Grand Valley State University
Seymour and Esther Padnos College of Engineering and Computing
School of Engineering

Detailed Design Document

Rod Storage Device

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EGR 485 Senior Engineering Project
Section 903

Sponsor: Bob Thompson
Advisor: Christopher Pung

GVSU Capstone Project 2024

Detailed Design Document Approval

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Asher Berends - Secretary

Signature ___________________________________ Date___________

Caleb Capps - Team Captain

Signature ___________________________________ Date___________

Darwin Bowman

Signature ___________________________________ Date___________

1. Project Summary

The goal of this project is to design and manufacture a device capable of presenting steel rods upright to an operator for ease of access.

1.1 Project Picture

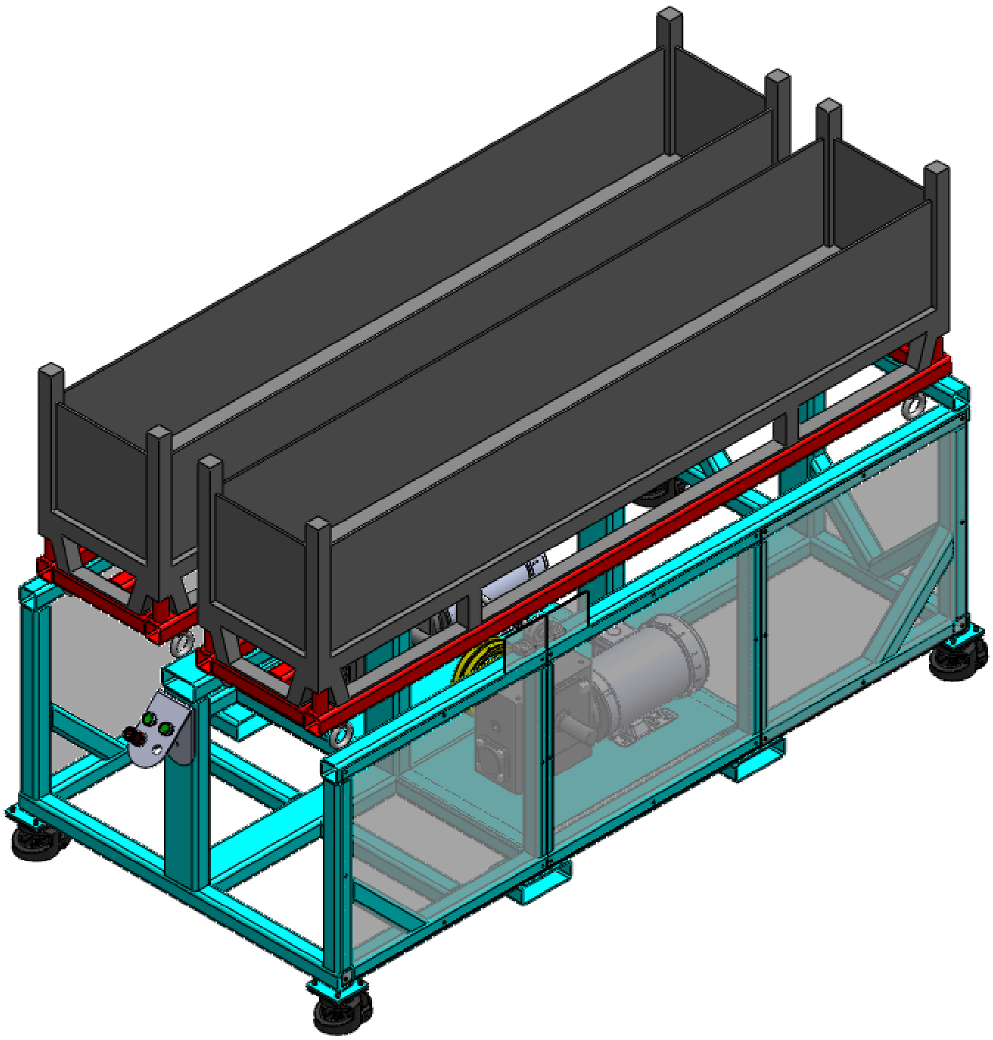


Figure 1. Rod Storage Device

1.2 Original Proposal

Figure 2. Original Sponsor Proposal

The platform is attached to the frame on a pivot point that allows for the rotation of the rods from horizontal to vertical position. Once the rod bin is placed onto the platform, an operator lifts and pivots the platform until it is in an upright position. Next, the operator tilts up the support beam that will keep the platform in an upright position and uses pins to lock it into position. While efficient in theory, the design offers several drawbacks. If the operator lets go of the platform while lifting it, there is no safety mechanism to keep the platform from falling back down. This poses a problem due to the heavy weight of a fully loaded bin. Additionally, the weight of the bins prevents the operator from lifting the platform, as each fully loaded bin weighs a minimum of 1000 lbs.

1.3 Functional Overview

Early concepts were evaluated and ranked based on the features of each concept. Taking the best features of each concept, the final concept for the project was made as shown in Figure 1. Some concepts such as a HiLo-powered mechanism for rotating the loaded bins were rated high in some categories but eventually eliminated due to major safety concerns. The points below detail a general view of the key components used in the final concept.

- Moveable: Casters with HiLo Pockets
- Framing Material: Steel Tubing
- Rotation Mechanism: Winch & Cable
- Pivot Point: 25 in from the side of the platform which is lowest when the bin is presented to the operator
- User Interface: Buttons
- Control Device: PLC
- Two bins loaded next to each other
    - Narrower base area per bin

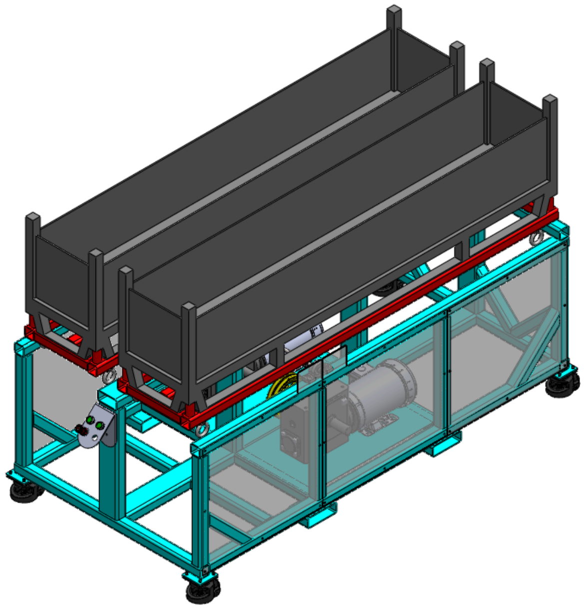


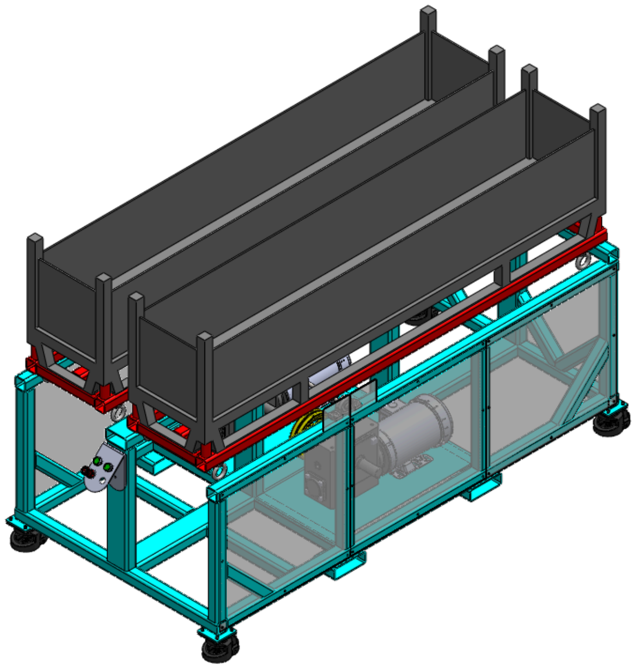
Figure 3. Project Concept

2. Specifications Summary

- The total cost of the project is $8,000 with an upper limit of $10,000. This cost includes materials, services, shipping, and any other miscellaneous costs.
- The maximum weight of the device should not exceed 2500 lbs and will be tested by weighing the device on a scale.
- The cycle time for operation is the time it takes to offload and reload the device. The time to complete the cycle should be no more than 7 minutes and will be tested by using a stopwatch.
- The maximum weight to be supported will be 3100 lbs and will be verified by calculations as well as field testing. All welds will be visually inspected to ensure compliance with AWS B1.11/B1.11:2015 (Appendix F).
- Electrical disconnects such as lock-out tag-out (LOTO) and breakers will be used to comply with OSHA 1910.47 (Appendix G).
- If the device is struck from the side it should not tip until it reaches an angle of 28 degrees off of horizontal. This will be tested with calculations using the center of mass of the device in both the loaded and unloaded states.
- The life span of the device will be a minimum of 260 cycles.
- The electronics will be protected from splashes from liquids according to IPX-4 and NEMA standard Type 2. The electrical box will be exposed to water by splashing and the interior will be inspected to determine if there is any infiltration of water.

- An emergency stop will be provided in order to halt the machine in case of an emergency. This will be tested by operating the machine activating the emergency stop and verifying the machine halts operation and that no live hazards are present while halted.

3. Design Summary



3.1 Frame

The frame was selected to be made out of 2 in x 2 in x 3/16 in steel tubing. The tubing will be cut into sections based on the specified lengths detailed in the drawings in the appendix section. The tubings themselves will then be welded together to create the frames.

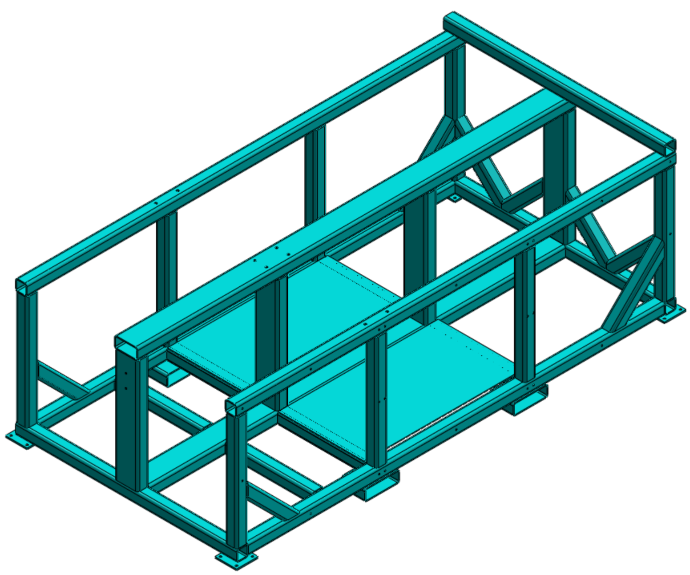


Fig 4: Weldment Subassembly

3.2 Motor

The figure below shows the motor picked for the final concept design. Moreover, the primary function of the motor will be to rotate the rod bins to an upright position as specified in the project summary. Based on calculations specified in Appendix C, the motor chosen for the mechanism has an rpm of 1800 to ensure it can be lifted from rest.

Figure 5. Selected winch - IronHorse Motor MTRP-002-3BD18

Voltage Rating	240 VAC
Horsepower	2 hp
Number of Phases	3 phase
Speed	1800 rpm
IP Rating	IP43

Table 1. Key motor specifications

3.3 Bearings

Figure 6 below shows the oil-embedded two-inch bearings that will be used for the final concept design. Moreover, it was intended to assist in transmitting motion and forces, preventing any metal-to-metal contact between the subsequent moving parts within the mechanism.

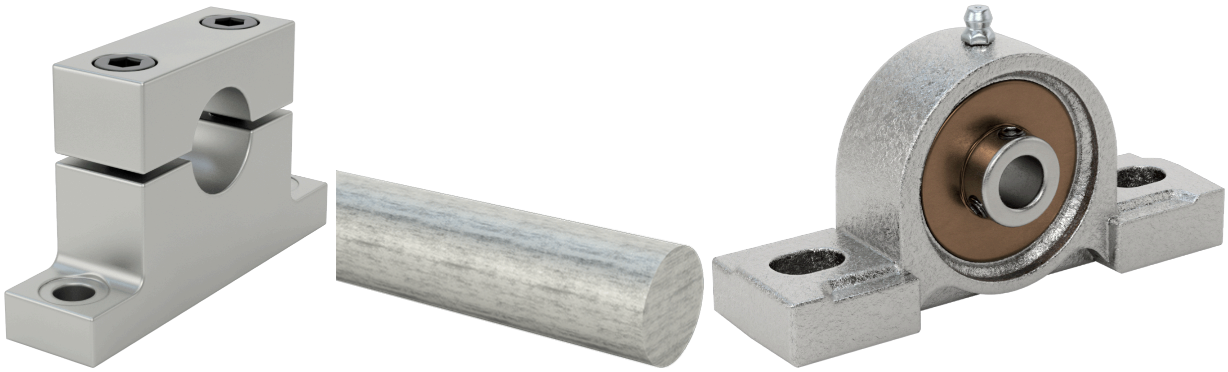


Figure 6. Selected winch - McMaster-Carr 3075T58

3.4 PLC

Figure 7 represents the PLC being used as the control system for this project. The port details and power are specified below, and the schematics are specified in Appendix D. In the future if the sponsor wants to expand this project to incorporate 4 boxes, the plc overview for that can be found in Appendix E.

Figure 7: Allen-Bradley 1766-L32BXBA MicroLogix 1400
Small Programmable Logic Controller

Table 2. PLC Port specifications

Digital input ports	12 fast 24V DC 8 24V DC
Digital output ports	6 Relay 3 Fast 24V DC 3 Normal 24V DC
Analog input ports	4 (12 bits)
Analog output ports	2 (12 bits)
Supply Voltage	24V DC

3.5 Casters
Figure 8 below shows the metal casters that will be used for the project. Moreover, they will be utilized to allow for the mechanism to be moved when necessary within the facility.

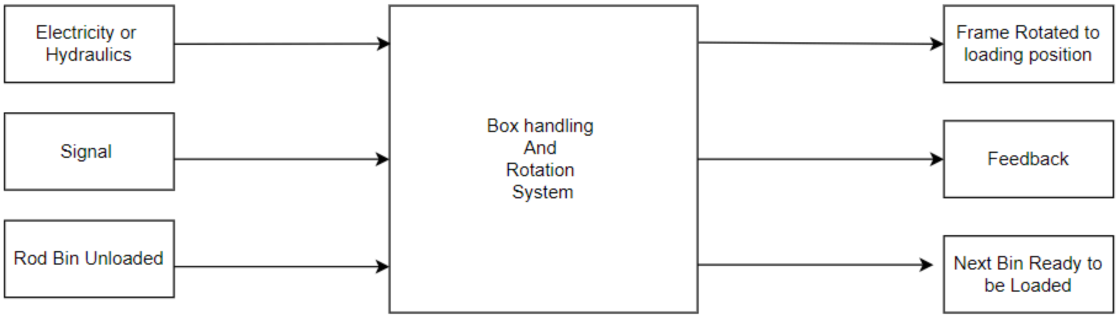
Figure 8: Casters

3.6 HiLo Pockets
HiLo Pockets will be part of the frame (see section 3.1). The HiLo pockets allow for easy mobility for the machine as an alternative to using the casters.

4. Diagrams

4.1 Black Box Diagram
Figure 9 below shows the black box diagram that details the inputs and outputs needed for the box handling and rotation system processes, including the flow of electrical mechanical, device input and outputs required for the system to work properly and details the process when the bin is loaded and unloaded.

Figure 9. Black Box Diagram



4.2 Function Structure Diagram

Figure 10 details the specifics of the mechanism's process from mechanical to information as well as vice versa. As described, when a mechanical button is pushed, a signal would be sent out, triggering the electrical components of the motor to begin rotating away from or to the loading position depending on if a bin is empty or not.

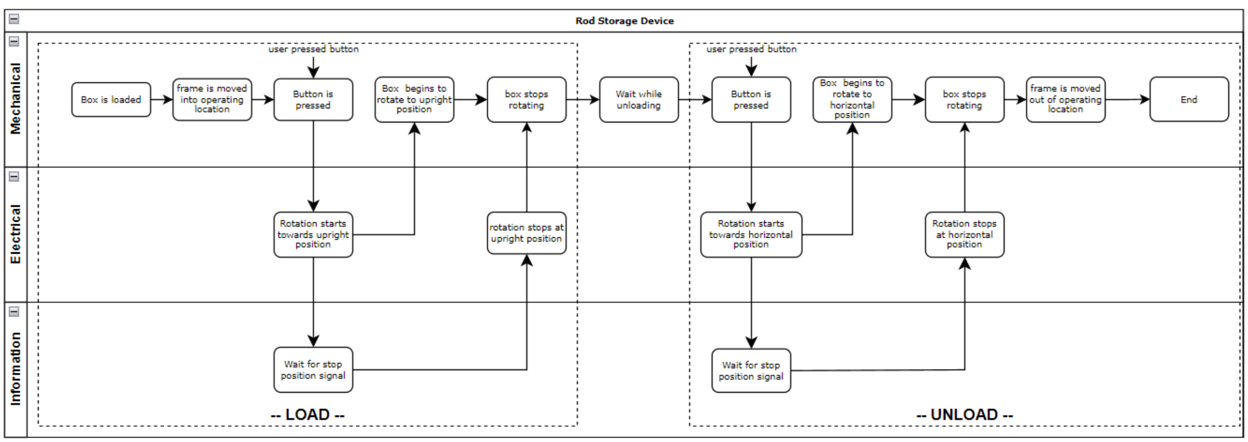


Figure 10. Function Structure Diagram

4.3 Block Diagram

The Block Diagram gives an overview of how the code will work for the machine

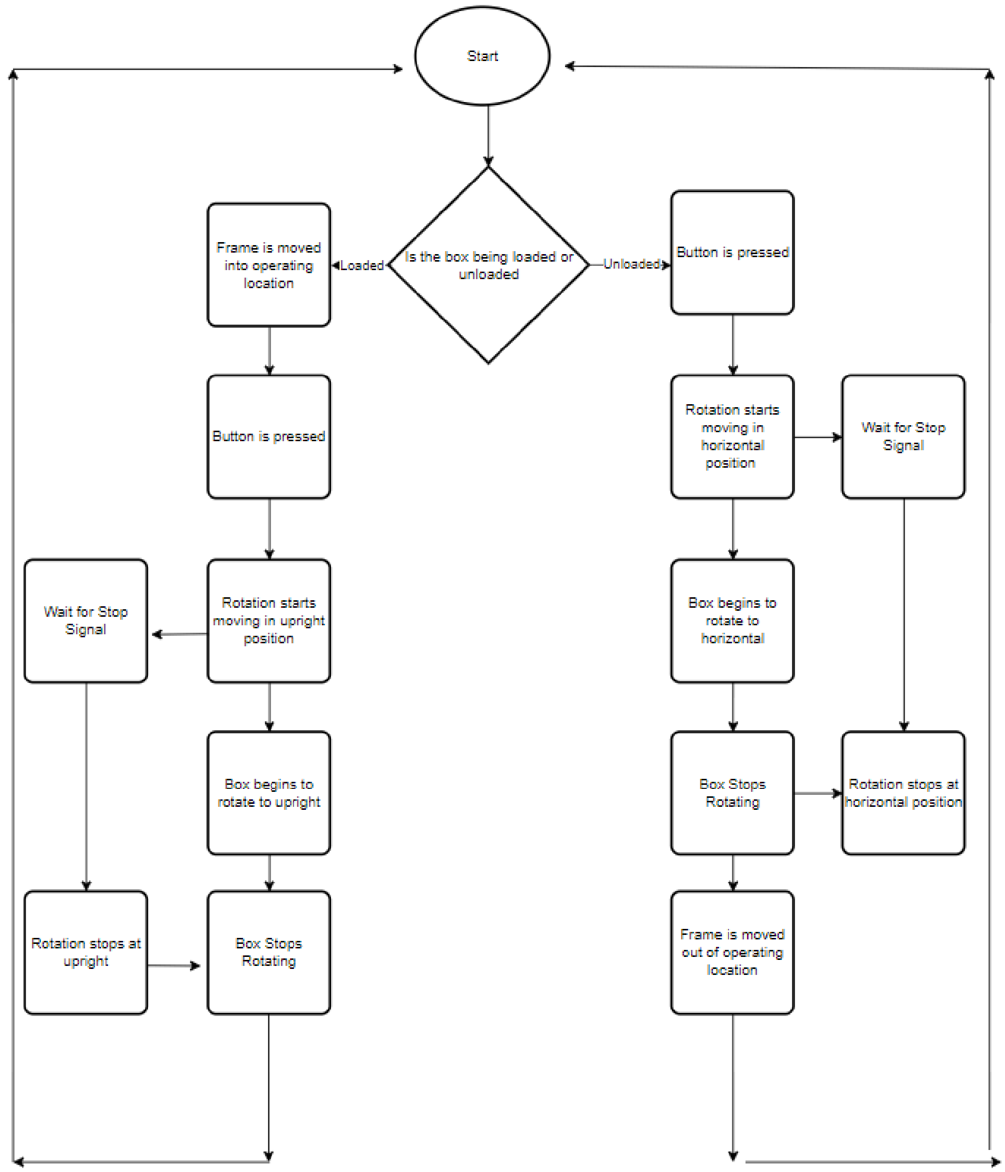


Figure 11: Block Diagram

4.4 State Diagram

Figure 12 below shows the different states the device will be in, as well as the prompts for the device to change state. The state diagram shown describes the process for when the device has been loaded, and the rods need to move towards the presentation angle.

