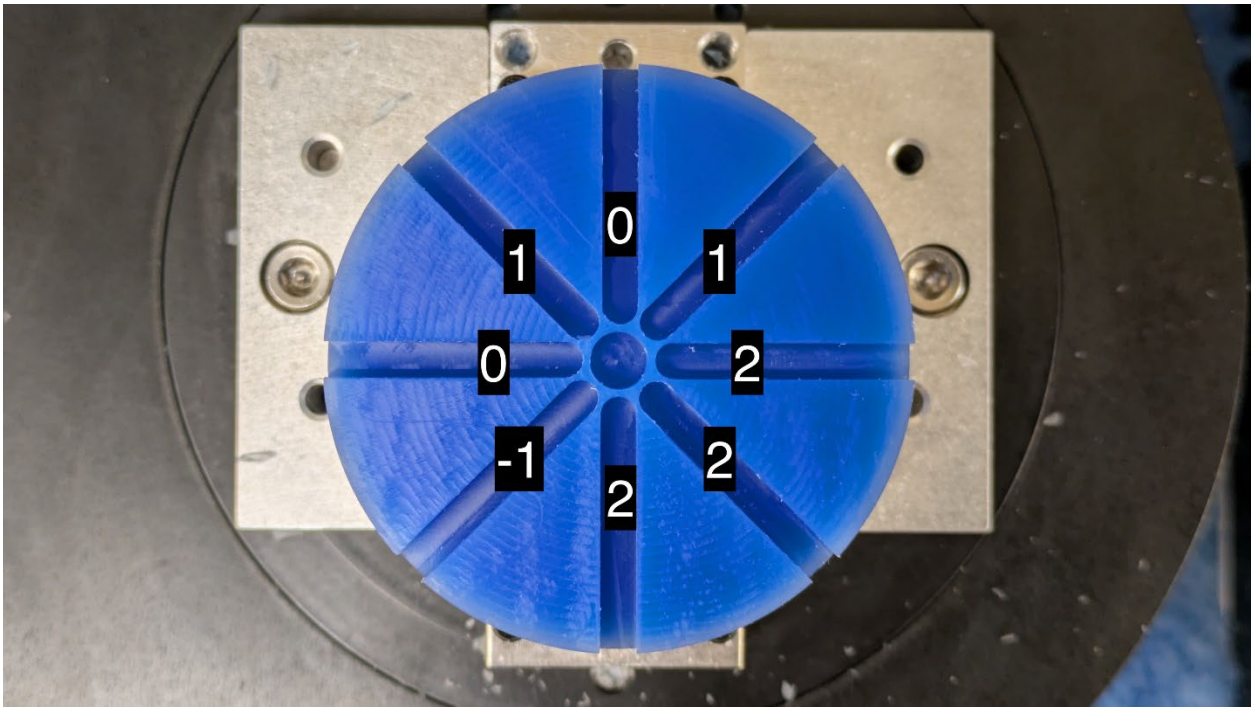

Figure 6 - Typical Errors in Thousandths After Calibration

Linear Axis Recalibration

Calibration Summary		
Machine Serial Number:	3069	
	AXIS	HOME_OFFSET
	X	2.6162
	Y	2.4922
	A	-17.5739
	B	-5.6026
PROBE_B_TABLE_OFFSET:		0.8375
PROBE_SENSOR_123_OFFSET:		-0.3688

Figure 7 7 - Linear Axis Recalibration Summary With New B-Table Offset

CMM Probe Data	
CMM X Home Offset	2.629060635
CMM Y Home Offset	2.494569419
CMM A Home Offset	-17.5738967
CMM B Home Offset	-5.602611294
CMM PROBE_B_TABLE_OFFSET	0.8366
CMM PROBE_SENSOR_123_OFFSET	0.3667

Figure 8 8 - CMM Probe Data From Factory

123 Block Measurement	
123 Block Z DRO Value:	-2.0118

Figure 9 9 - Manually Measured Tool Length Offset

X and Y Measurement	
X diameter	0.575
Y diameter	0.572

Figure 10 10 - Measured Distance Across Flats on Calibration Part

X, Y, and Z Touch-Offs					
X Home Offset	2.629060635	2.6167	2.6162	2.6162	2.6162
New X Home Offset	2.6167	2.6162	2.6162	2.6161	2.6161
X error	0.026	0.001	0	0.0002	0.0003
Y Home Offset	2.494569419	2.4932	2.4922	2.4922	2.4922
New Y Home Offset	2.4932	2.4922	2.4917	2.4918	2.4919
Y error	0.0029	0.002	0.001	0.0009	0.0006
Measured Values					
X touch-off A90	0.376	0.351	0.35	0.3502	0.3503
Y touch-off A90	0.3499	0.349	0.348	0.3479	0.3476
Z touch-off A0			-2.886	-2.887	-2.8871
Calculated Values					
B-table Offset	3.7113	3.7238	0.8383	0.8372	0.83705
Tool Length Offset	-0.3005	-0.288	-3.1735	-3.1746	-3.17475