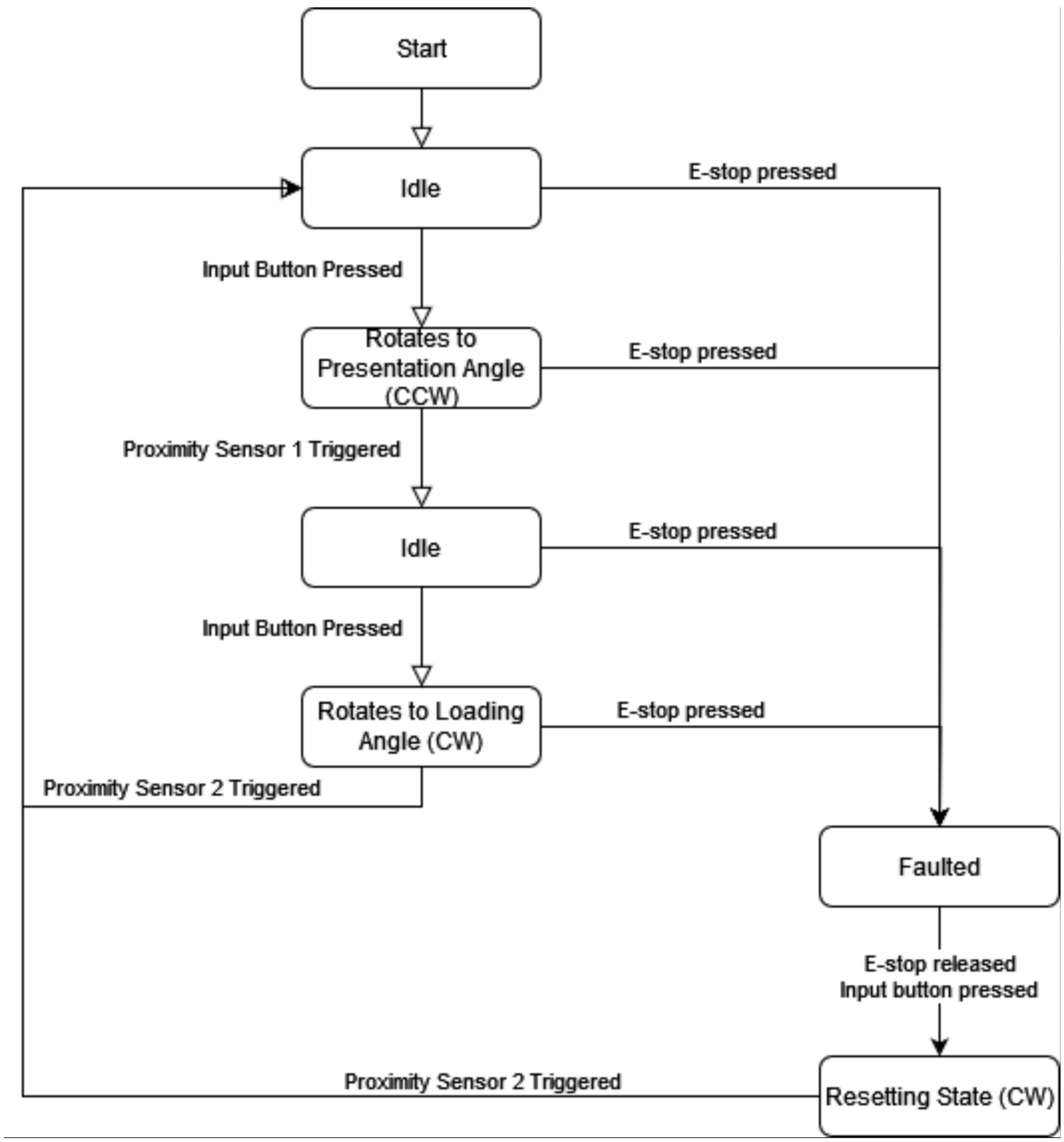


Figure 12: State Diagram

4.5 Timing Diagram

Figure 13 below details the estimated time taken by the device during normal operation. Based on current estimations, the operation will require approximately 2.12 minutes (or 127 seconds) of time to complete all operations. The required time listed in the scoping document has an upper limit of 7 minutes (420 seconds). The precise breakdown of where time is spent is shown below.

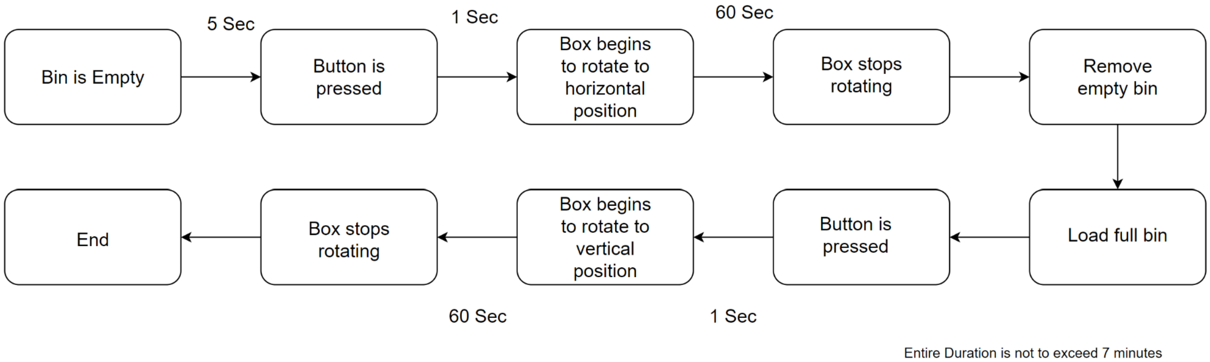


Figure 13: Timing Diagram

4.6 Space Usage

The space available is defined by the area taken up by the setup being replaced. The replaced setup has both positions for the bins, as well as a separate rack which the rods are added to by hand. This area comes to a combined total of just over 45 square feet, distributed as shown in the figure below. The operators approach from the walkway, and the HiLos place bins from the side opposite the walkway.

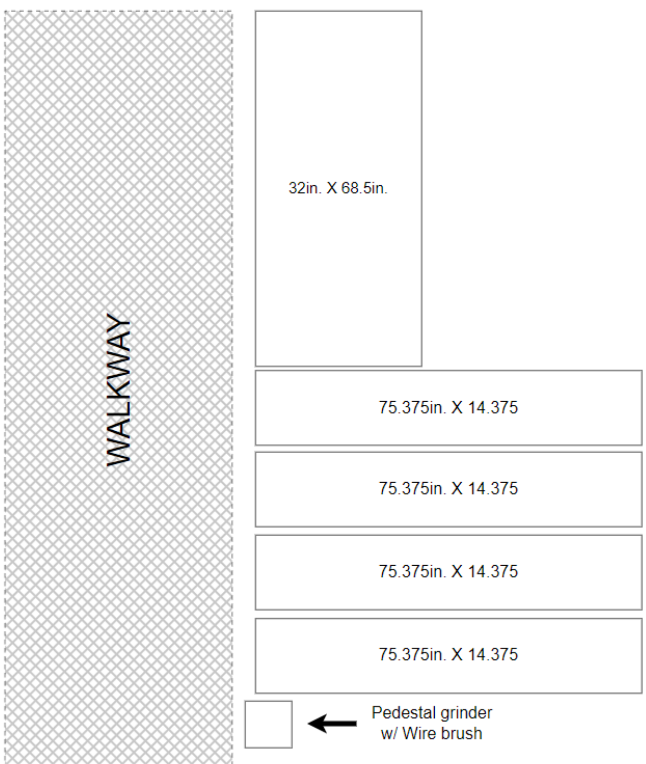


Figure 14: Space Usage

5. Bill of Materials

The following sections contain the components used in the mechanical and electrical sections of the project.

5.1 Electrical Components

Table 3. Electrical components

Part Name	**Details**	**Quantity**	**Bought or Made**
24 VDC Push Button	22mm Push Button Green	2	Bought
Estop	Emergency Stop	1	Bought
VFD	460 VAC, 2hp, 3 Phase	2	Bought
PLC	1766-L32BXBA/B	1	Bought
Safety Relay	24 VAC/VDC Safety Relay	2	Bought
24 VDC Power Supply	24 VDC Power Supply	1	Bought
Motor Disconnect	2 Position, Lockable	2	Bought
Proximity Sensors	8mm Dia x 45mm Body, 4mm Sensing Dist	4	Bought
Stack light	Red, Amber, Green	1	Bought
Electrical Wire	Variety of Gauge Wire	________________	Bought
Terminal Block	35mm Din Rail Mount	25	Bought
Din Rail	35mm, 1 m Length	2	Bought
Panduit	1” Width, 3” Height, 6.5 ft	1	Bought
Cable Tie Mount	Nylon Plastic	50	Bought

Reusable Cable Tie	5.5” Len,	100	Bought
Part Name	**Details**	**Quantity**	**Bought or Made**
VFD to Motor MCW	8 AWG 4 Conductors	1 (10 ft)	Bought
Stack Light MCW	10 AWG 3 Conductors	1 (10 ft)	Bought

5.2 Mechanical Components

Table 4. Mechanical Components

Part	**Description**	**Quantity**	**Bought or Made**
Iron Horse Motor	240 VAC, 2 hp, 3 phase, 1800 RPM	2	Bought
IronHorse Worm Gearbox	Worm Gear, 60:1, 1.375 in Output Shaft	2	Bought
Enclosure	24”x24”x6”	1	Bought
Frame Component 1	Tubing 2x2x0.1875x38 in	3	Made
Frame Component 2	Tubing 2x2x0.1875x 71.5 in	2	Made
Frame Component 3	Tubing 2x2x0.1875x19.5 in	4	Made
Frame Component 4	Plate 3.125x4.125x0.25 in	4	Made
Frame Component 5	Tubing 2x2x0.1875x12.11 in	2	Made
Frame Component 6	Plate 27.5x14.75x0.125 in	2	Made
Frame Component 7	Tubing 2x2x0.1875x75.5 in	2	Made
Frame Component 8	Tubing 4x2x0.1875x71.5 in	1	Made
Frame Component 9	Tubing 4x2x0.1875x19.5	4	Made

Part Name	**Details**	**Quantity**	**Bought or Made**
Frame Component 10	Tubing 2x2x0.1875x12.9 in	4	Made
Frame Component 11	Tubing 2x2x0.1875x19.5 in	4	Made
Frame Component 12	Tubing 2x2x0.1875x10.69 in	2	Made
Frame Component 13	Tubing 2x2x0.1875x15 in	8	Made
Frame Component 14	Tubing 4x2x0.1875x75.5 in	1	Made
PlexiGlass	Clear, 48x96x7/64 in	2	Bought
Pulley Wheel	6.95 in OD, 1.375 in Shaft	4	Bought
Hoist Ring	Triangle Swivel	8	Bought
Casters	3 in Diameter	4	Bought
Cable	⅜ in Diameter 6x37, IWRC	25 ft	Bought
Cable Loop Reinforced	Galvanized, ⅜ in Wire Diameter	16	Bought
Steel Wire Clamp	⅜ in Dia Clamp	12	Bought
Pillow Block Bearings	Tritan Pillow Block 1.25” Bore	4	Bought
Cable Loop Reinforcement	Wire Thimble ⅜ in	16	Bought
Tslot Framing	1 in x 1 in Hollow	2 (8ft)	Bought

6. Budget

The following sections contain the budget allotment for the electrical, mechanical, shipping, and total costs of the project.

6.1 Electrical Components

Table 5. Electrical Budget

Description	Part #	Quantity	Price Per Unit ($)	Price ($)	Source
24 VDC Push Button	8382K872	2	64.19	128.38	Mcmaster-Carr
Estop	6741K111	1	81.88	81.88	Mcmaster-Carr
VFD	15573819	2	408.00	816.00	Automation Direct
PLC	1766-L32BXBA/B	1	444.00	444.00	PLC Hardware
24 VDC Power Supply	PSL-24-010	1	32.00	32.00	Automation Direct
Safety Relay	LG5929-60-100-61	1	136.00	136.00	Automation Direct
Motor Disconnect	ML1-016-E-H03R	2	30.00	60.00	Automation Direct
Proximity Sensors	AE1-AP-4A	4	31.00	124.00	Automation Direct
Stack light	ME-302A-RYG	1	156.00	156.00	Automation Direct
Terminal Block	KN-T12GRY-25	1 (25 pack)	9.00	9.00	Automation Direct
Din Rail	DN-R35S1-2	1 (2 Pack)	11.00	11.00	Automation Direct
Panduit	T1-1030G-1	1	28.00	28.00	Automation Direct
Cable Tie Mount	7566K205	1 (50 pack)	15.54	15.54	McMaster-Carr
Reusable Cable Tie	7134K145	1 (100 pack)	9.00	9.00	McMaster-Carr

Description	**Part #**	**Quantity**	**Price Per Unit ($)**	**Price ($)**	**Source**
VFD to MOTOR MCW	SOOW-8-4BK-1	1 (10 Ft)	51.10	51.10	Automation Direct
Stack Light MCW	SJOOW-14-4BK-1	1 (10 Ft)	22.40	22.40	Automation Direct

6.2 Mechanical Components

Table 6. Mechanical Budget

Description	Part #	Quantity	Price per Unit ($)	Price ($)	Source
Iron Horse Motor	MTRP-002-3BD18	2	349.00	698.00	Automation Direct
IronHorse Worm Gearbox	WG-325-060-DA	2	483.00	966.00	Automation Direct
Enclosure	SCE-24N2406LP	1	225.00	225.00	Automation Direct
Frame Tubing	Alro Quote	1	732.93	732.92	Alro Steel
PlexiGlass	8560K198	2	121.66	243.32	McMaster
Pulley Wheel	6204k374	4	68.68	274.72	McMaster
Hoist Ring	29505T22	8	32.41	259.28	McMaster
Casters	24125T27	4	107.67	430.68	McMaster
Cable	3441T67	25	4.87	121.75	McMaster
Cable Loop Reinforcement	3495T16	16	2.98	47.68	McMaster
Steel Wire Clamp	3897T12	8 (2 pkg)	10.77	86.16	McMaster
Springs	9630K9	4	30.71	122.96	McMaster
Shaft Clamp	1865K3	4	28.20	112.80	McMaster
Pillow Block Bearing	36UZ12	4	58.67	234.68	Grainger
TSolt Framing	47065T101	2 (8 ft)	44.32	88.64	McMaster

6.3 Shipping

Table 7. Shipping Budget

Company	Shipping Cost ($)
Automation Direct	0[1]
Grainger	24.02
McMaster	191.49
Alro Steel	NA[2]
PLC Hardware	26.40

6.4 Total Budget

Table 8. Total Budget

Section	Cost ($)
Electrical	2124.30
Mechanical	4677.59
Shipping	241.91
Tax	406.13
20% Allowance	1483.39
Total	8900.32

[1] The shipping cost for Automation Direct is $0.00 due to free shipping.
[2] The shipping cost for Alro Steel is built into the cost.

7. Testing Specifications and Results

Table 9. Testing Specifications

Number	Specification	Required/Optional	Value	Tolerance Limit	Unit	Testing Method
1	Cost of the Device (Materials + Manufacturing)	Required	8000	+2000	$ (USD)	The total cost does not exceed the limit assigned
2	Device Weight [for the Sake of Mobility]	Required	2250	+250	lbs	Place on Scale
3	Cycle Time	Required	6.5	+0.5	min	Stopwatch
4	Support Weight per Box	Required	3100	-50	lbs	FEA/Hand calculations, followed by loading
5	Boxes Supported	Optional	2	n/a	n/a	Count
6	Weldment Safety	Required	AWS B1.11/B1.11:2015	n/a	n/a	Visual inspection according to standard
7	Electrical Disconnections for Maintenance	Required	OSHA 1910.147	n/a	n/a	Meets standard according to lock-out tag-out and power-cutoff requirements

8	Operating Height, Center of Gravity for Rod	Required	43.5	+/-4.5	in.	Rod's midpoint is within a range based on the tape measure value
9	Floor space 3 Units	Required	14 x 7.5	Maximum	ft	Measure with a tape measure length and width dimension
10	Bin Sizes Accommodated	Required	51.375 (L1) & 75.375 (L2) x 14.375 W x 19.25 H	+/- 0.005	in	Tape measure
11	Tipping Angle	Required	28	+/-2	Degr ees	Center of Gravity Calculations
12	Lifespan	Required	280	+/-20	Cycle s	Test for 10% expected use, check for degradation
13	Coating	Optional	Powder Coat Paint	n/a	n/a	Sent to the painter. Inspected for chips, missing spots, or rust upon return
14	Splash Protection	Required	Corrosion Resistance against Water, Oil, & Cleaning Products	n/a	n/a	Application with a set time of 5 minutes, or check manufacture specifications for coatings as applicable
15	HiLo Strike Durability	Required	200	+/-	lbs	Impacts with a steel hammer
16	Expected Maintenance	Required	Annual	n/a	n/a	n/a
17	Emergency Stop	Required	0	0	W	Test if any Watts are outputted after shutoff

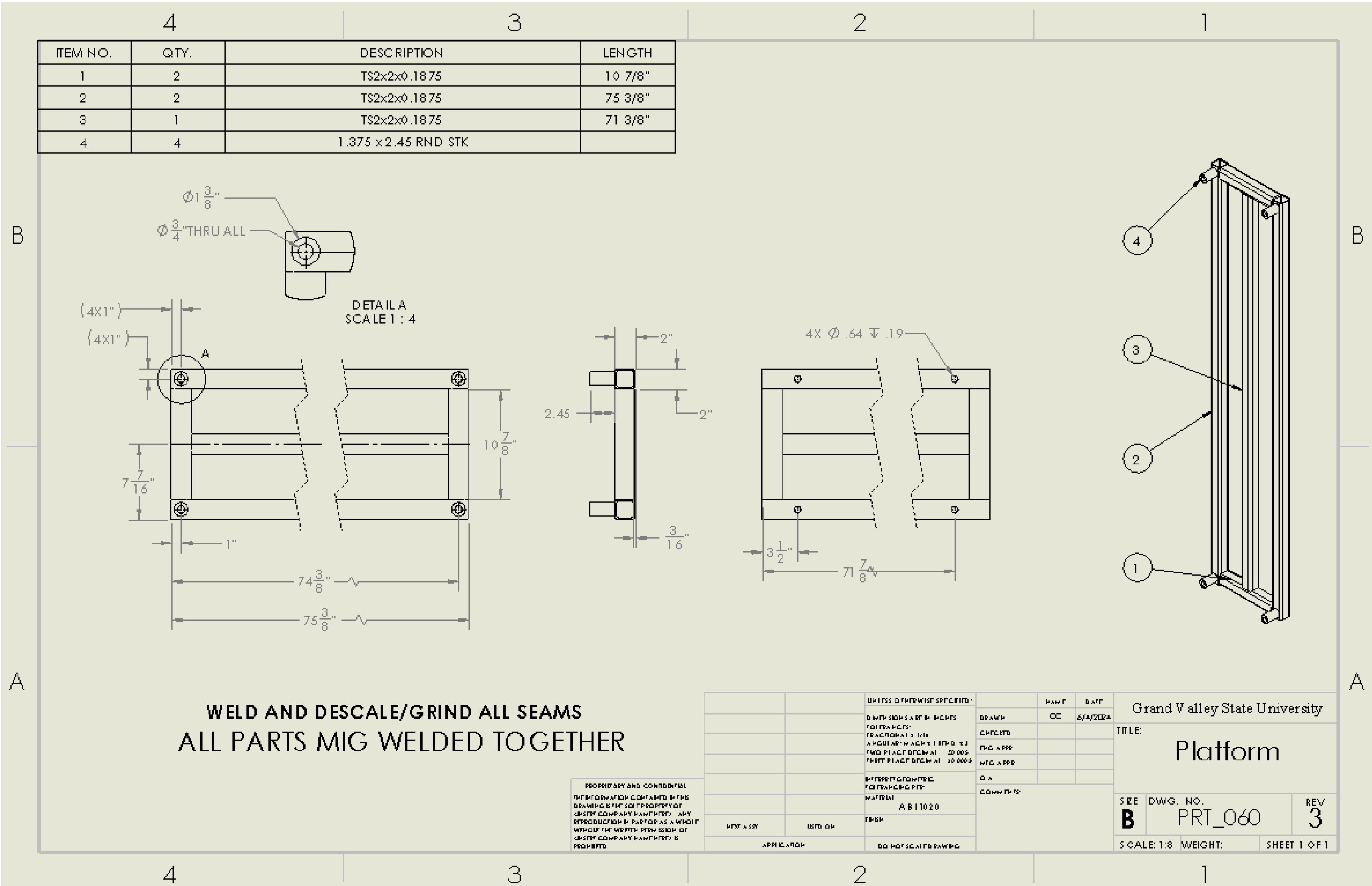
18	Box Angle Presentation	Required	70	+/-5	Degr ees	Measure with protractor
19	Color	Optional	Powder Coat Black	n/a	n/a	Inspect Color Selection
20	Operating Temperature	Required	70	+/-70	°F	Manufacturer specification
21	Display of Stored Rods	Optional	Current value	+/-5%	Rods	Place 40 rods in count the number of rods and compare to display the amount

8. Engineering Responsibilities

The most significant engineering responsibility considered in regards this device is public safety. The device has been designed to maximize the safety and health of the operators. Given the immense weight of the rods being moved, tipping is the primary safety concern. Measures against tipping have been taken into account. The device includes safety guarding to prevent pinch points, and all connection points for electricity are shrouded to prevent injuring operators. The economic engineering responsibility is significant for this project in that the sponsor benefits from the project being inexpensive. However, this responsibility is secondary to public safety. The environmental impact was considered less significant, as the device is located inside, and the material consumption is relatively low. The engineering responsibility of global impact was deemed inconsequential for this project, as the project is designed for very specific applications improving ergonomics and surface finish for the manufacturing of one particular product.
The engineering responsibilities of societal and cultural impact were deemed inconsequential for this project, as it only affected the ergonomics and surface finish for the manufacturing of one product.