Figure 11 11 - Touch-Off Measurements and Calibration Data for X, Y, and Z Axes

Tool Length Probe Calibration								
Calculated Tool Length Offset	-3.174283333							
PROBE_SENSOR_123_OFFSET	0.3667	0.364975	-0.29519	-0.360995	-0.36812	-0.368765	-0.36876	-0.36876
Tool Probe TLO	-3.1762	-3.9078	-3.2474	-3.1822	-3.175	-3.1735	-3.1735	-3.1736
Error	-0.001916667	-0.733516667	-0.073116667	-0.007916667	-0.000716667	0.000783333	0.000783333	0.000683333
123_Offset New	0.364975	-0.29519	-0.360995	-0.36812	-0.368765	-0.36806	-0.36806	-0.36815

Figure 12 12 - Final Measurements and Calculations For Tool Setter Calibration

Appendix B – Detailed Drawings

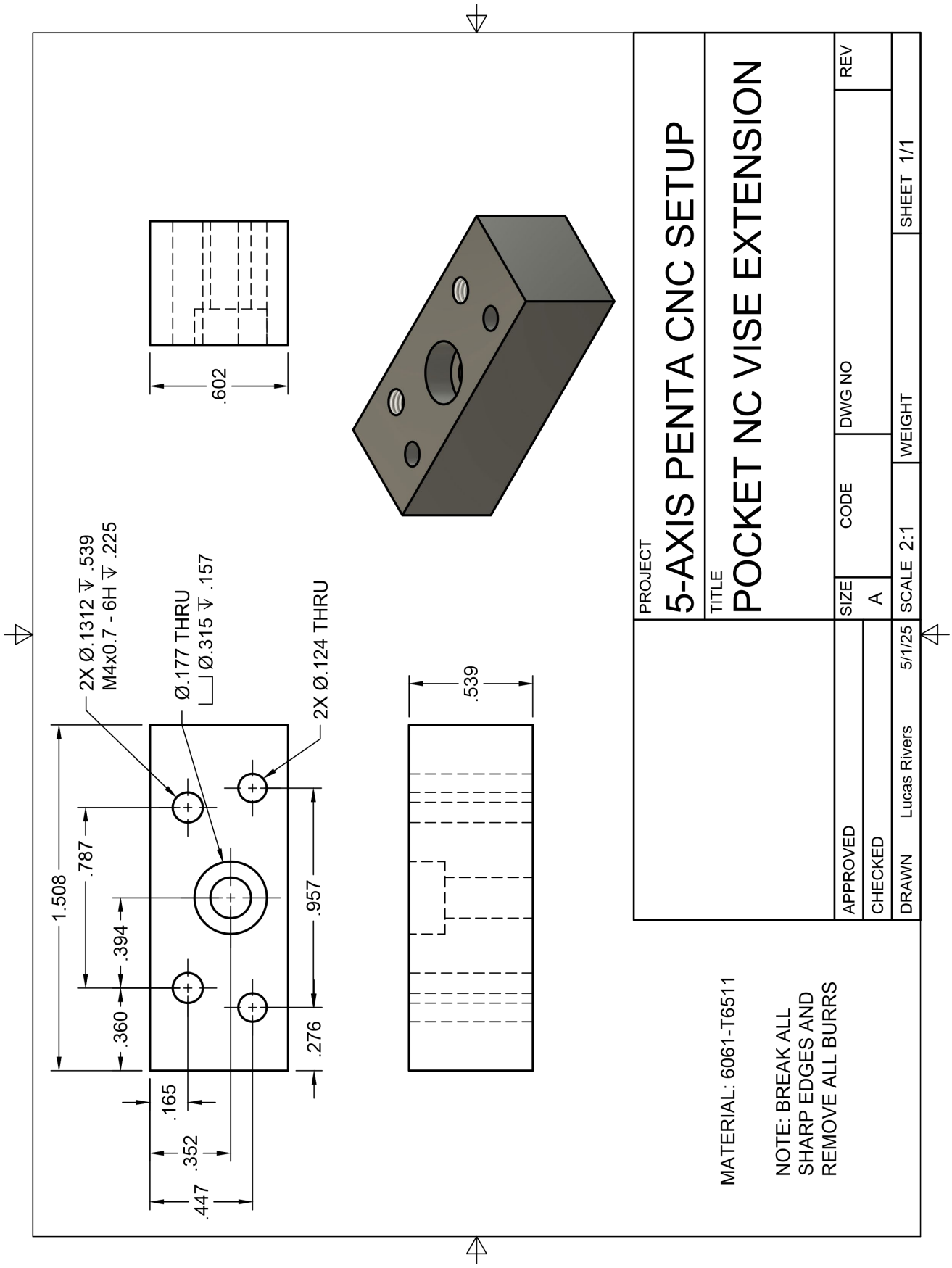

Figure 13 13 - Vise Extension Drawing

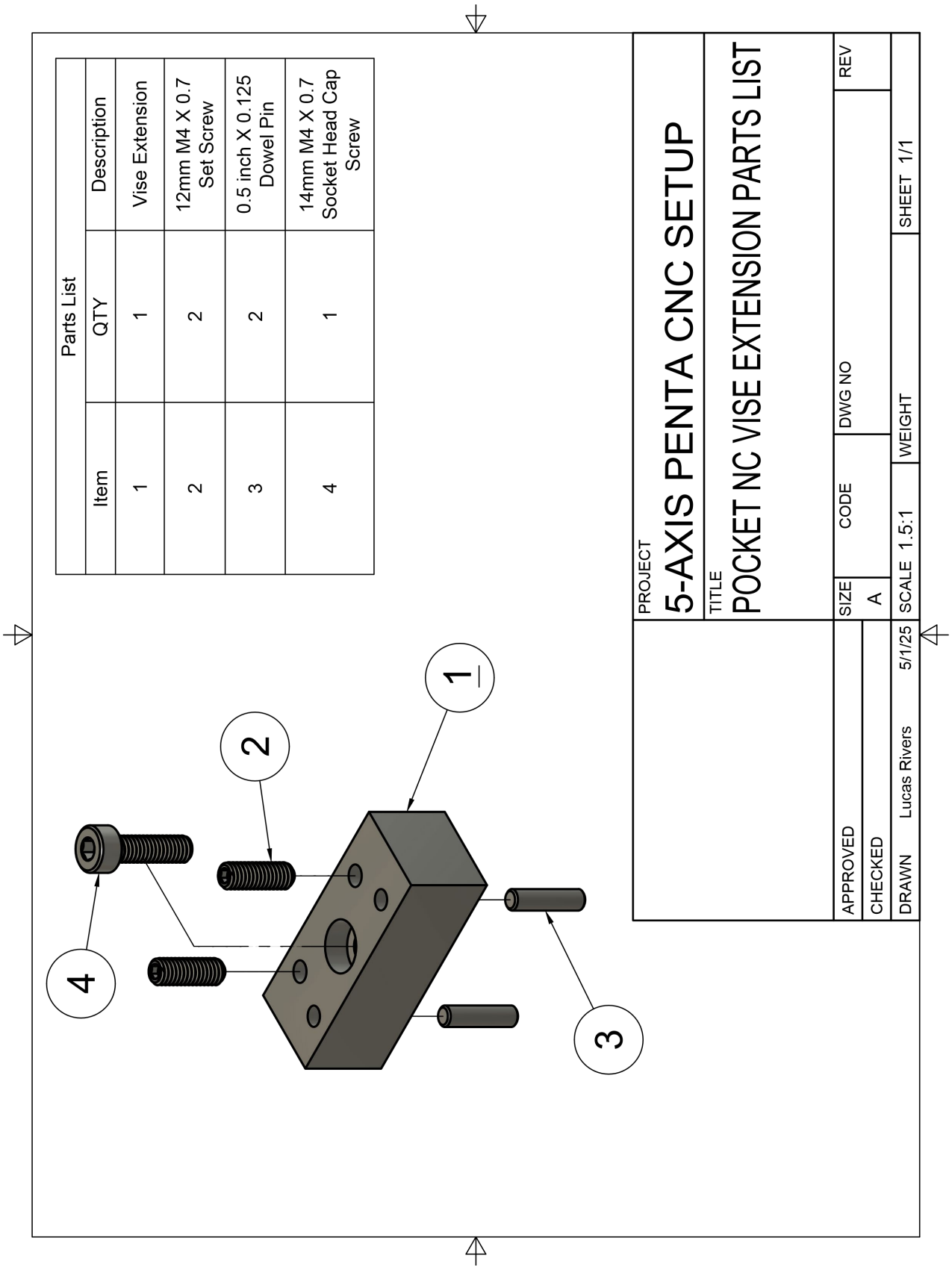

Figure 14 14 - Vise Extension Parts List

Appendix C – Developed Guides

See the linked folder named “Developed Guides” in the “TECH7991_lrivers” documentation files that were submitted along with this report.