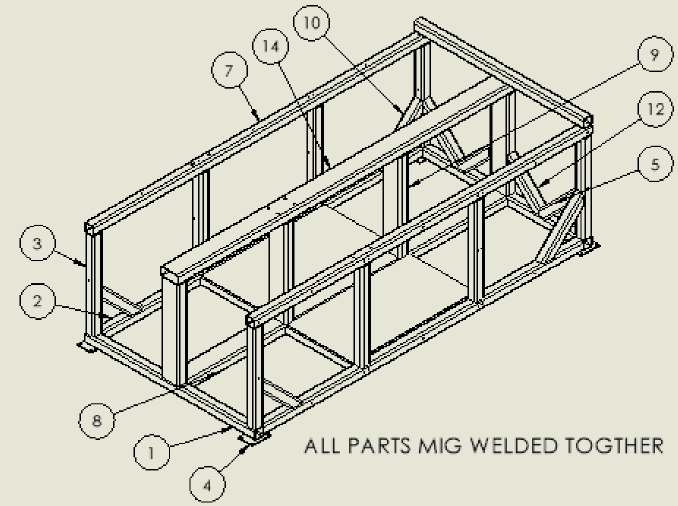
Appendix A - Drawings

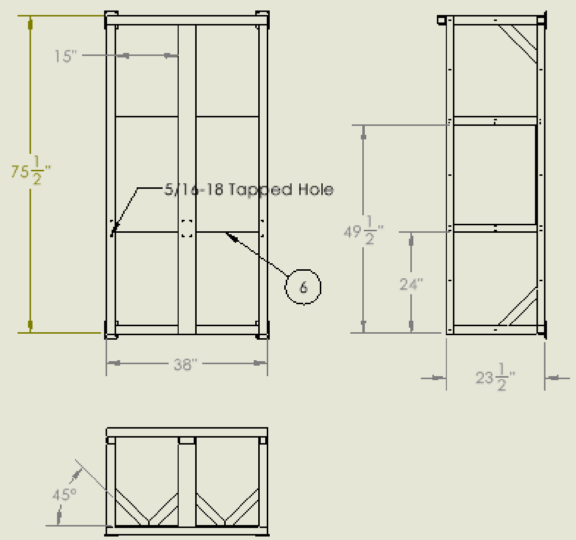
Platform (PRT-060)



Frame (PRT-010)

ITEM NO.	QTY.	DESCRIPTION	LENGTH
1	3	TS2x2x0.1875	38"
2	2	TS2x2x0.1875	71 1/2"
3	4	TS2x2x0.1875	19 1/2"
4	4	3.125x4.125x0.25	
5	2	TS2x2x0.1875	12.11
6	2	27.5x14.75x0.125	
7	1	TS2x2x0.1875	75 1/2"
8	1	TR4x2x0.1875	71 1/2"
9	4	TR4x2x0.1875	19 1/2"
10	4	TS2x2x0.1875	12.9
11	4	TS2x2x0.1875	19 1/2"
12	2	TS2x2x0.1875	10.69
13	8	TS2x2x0.1875	15"
14	1	TR4x2x0.1875	75 1/2"
15	1	TS2x2x0.1875	75 1/2"





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NEXT ASSY | USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL AISI 1020
FINISH
DO NOT SCALE DRAWING

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ENG APPR.		
MFG APPR.		
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COMMENTS:

Grand Valley State University
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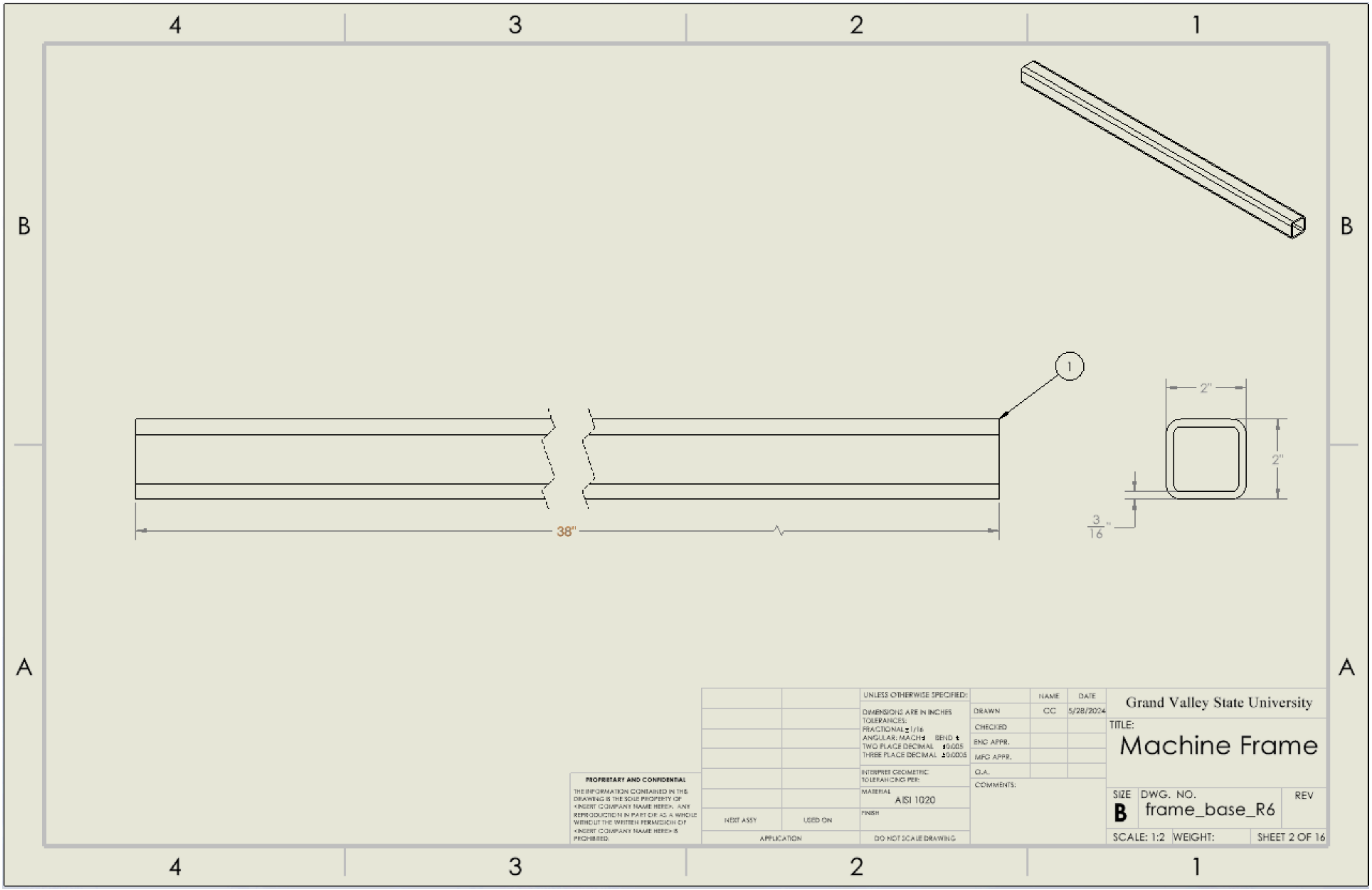
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INTERPRET GEOMETRIC TOLERANCING PER:
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Grand Valley State University
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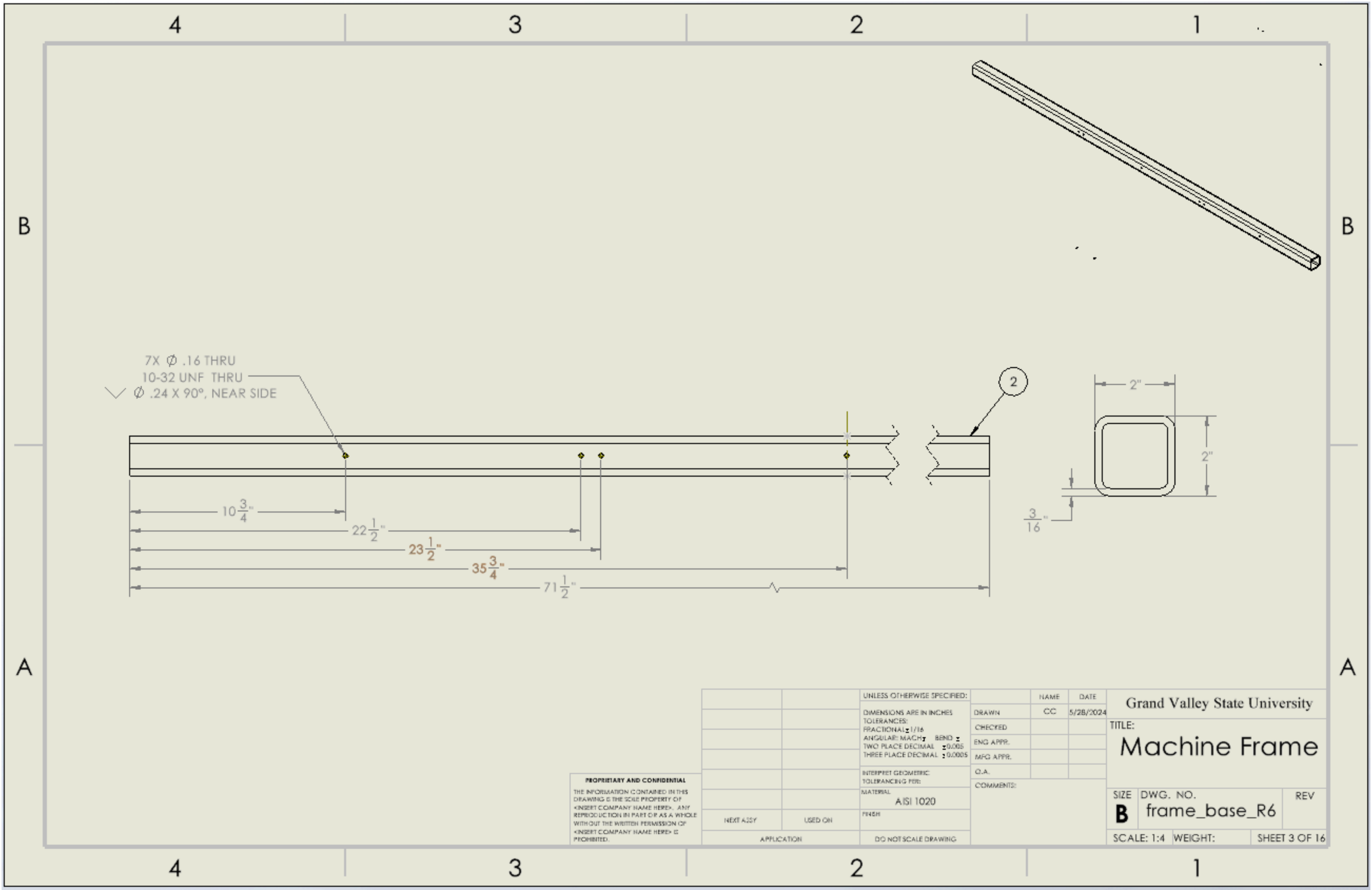

7X ⌀ .16 THRU
10-32 UNF THRU
⌵ ⌀ .24 X 90°, NEAR SIDE
2
2"
2"
3/16"
10 3/4"
22 1/2"
23 1/2"
35 3/4"
71 1/2"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ± 0.005
THREE PLACE DECIMAL ± 0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
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NEXT ASSY
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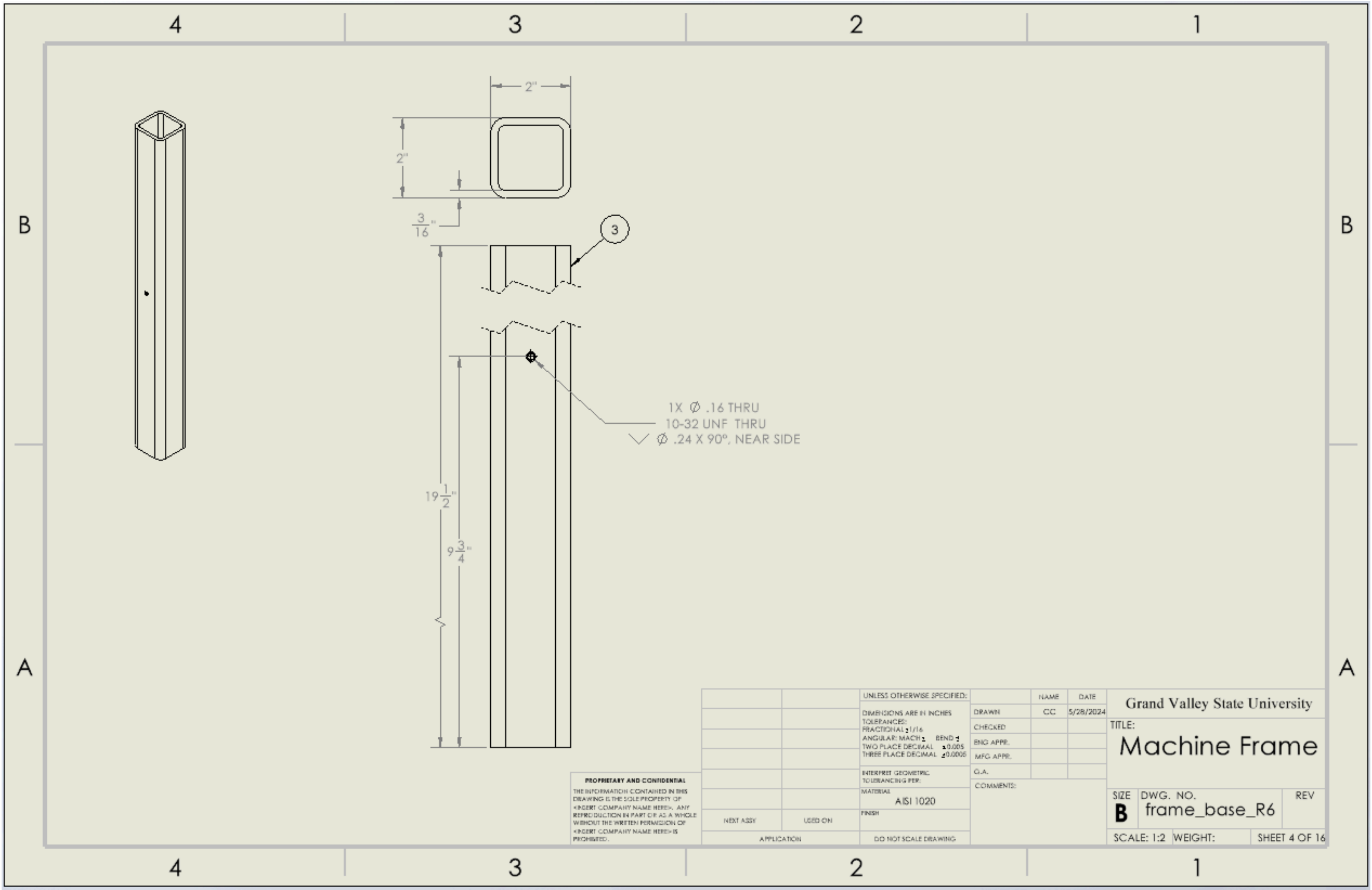
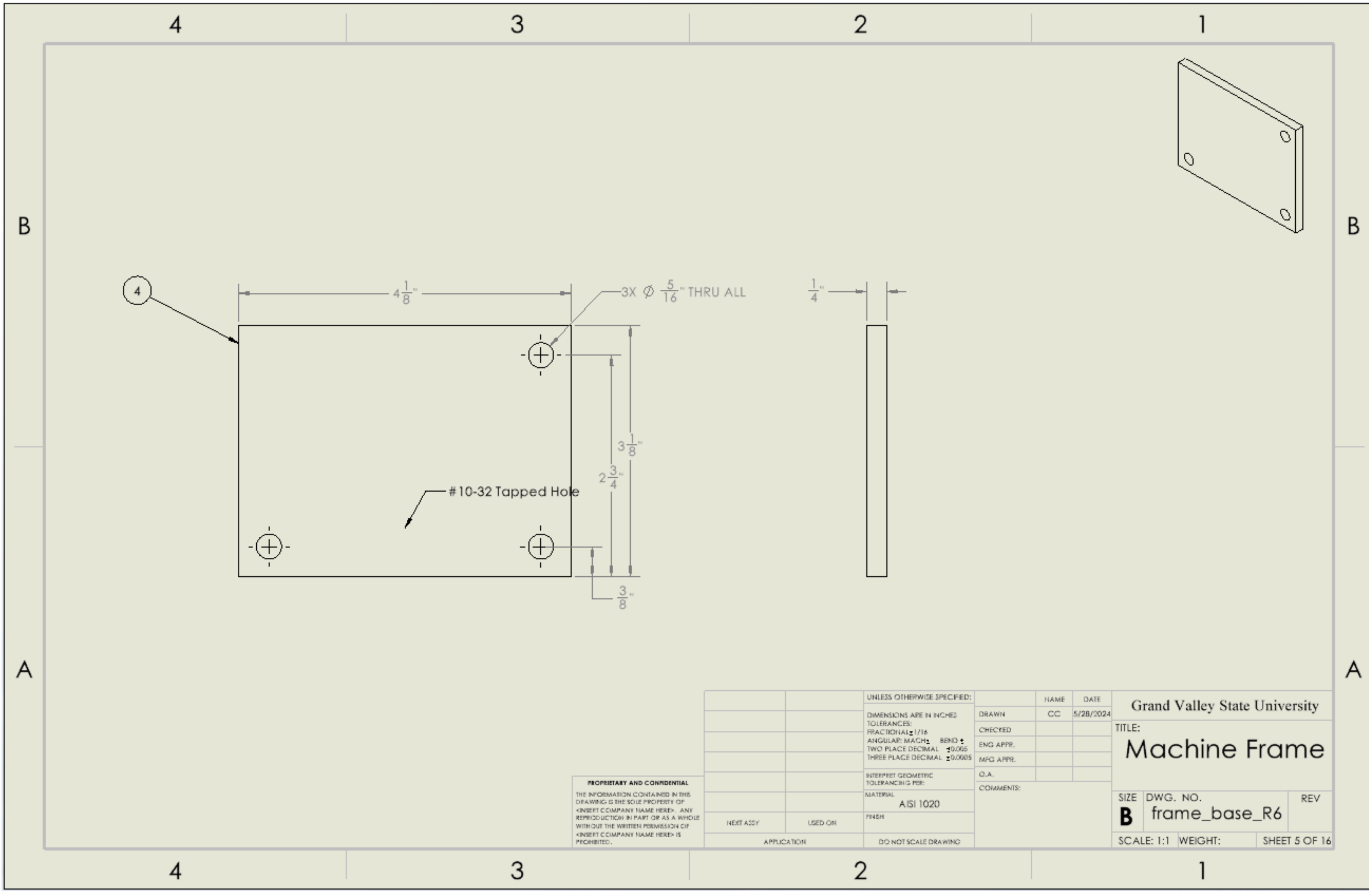
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:4
WEIGHT:
SHEET 3 OF 16
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.



2"
2"
3/16"
3
1X ∅ .16 THRU
10-32 UNF THRU
⌵ ∅ .24 X 90°, NEAR SIDE
19 1/2"
9 3/4"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AISI 1020
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 4 OF 16
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL



4 1/8"
3X ∅ 5/16" THRU ALL
1/4"
3 1/8"
2 3/4"
3/8"
#10-32 Tapped Hole
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
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AISI 1020
FINISH
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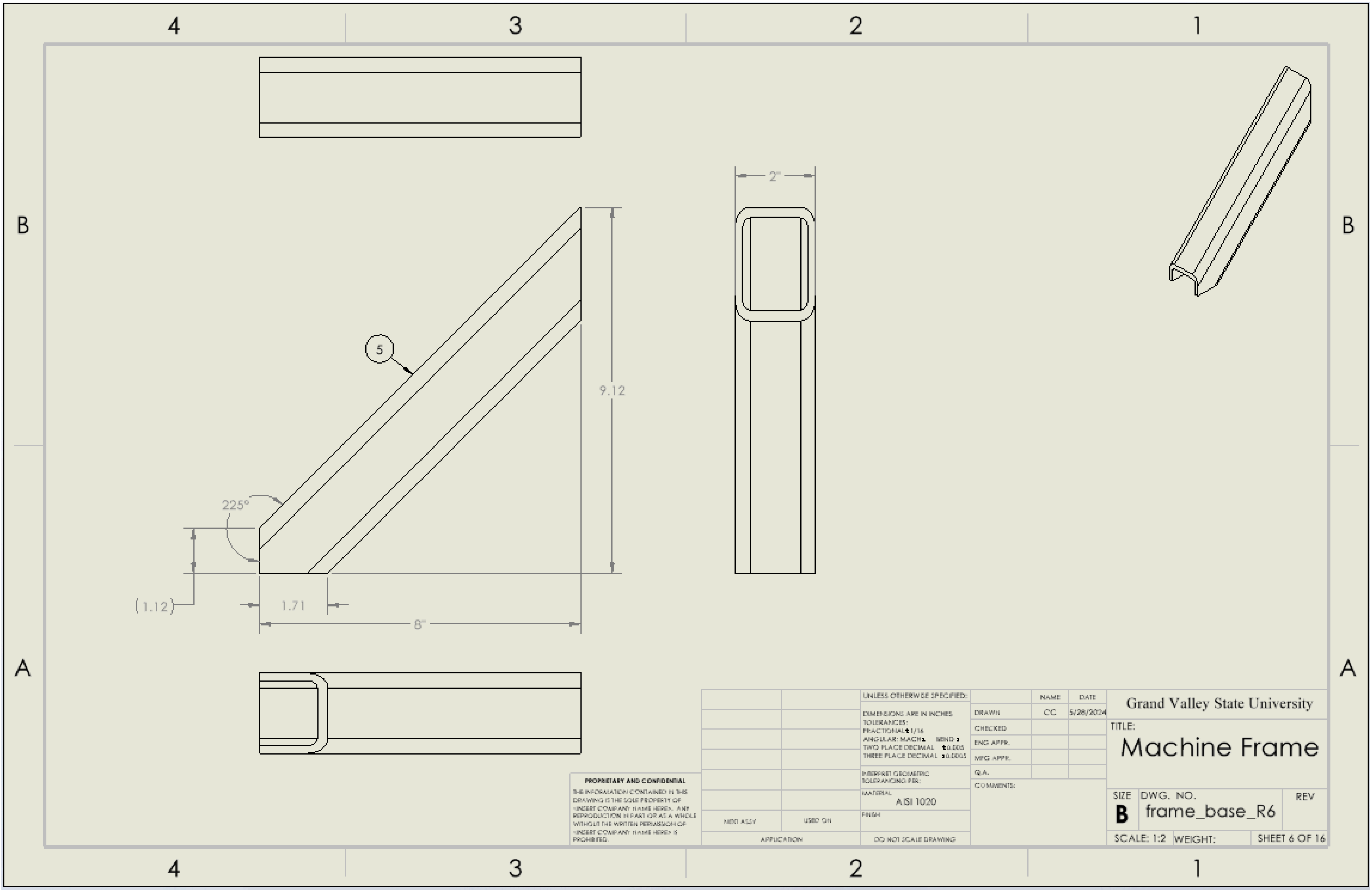
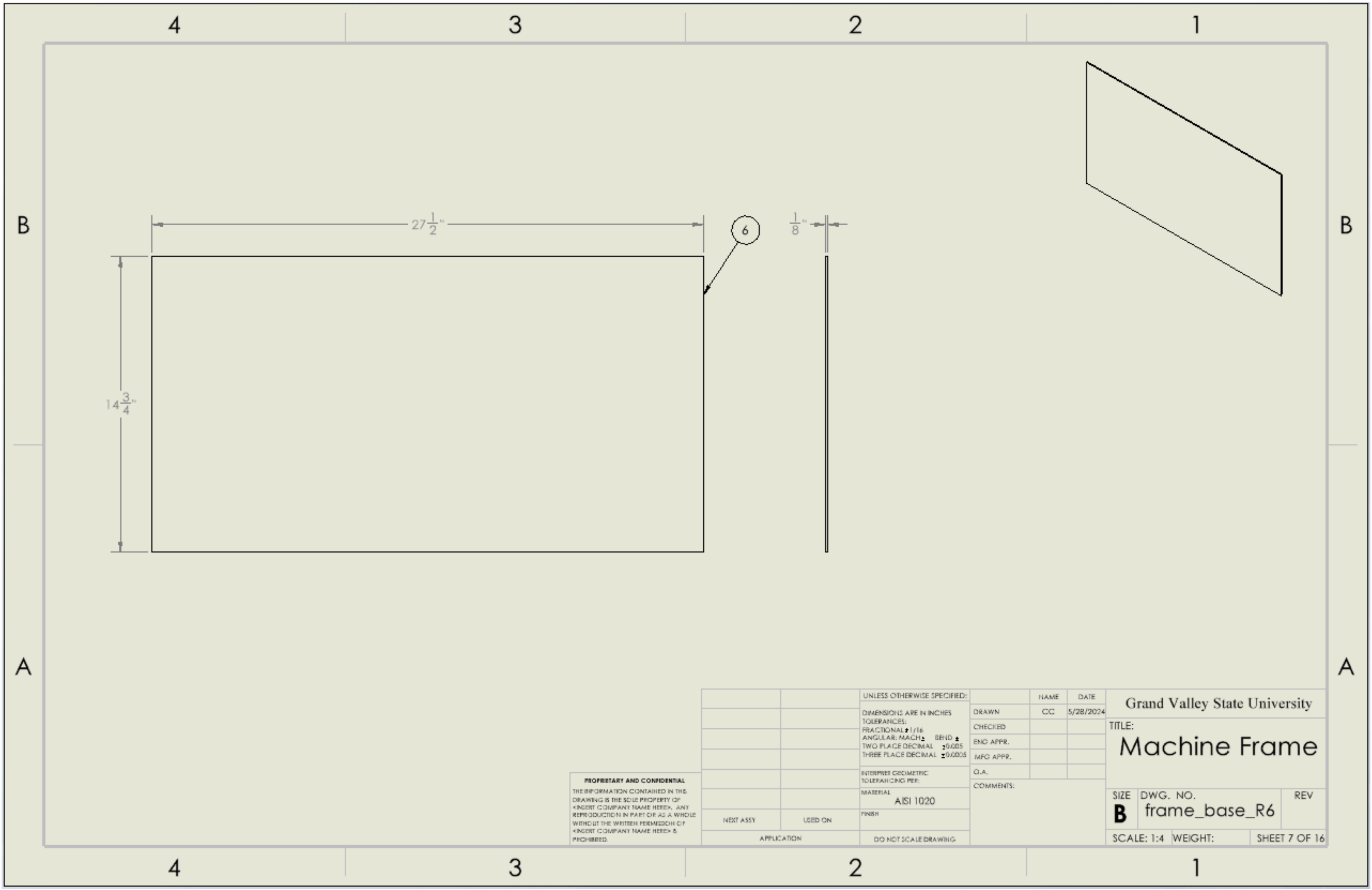
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:1
WEIGHT:
SHEET 5 OF 16



2"
9.12
5
225°
(1.12)
1.71
8"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AISI 1020
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 6 OF 16



27 1/2"
6
1/8"
14 3/4"
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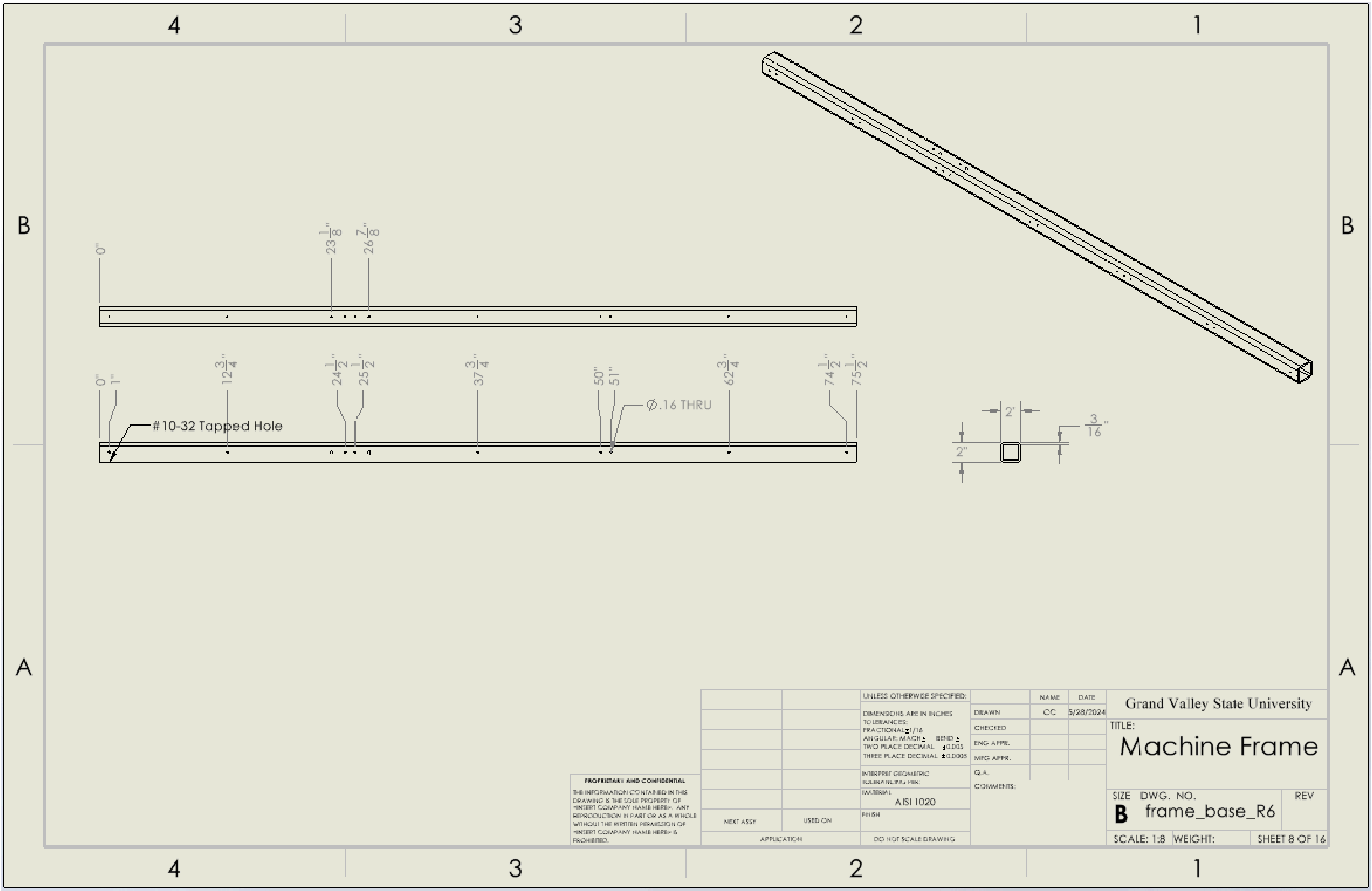
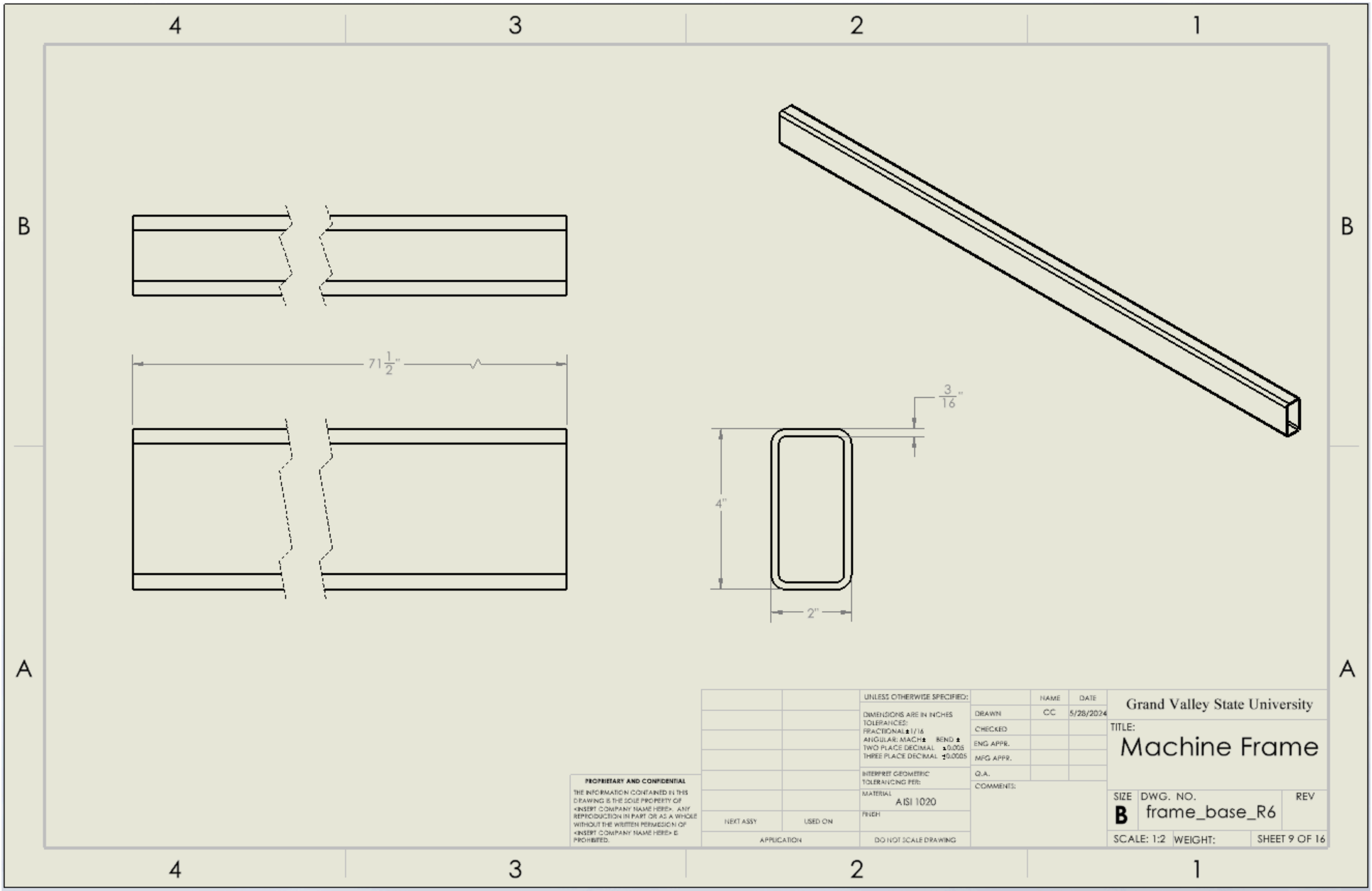
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AISI 1020
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:4
WEIGHT:
SHEET 7 OF 16


#10-32 Tapped Hole
Ø.16 THRU
2"
UNLESS OTHERWISE SPECIFIED:
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
MATERIAL
AISI 1020
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:8
WEIGHT:
SHEET 8 OF 16


71 1/2"
3/16"
4"
2"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ± 0.005
THREE PLACE DECIMAL ± 0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL AISI 1020
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
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APPLICATION
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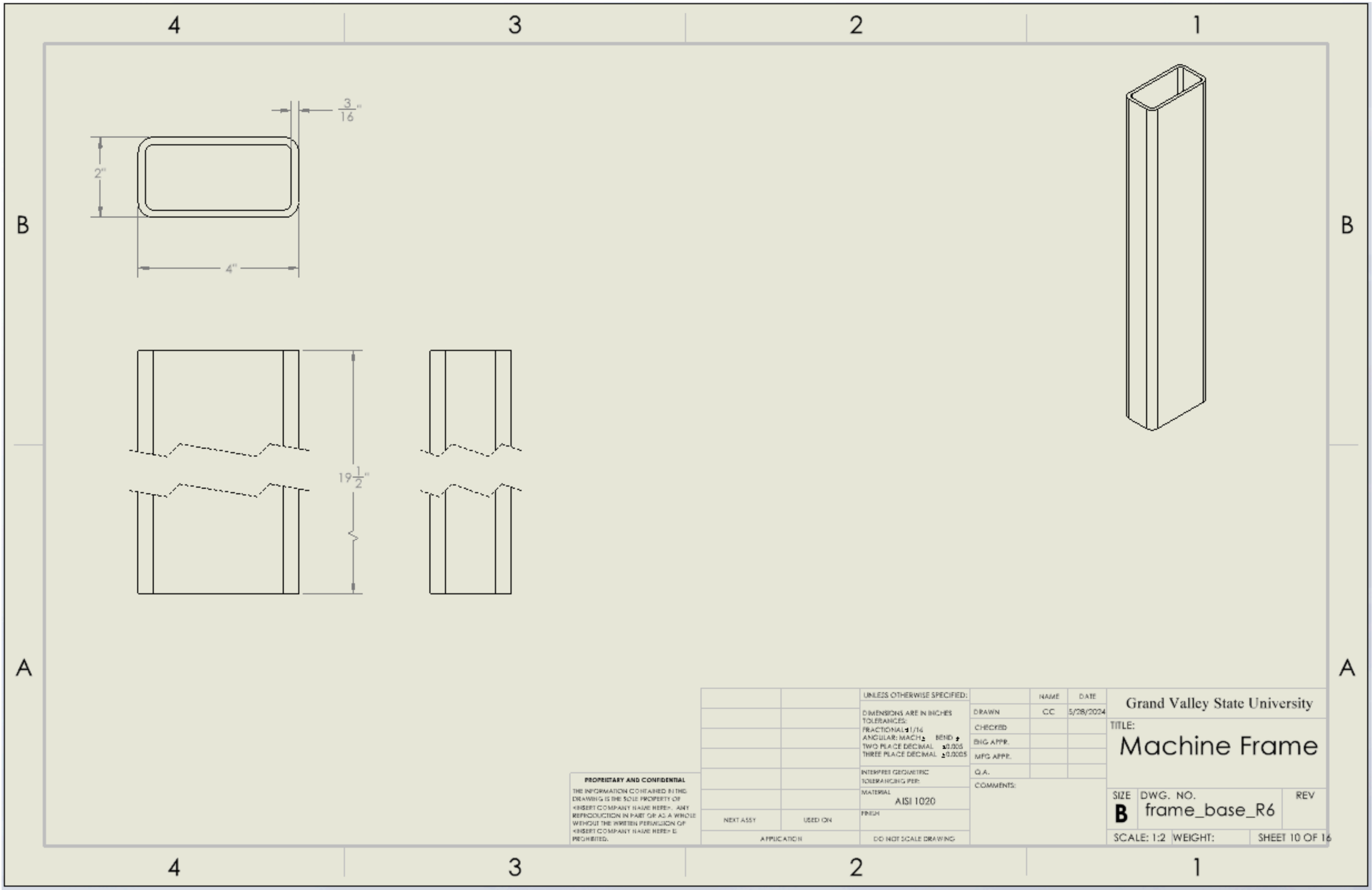
NAME DATE
DRAWN CC 5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE B
DWG. NO. frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 9 OF 16



3/16"
2"
4"
19 1/2"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AISI 1020
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
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APPLICATION
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
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MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 10 OF 16
PROPRIETARY AND CONFIDENTIAL
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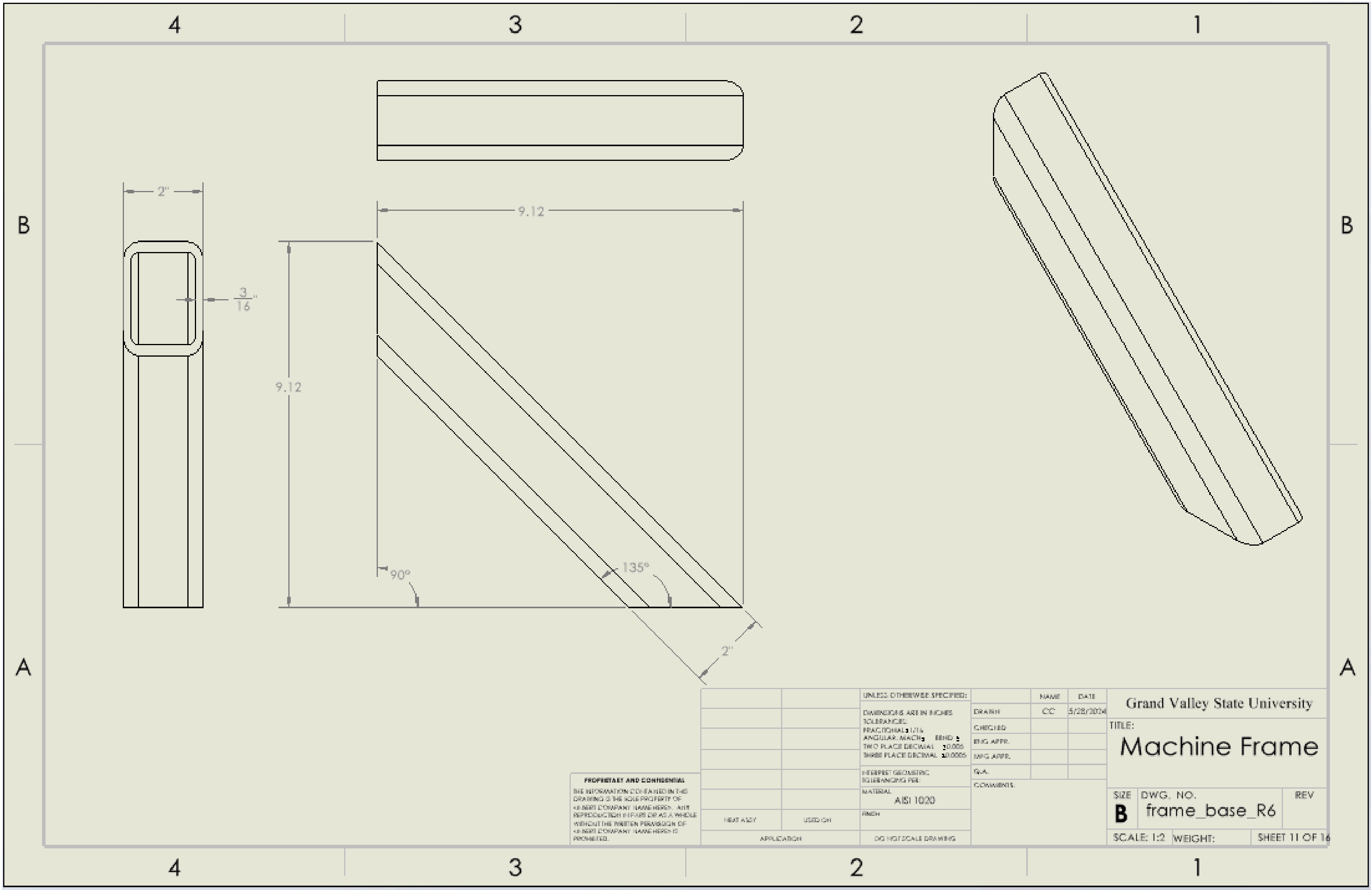
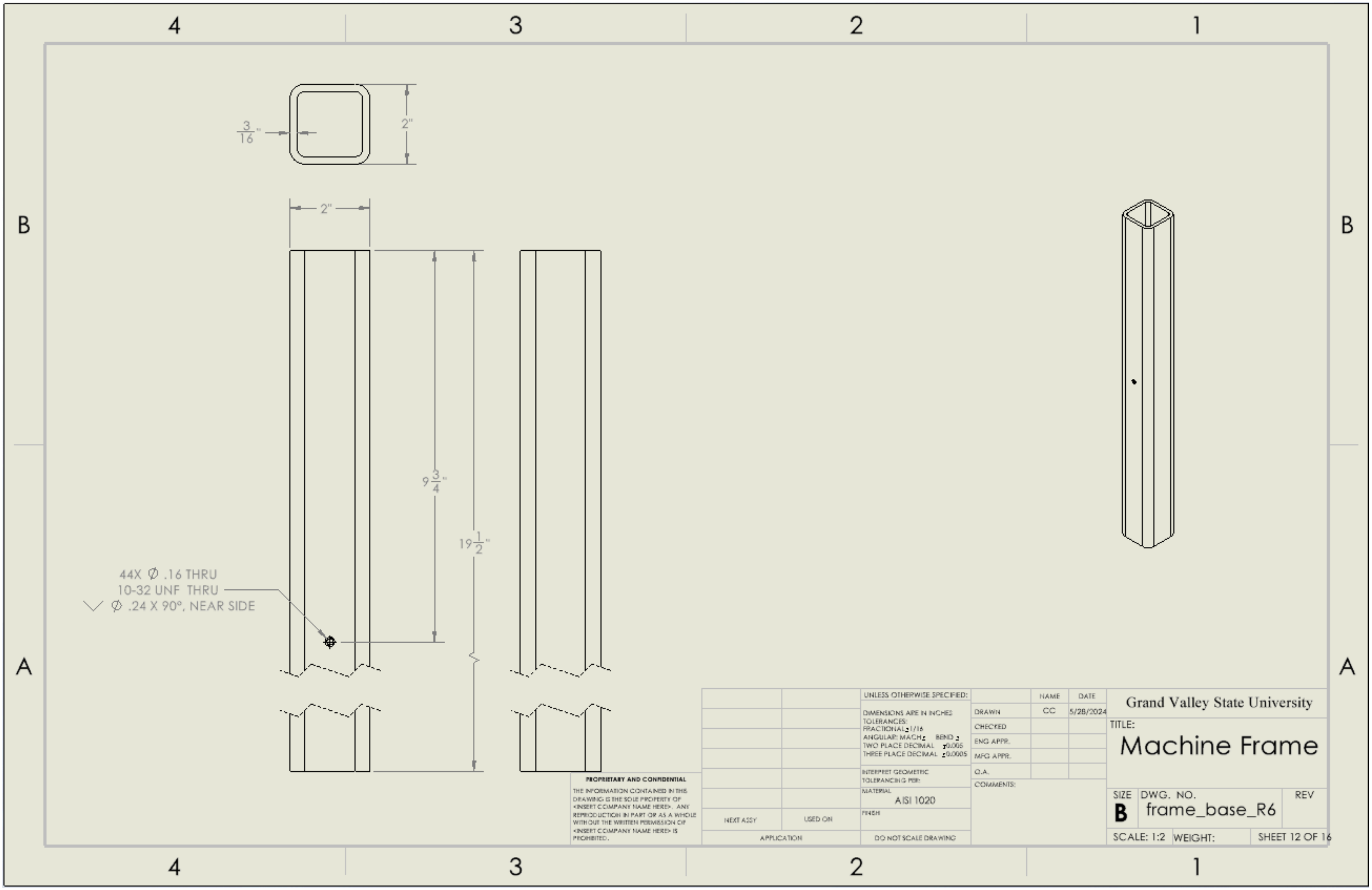

2"
3/16"
9.12
9.12
90°
135°
2"
Grand Valley State University
TITLE:
Machine Frame
DRAWN CC 5/28/2024
MATERIAL
AISI 1020
SIZE B
DWG. NO. frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 11 OF 16
UNLESS OTHERWISE SPECIFIED:
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL



4
3
2
1
B
A
3/16"
2"
2"
9 3/4"
19 1/2"
44X ∅ .16 THRU
10-32 UNF THRU
∅ .24 X 90°, NEAR SIDE
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AISI 1020
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 12 OF 16
PROPRIETARY AND CONFIDENTIAL
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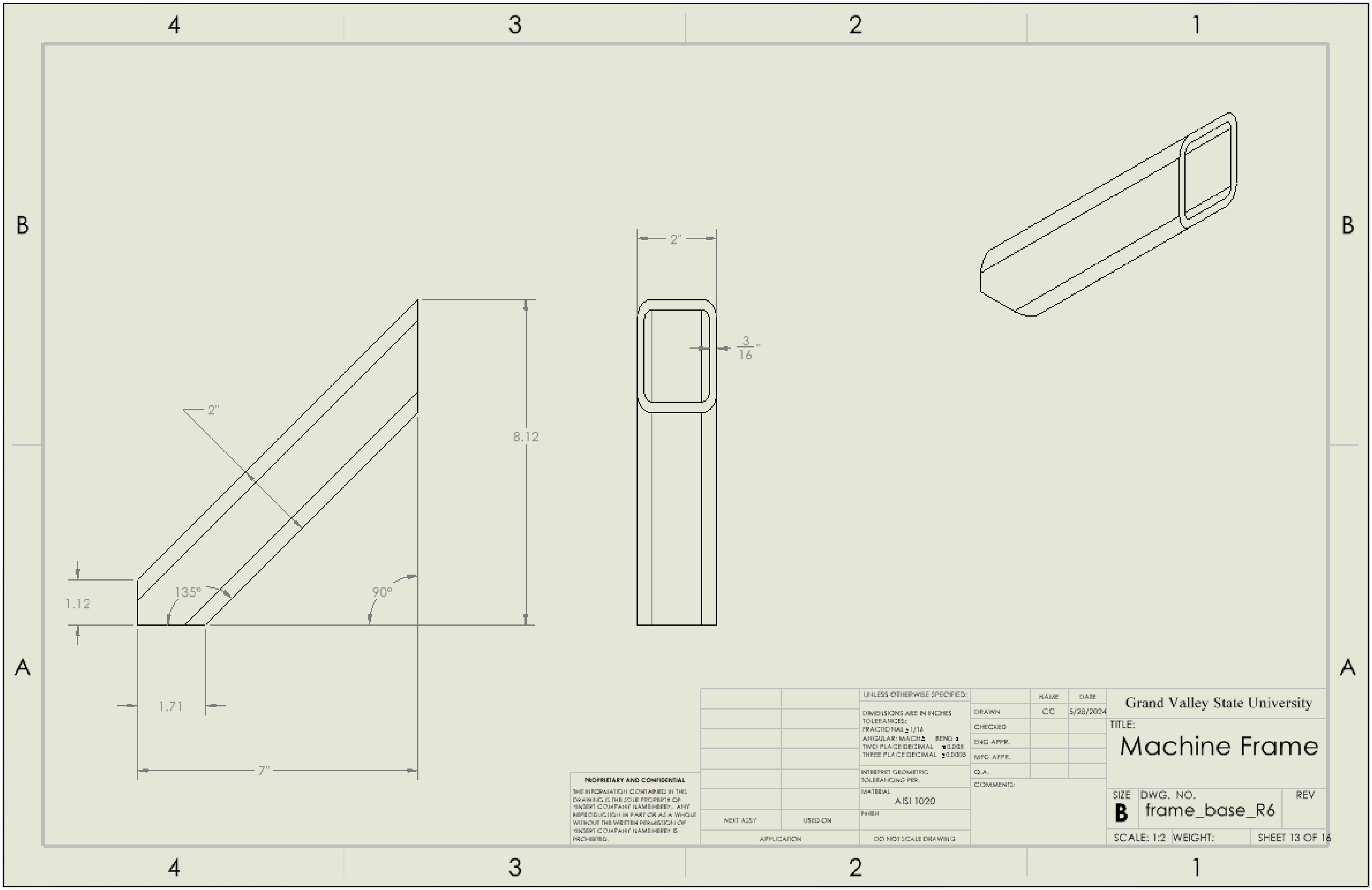
APPLICATION



2"
8.12
2"
3/16"
1.12
135°
90°
1.71
7"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±1/16
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
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APPLICATION
PROPRIETARY AND CONFIDENTIAL
NAME
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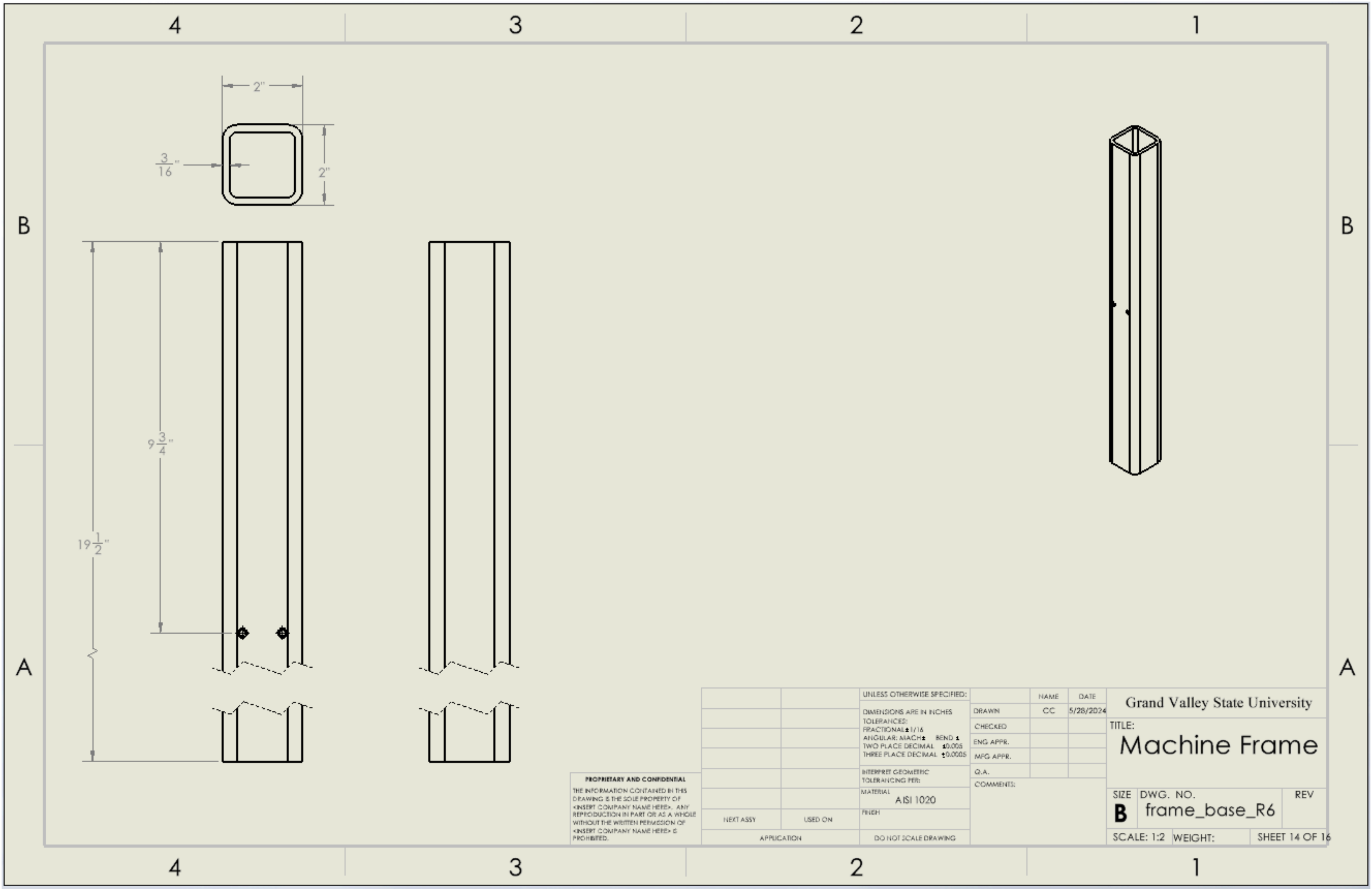
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 13 OF 16


2"
2"
3/16"
9 3/4"
19 1/2"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL± 1/16
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
AISI 1020
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
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APPLICATION
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:2
WEIGHT:
SHEET 14 OF 16
PROPRIETARY AND CONFIDENTIAL
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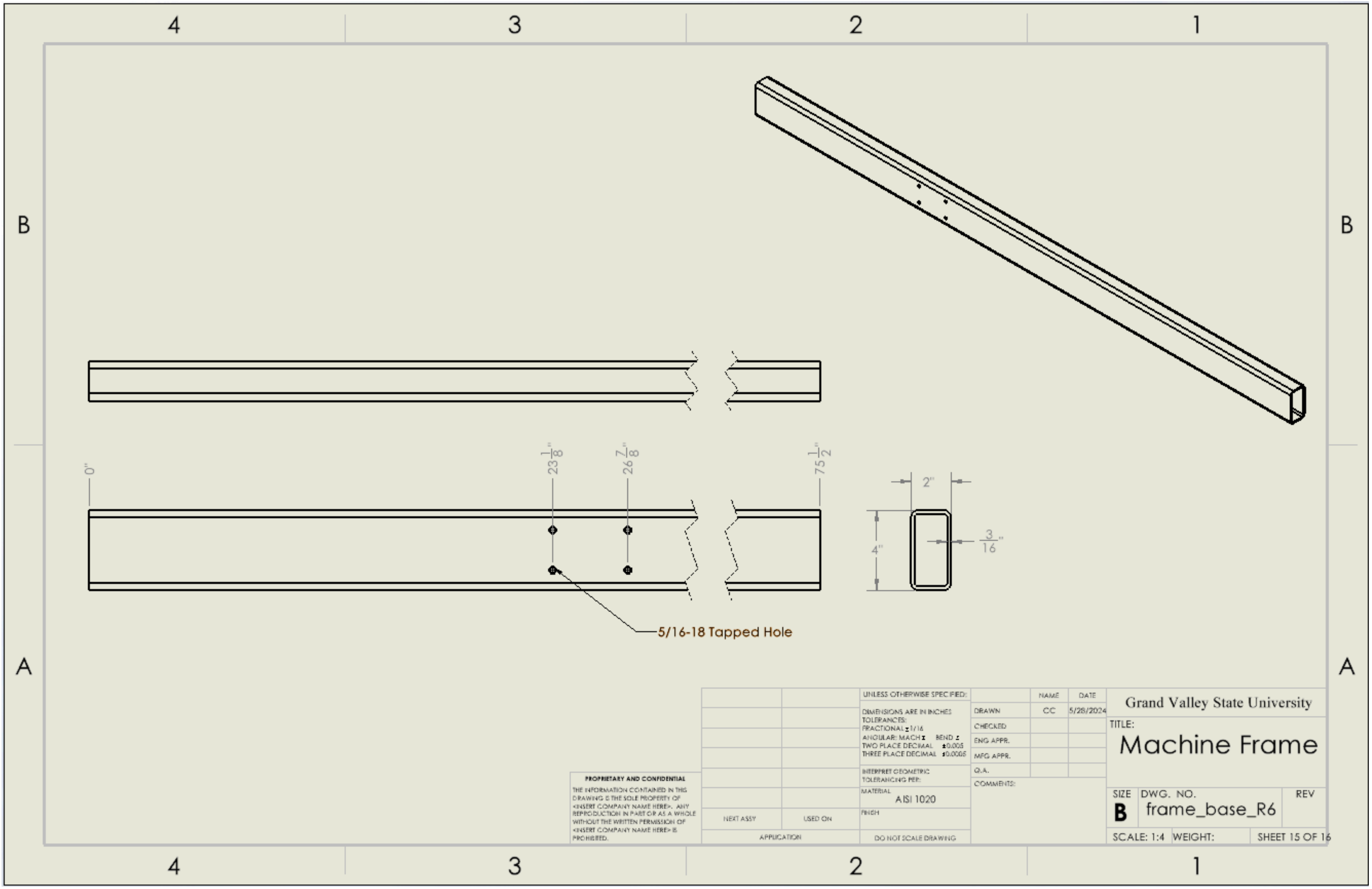

0"
23 1/8"
26 7/8"
75 1/2"
2"
4"
3/16"
5/16-18 Tapped Hole
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ± 1/16
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±0.005
THREE PLACE DECIMAL ±0.0005
INTERPRET GEOMETRIC TOLERANCING PER:
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AISI 1020
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NEXT ASSY
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APPLICATION
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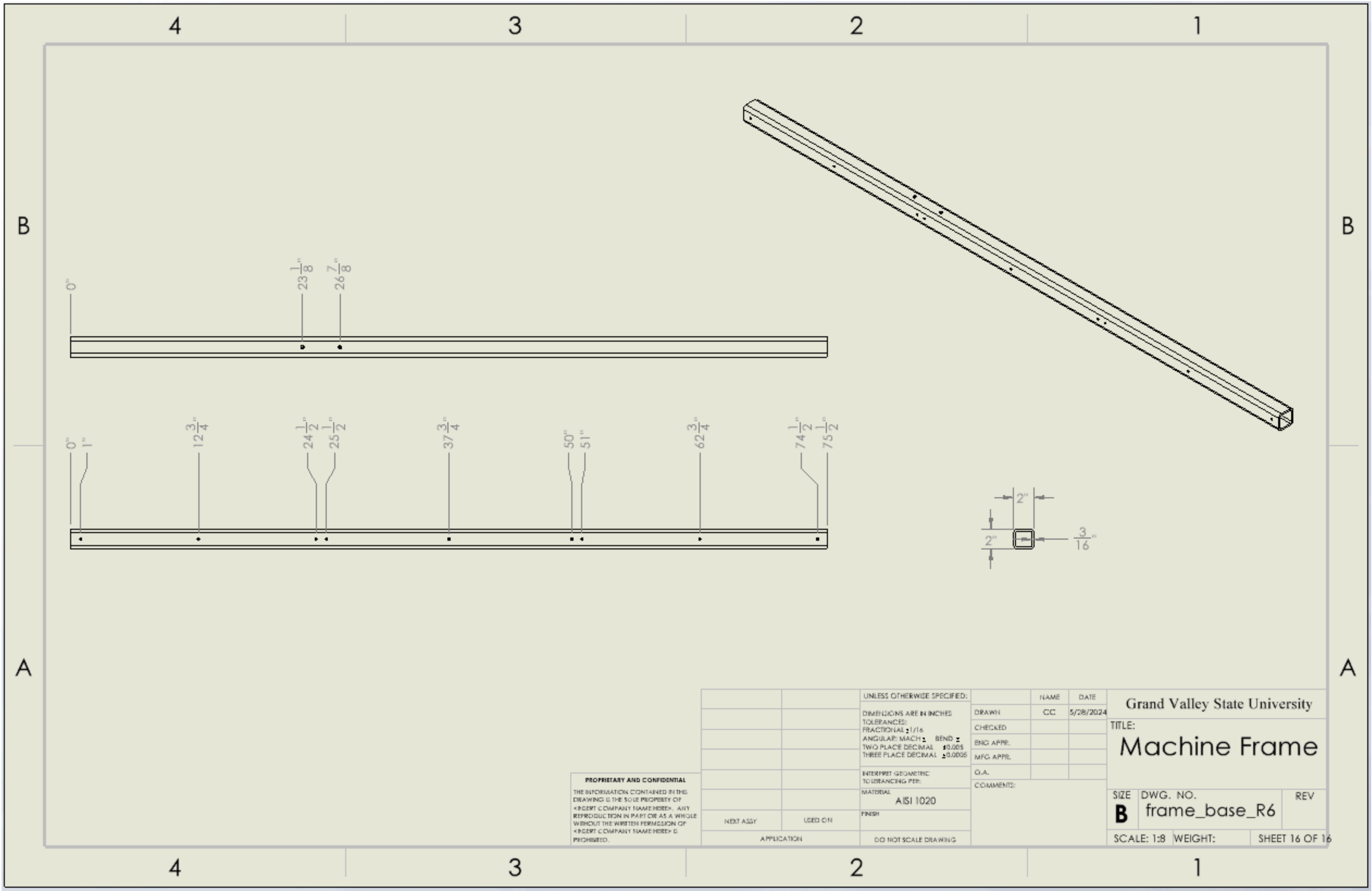
NAME
DATE
DRAWN
CC
5/28/2024
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
Grand Valley State University
TITLE:
Machine Frame
SIZE
B
DWG. NO.
frame_base_R6
REV
SCALE: 1:4
WEIGHT:
SHEET 15 OF 16


Grand Valley State University
TITLE:
Machine Frame
DRAWN CC 5/28/2024
MATERIAL AISI 1020
SIZE B DWG. NO. frame_base_R6
SCALE: 1:8 WEIGHT: SHEET 16 OF 16
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
DO NOT SCALE DRAWING
PROPRIETARY AND CONFIDENTIAL

Appendix B - Vendor Quotes

Merchandise	1,801.33
Shipping	111.01
Tax	108.08
Total	**$2,020.42**

PLACE ORDER

Close

Delivery address
Grand Valley State University
301 Fulton St W
Grand Rapids MI 49504

Delivery attention : None

Shipping and delivery notifications
None

Billing address
Grand Valley State University
301 Fulton St W
Grand Rapids MI 49504

Billing attention : None

Payment method
Invoice

Invoice / receipt preference
vedderst@mail.gvsu.edu

Figure 15. McMaster Shipping Quote

Alro Steel

1033 Freeman S.W.
Grand Rapids, MI 49503-4813

DUNS: 18-503-4527
Phone: (616) 452-5111

Quote

Alro Quote	107115603
Date	5/21/24
Purchase Order	

Bill To	Ship To
Attn: SARAH T & T Tools Inc 4470 128th Ave. Holland, MI 49424 (800) 521-6893	T & T Tools, Inc 4470 128th Ave. Holland, MI 49424

Sales Contact	Customer Number	Ship Via	FOB	Release
Penny Majewski	00005482	GR TRUCK	DESTINATION	

Line	Quantity	Description	Length/Size	Weight	Price	Ext. Price	Delivery Date
1	4.00 LNG	2 SQ X 7 GA (3/16) WALL TUBING ASTM A-500 GRADE B 1. Alro Part: 13009024	24 FT		103.8019 LNG	$415.21	0/00/00
2	1.00 LNG	4 X 2 X 7 GA (3/16)WALL TUBING ASTM A-500 GRADE B 1. Alro Part: 13028024	24 FT		169.8675 LNG	$169.87	0/00/00
3	2.00 PC	10 GA CR SHEET MISC TEMPER PASS A1008 CS TYPE B .1345 NOM 1. Alro Part: 08103200 2. Shearing 3. Cut Tolerance: +1/8 / -0	14.75 X 27.5 IN		67.0000 PC	$134.00	0/00/00

Email acceptance to: PMAJEWSKI@ALRO.COM or Fax to: (616) 452-2779

PO# ______________ Due Date ______________ Signed/Date ______________

Total Lines	3	**Weight**		**Quantity**	7.00
Fuel Surcharge	$13.85	**Tax**		**Total Price**	$732.93 USD

- Customer will verify physical receipt with packing slip within 48 hours of receipt. Claims for deviations shall be made in writing within 10 days and shall not exceed the price of the material.
- Pounds shown are based on material required to produce and fill your order and are based on calculated weights within normal mill tolerances and may vary from actual weight shipped.
- The above quote is for your internal use only and should not be shared with any third party in any form.
- Availability subject to prior sale(s).
- All amounts are stated in U.S. Dollars & must be paid in U.S. Dollars.
- Only one fuel surcharge will be charged per scheduled delivery day.
- Alro will not be held responsible for customer specifications unless those specifications are mutually agreed to in writing at the time of order.
- Subject to terms and conditions per Alro invoices.
- Prices quoted will be honored if ordered and shipped within 24 hours of this quote.
- Prices are predicated on receiving the total order.
- All other orders will be priced based on pricing levels at time of delivery.
- Prices include raw material surcharges where applicable.
- Alro's standard payment terms are 1/2% 10 days, net 30 days.

Prices quoted will be honored if ordered and shipped within 24 hours of this quote. **Page 1**

Figure 16. Alro Steel Quote

Appendix C - FEA & Verification

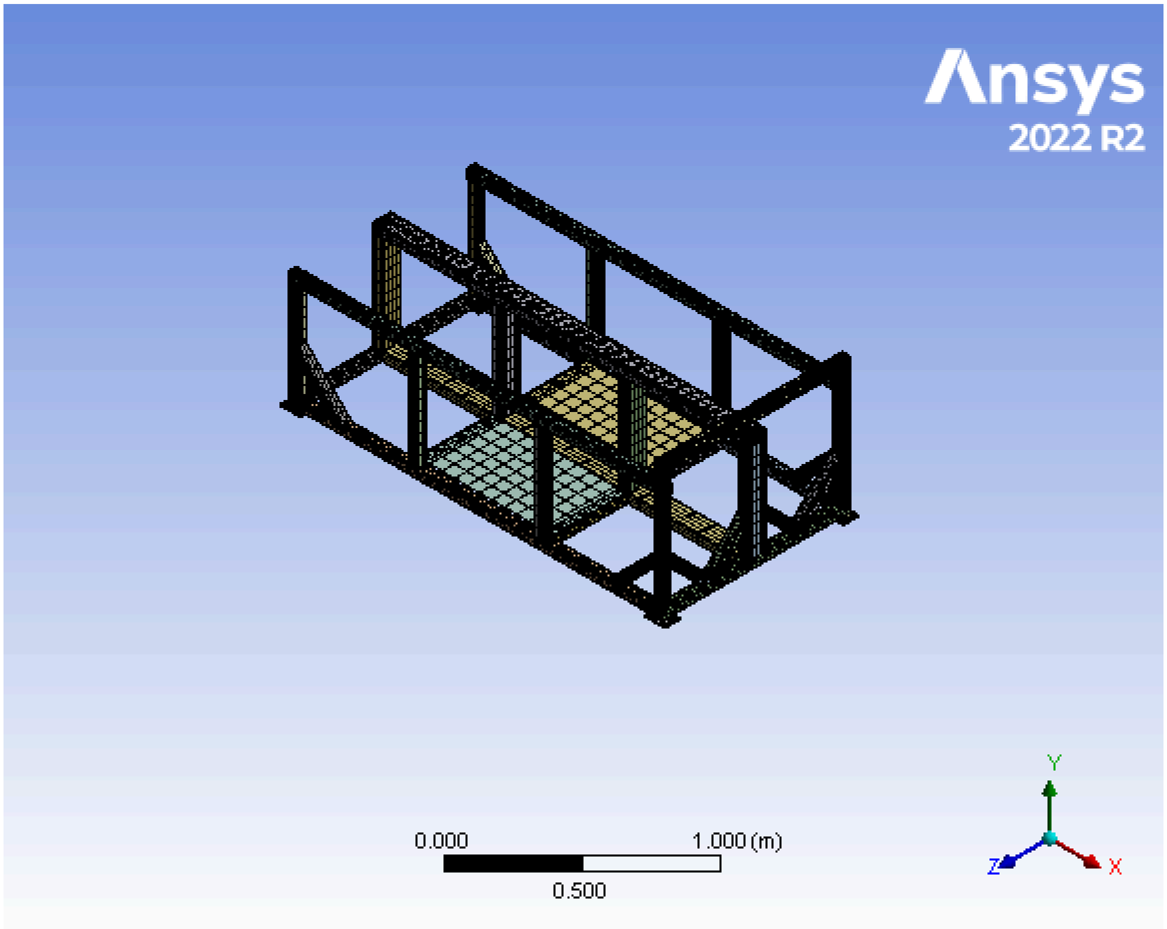


Figure 17. Frame Mesh

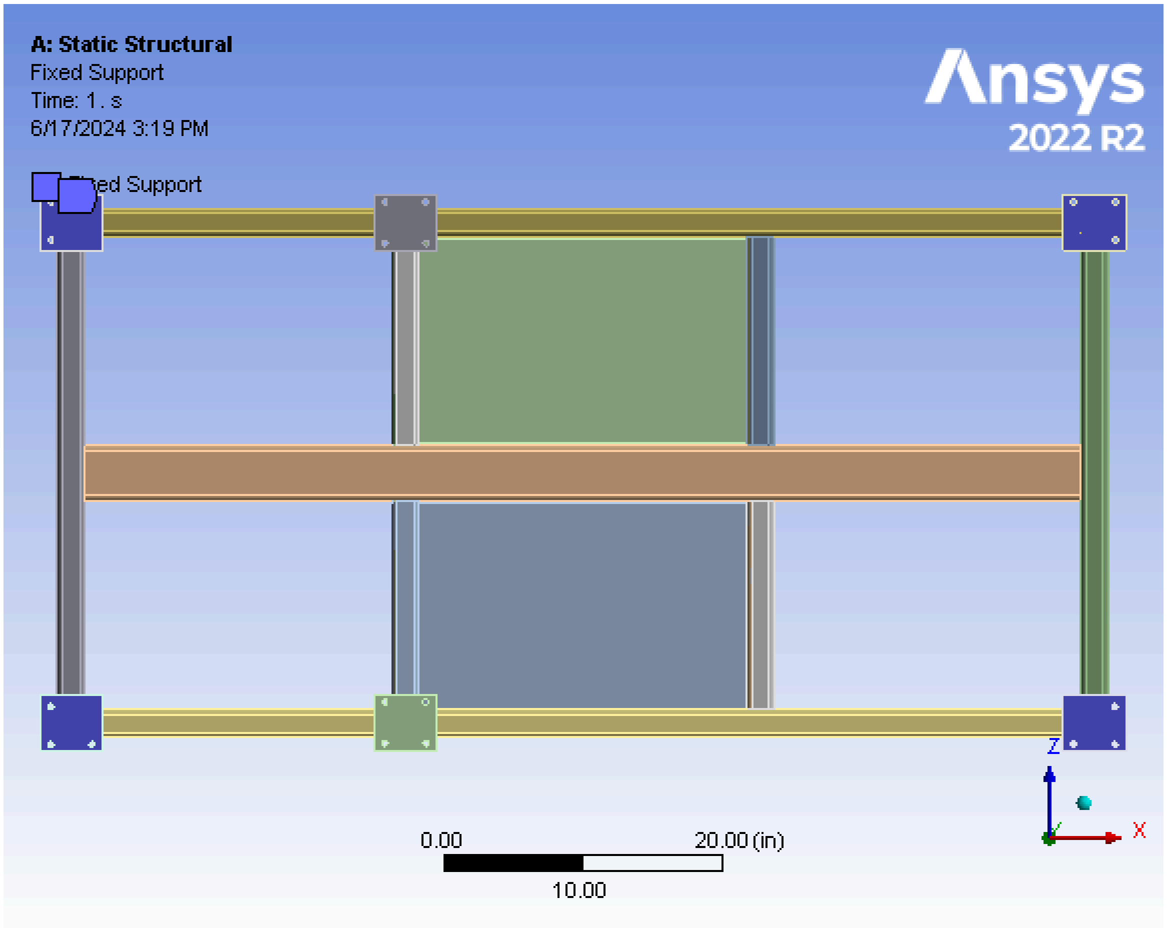


Figure 18. Fixed support on Frame

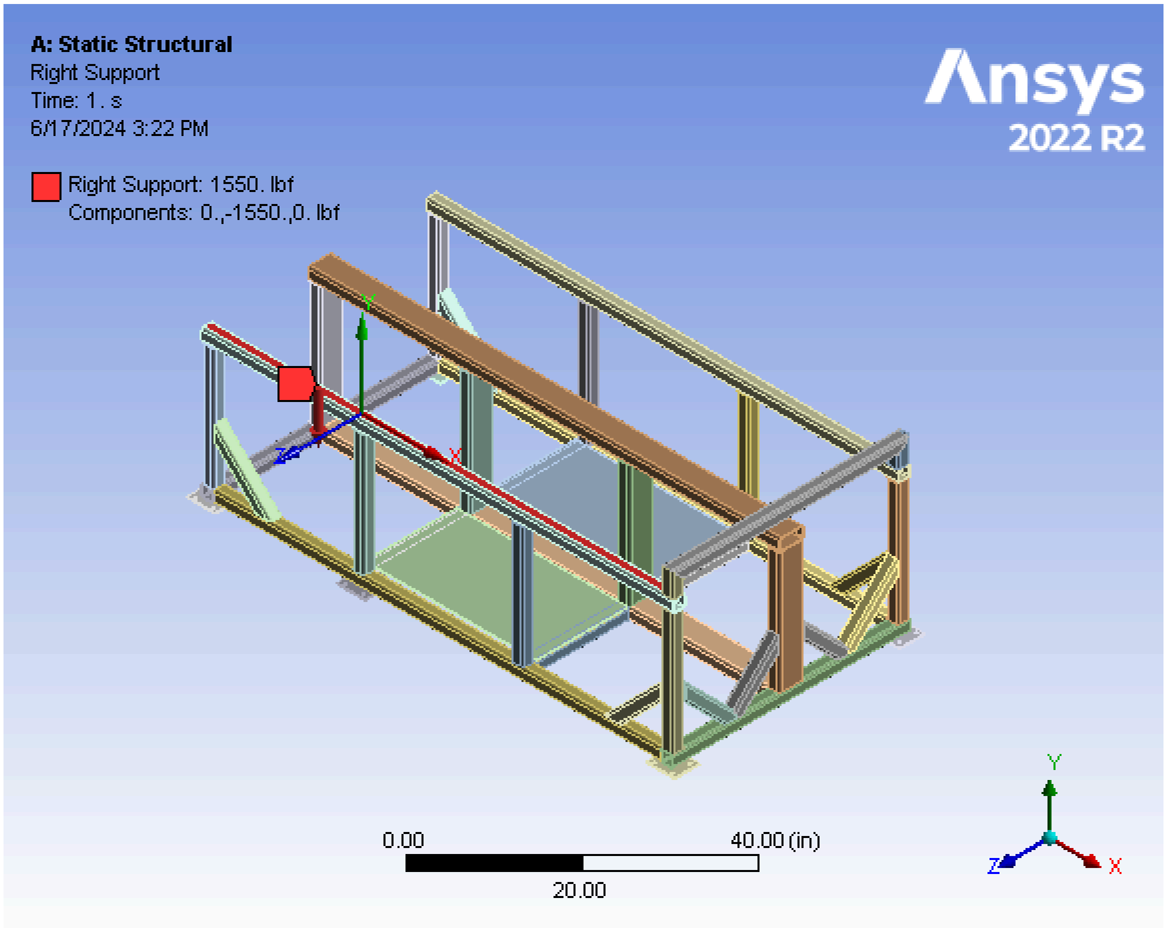


Figure 19. Loading of Center Support on Frame

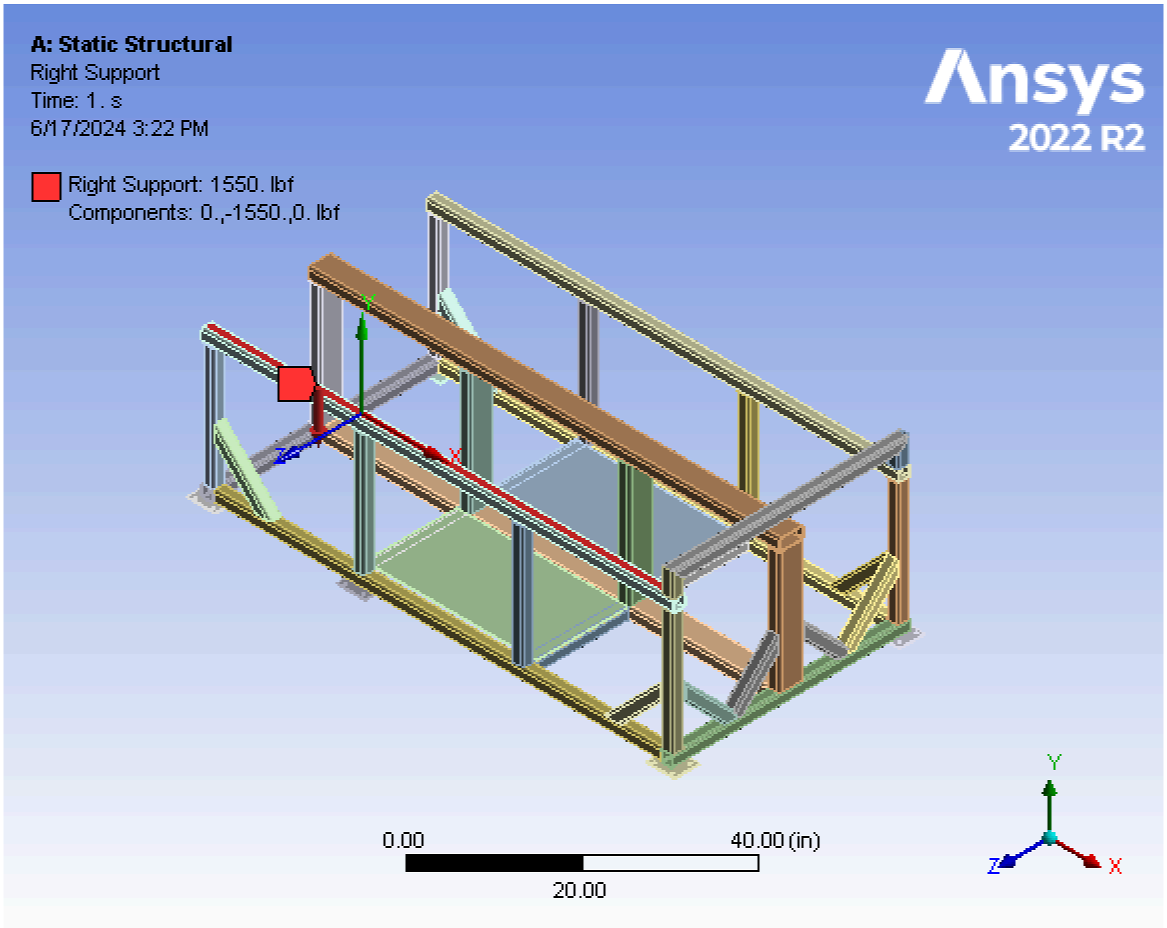


Figure 20. Loading of Left Support on Frame

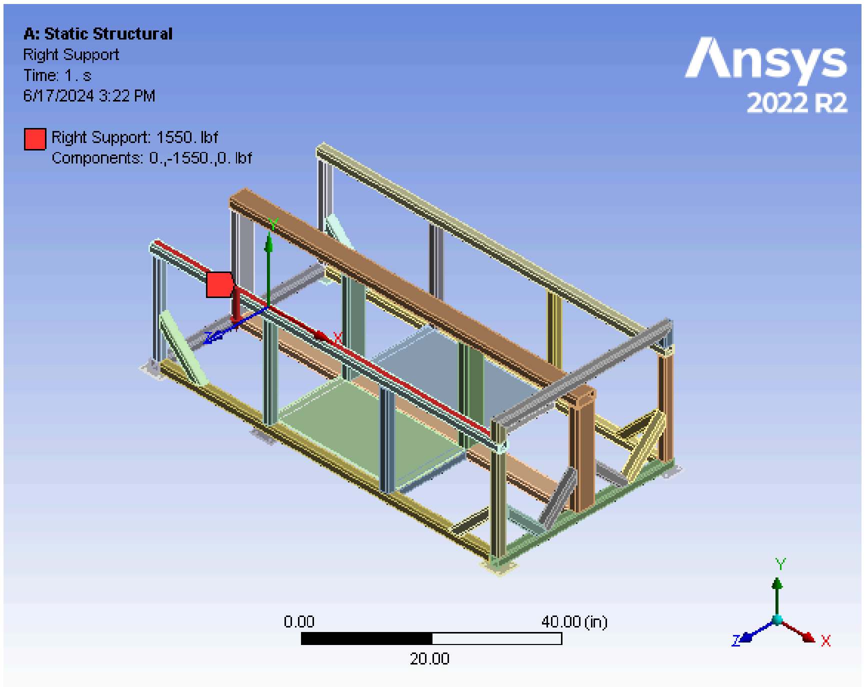


Figure 21. Loading of Right Support on Frame

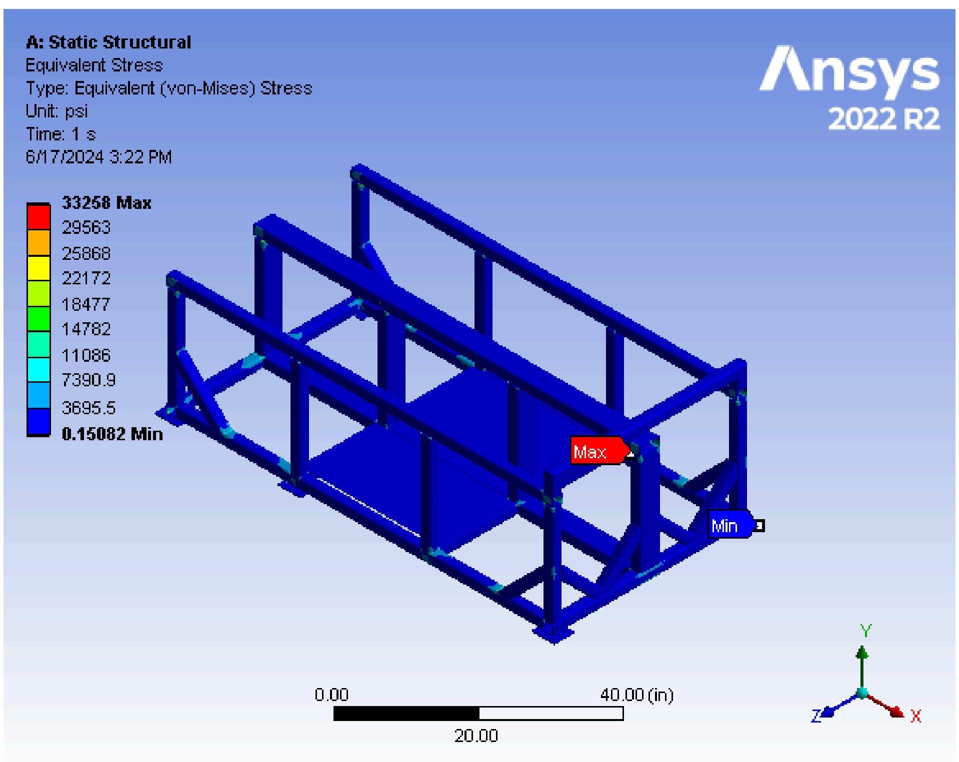


Figure 22. Stress in Frame

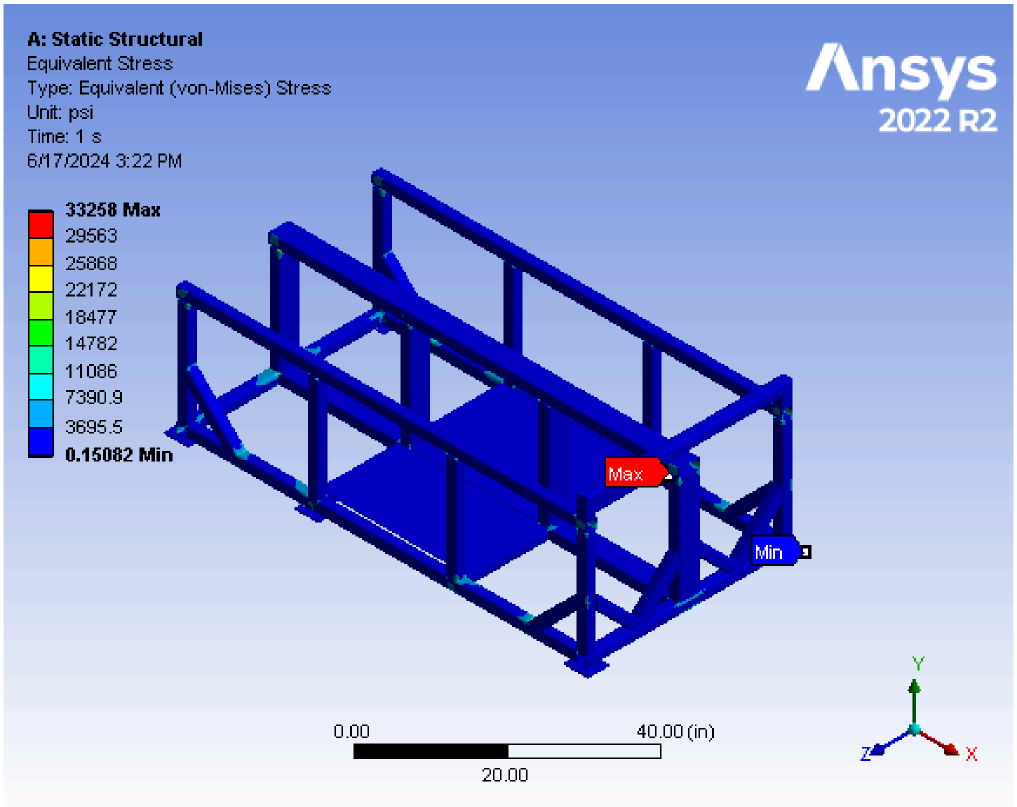


Figure 23. Fixed Support Swivel Hoist Ring

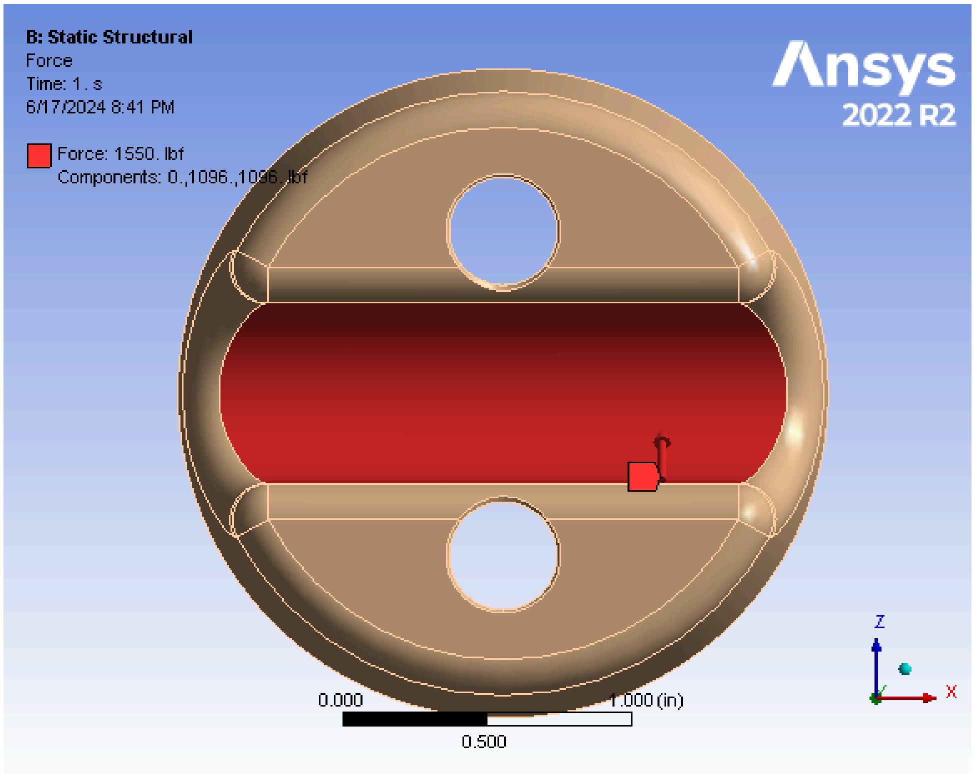


Figure 24. Force on Swivel Hoist Ring

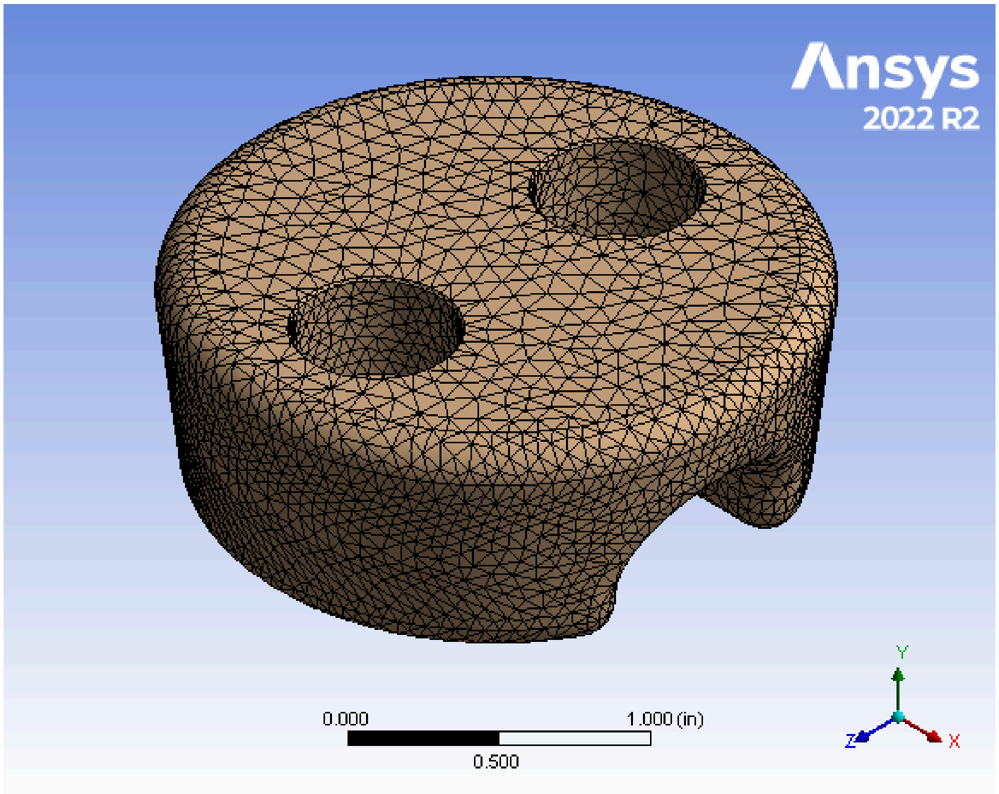


Figure 25. Mesh on Swivel Hoist Ring

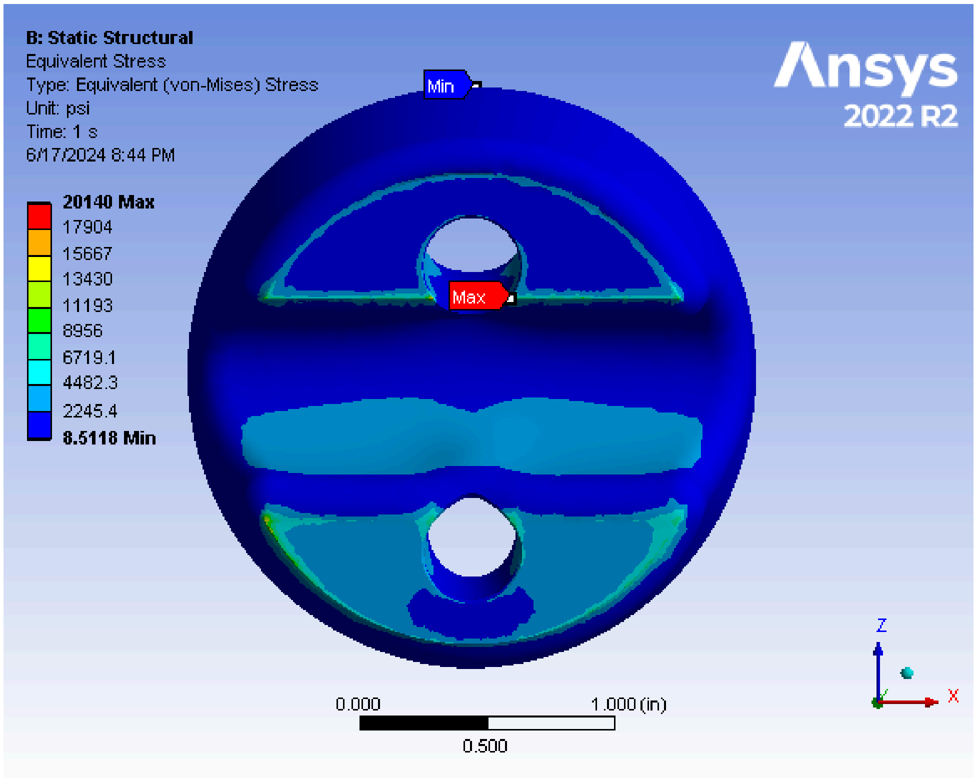
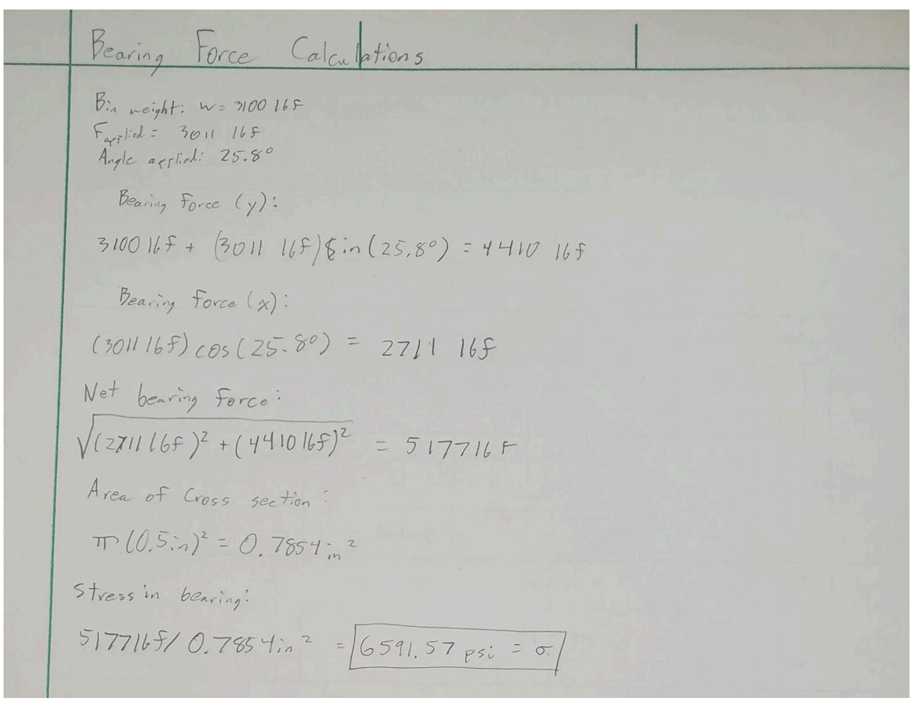


Figure 26. Swivel Hoist Ring



Bearing Force Calculations

Bin weight: w = 3100 lbf
$F_{applied}$ = 3011 lbf
Angle applied: 25.8°

Bearing Force (y):

$3100\ lbf + (3011\ lbf)\sin(25.8°) = 4410\ lbf$

Bearing Force (x):

$(3011\ lbf)\cos(25.8°) = 2711\ lbf$

Net bearing force:

$\sqrt{(2711\ lbf)^2 + (4410\ lbf)^2} = 5177\ lbf$

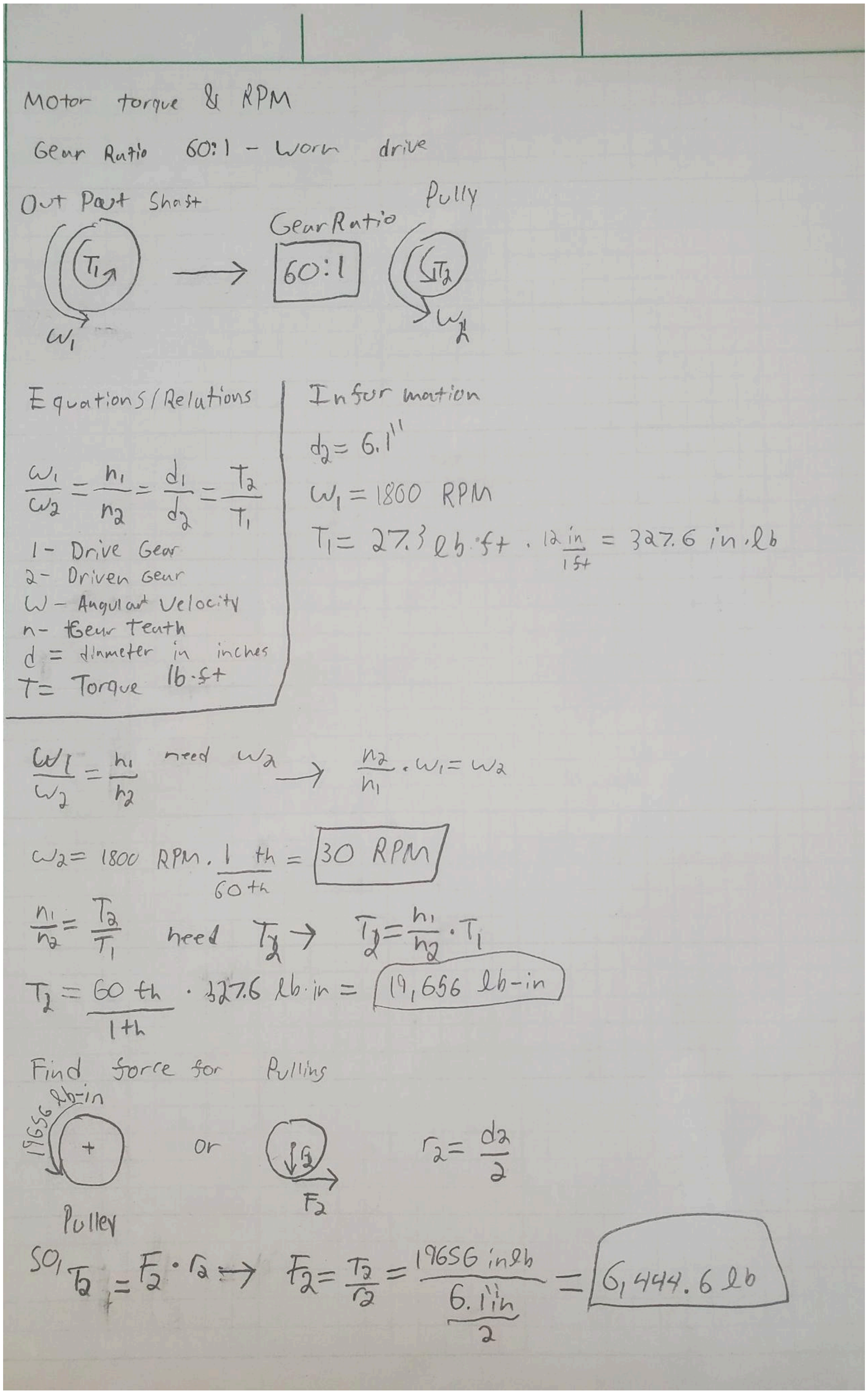
Area of Cross section:

$\pi(0.5in)^2 = 0.7854\ in^2$

Stress in bearing:

$5177\ lbf / 0.7854\ in^2 = \boxed{6591.57\ psi = \sigma}$

Figure 27. Bearing Calculations



Motor torque & RPM

Gear Ratio 60:1 - Worm drive

Out Put Shaft → Gear Ratio $\boxed{60:1}$ → Pully

T_1, ω_1 $\qquad$ T_2, ω_2

Equations/Relations

$$\frac{\omega_1}{\omega_2} = \frac{n_1}{n_2} = \frac{d_1}{d_2} = \frac{T_2}{T_1}$$

1 - Drive Gear
2 - Driven Gear
ω - Angular Velocity
n - Gear teeth
d = diameter in inches
T = Torque lb·ft

Information

$d_2 = 6.1''$

$\omega_1 = 1800$ RPM

$T_1 = 27.3\ lb \cdot ft \cdot \frac{12\ in}{1\ ft} = 327.6\ in \cdot lb$

$$\frac{\omega_1}{\omega_2} = \frac{n_1}{n_2} \quad \text{need } \omega_2 \longrightarrow \frac{n_2}{n_1} \cdot \omega_1 = \omega_2$$

$$\omega_2 = 1800\ RPM \cdot \frac{1\ th}{60\ th} = \boxed{30\ RPM}$$

$$\frac{n_1}{n_2} = \frac{T_2}{T_1} \quad \text{need } T_2 \rightarrow T_2 = \frac{n_1}{n_2} \cdot T_1$$

$$T_2 = \frac{60\ th}{1\ th} \cdot 327.6\ lb \cdot in = 19{,}656\ lb\text{-}in$$

Find force for Pulling

19656 lb-in

Pulley $\qquad$ or $\qquad$ F_2 $\qquad$ $r_2 = \frac{d_2}{2}$

$$\text{so, } T_2 = F_2 \cdot r_2 \Rightarrow F_2 = \frac{T_2}{r_2} = \frac{19656\ in\,lb}{\frac{6.1''\ in}{2}} = \boxed{6{,}444.6\ lb}$$

Figure 28. Hand Calculation for Motor Speed and Torque

Appendix D - Electrical Diagram

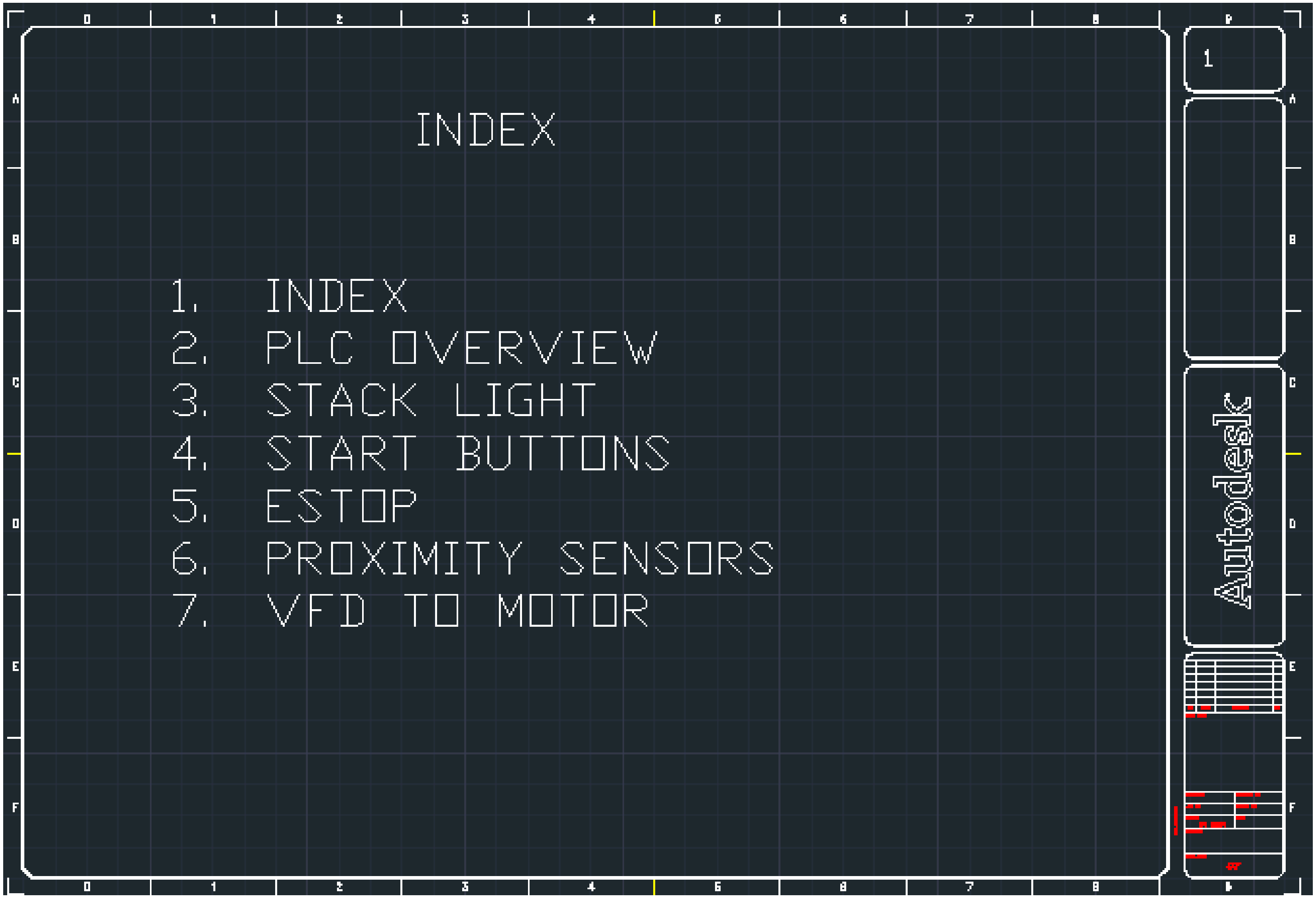


Figure 29: Index

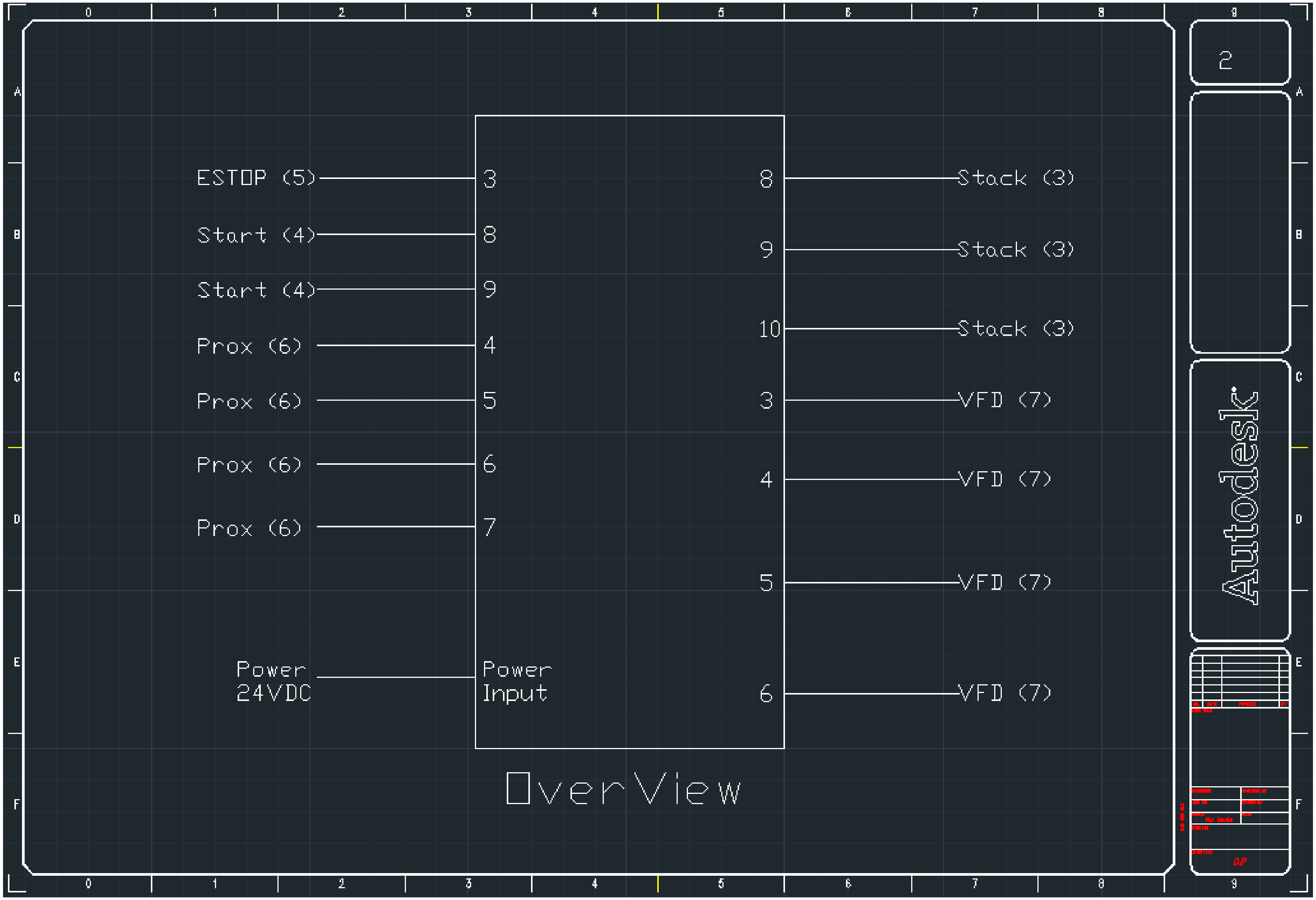


Figure 30: PLC Overview

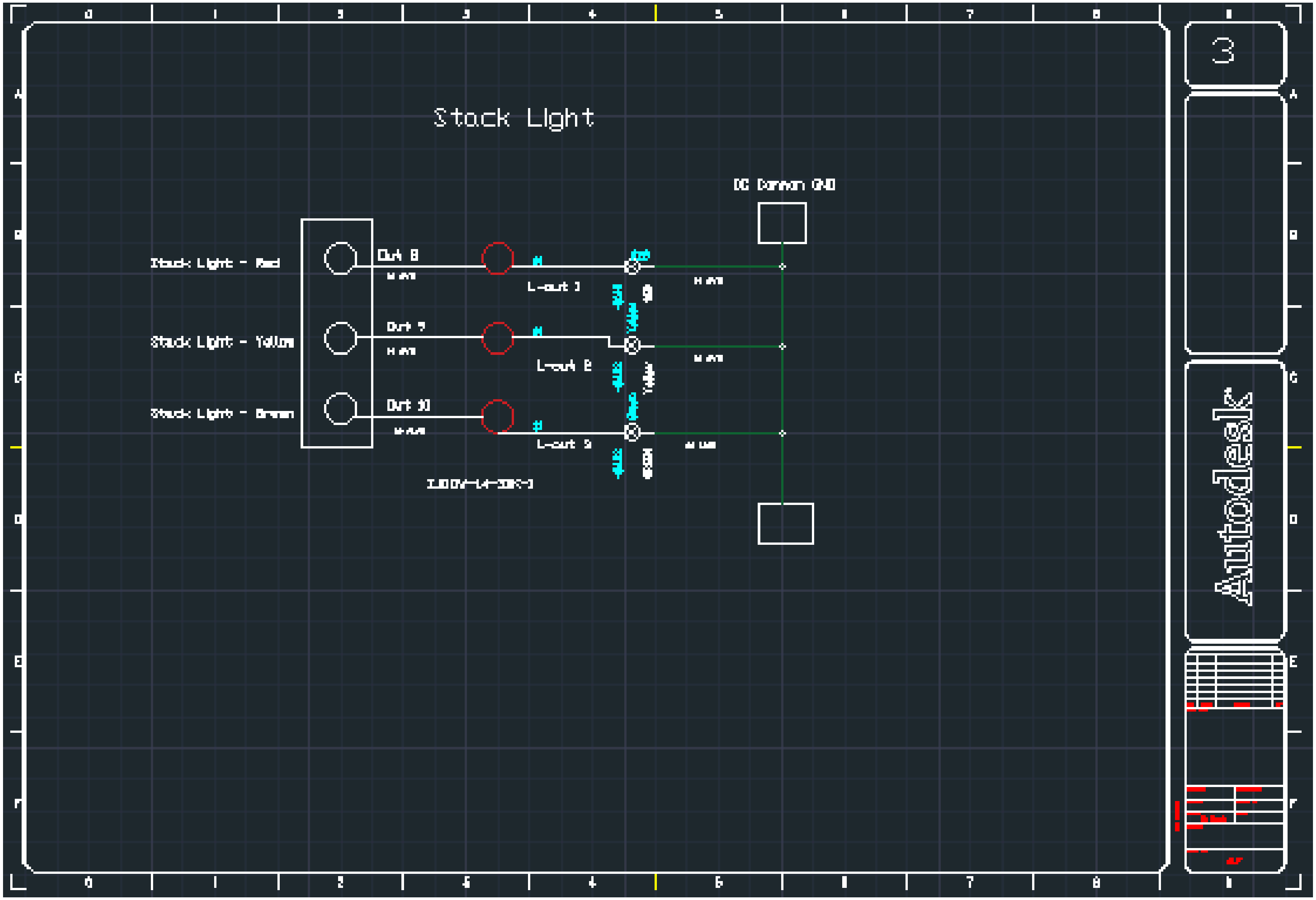


Figure 31: Stack Light

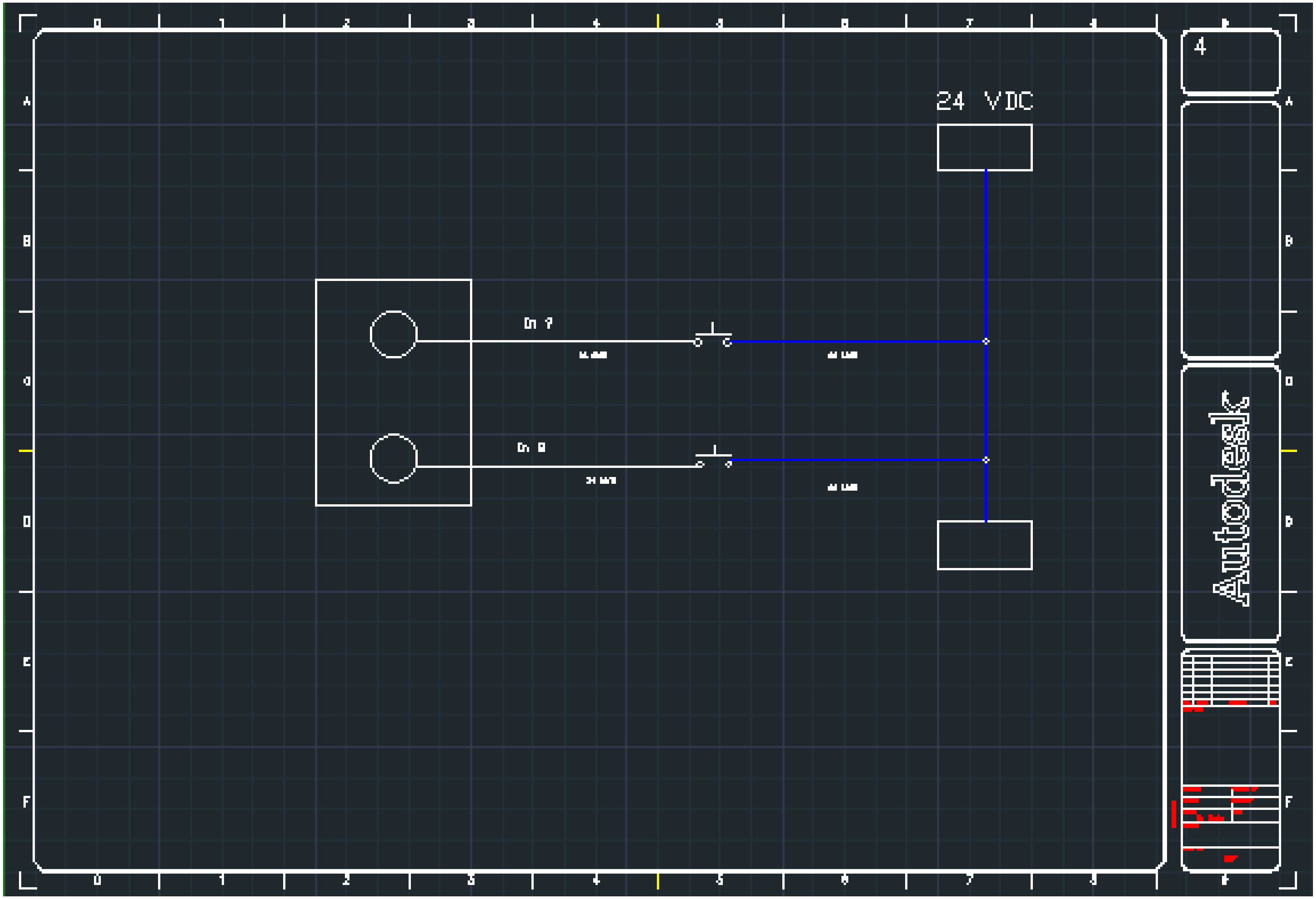


Figure 32: Start Buttons

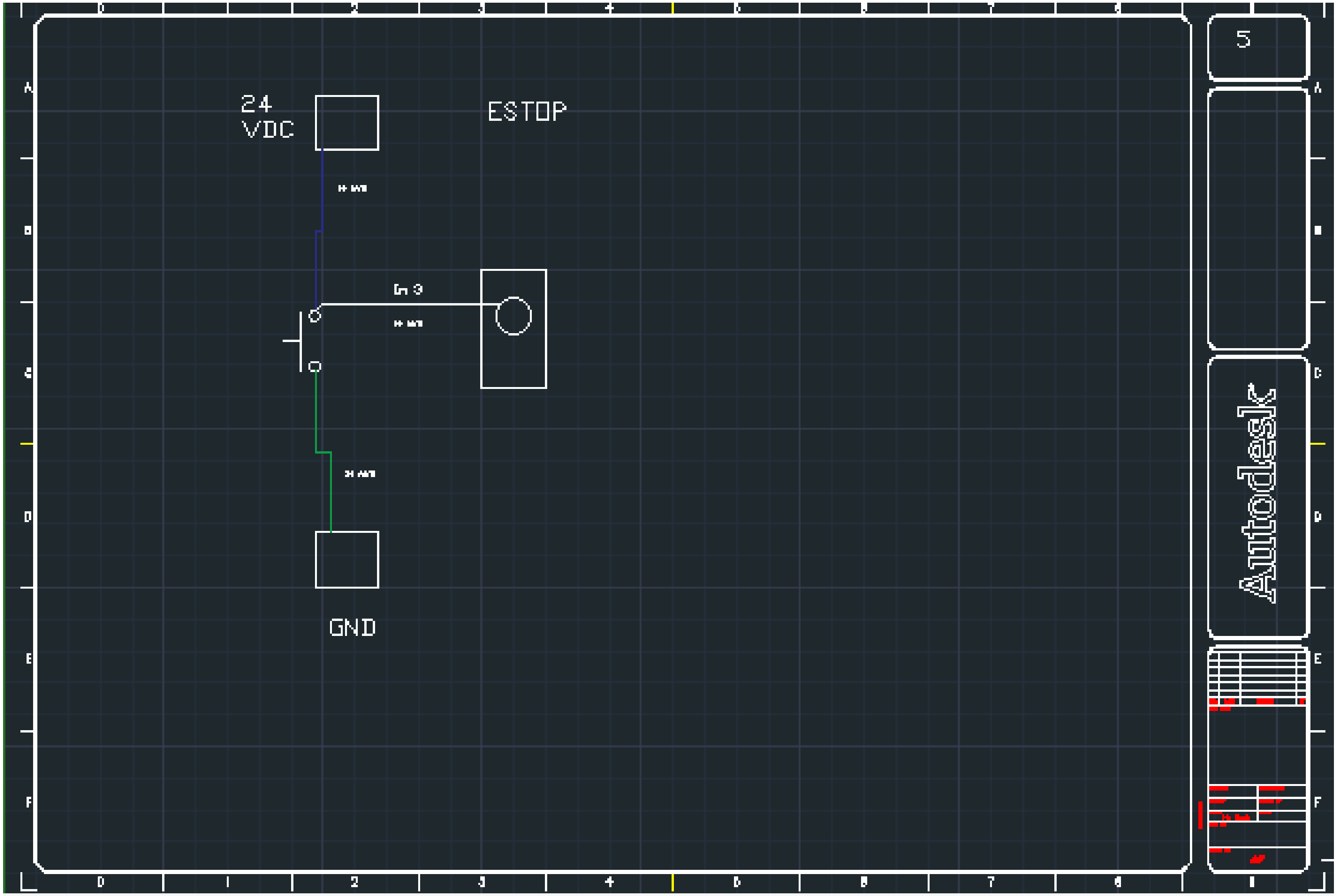


Figure 33: E-STOP

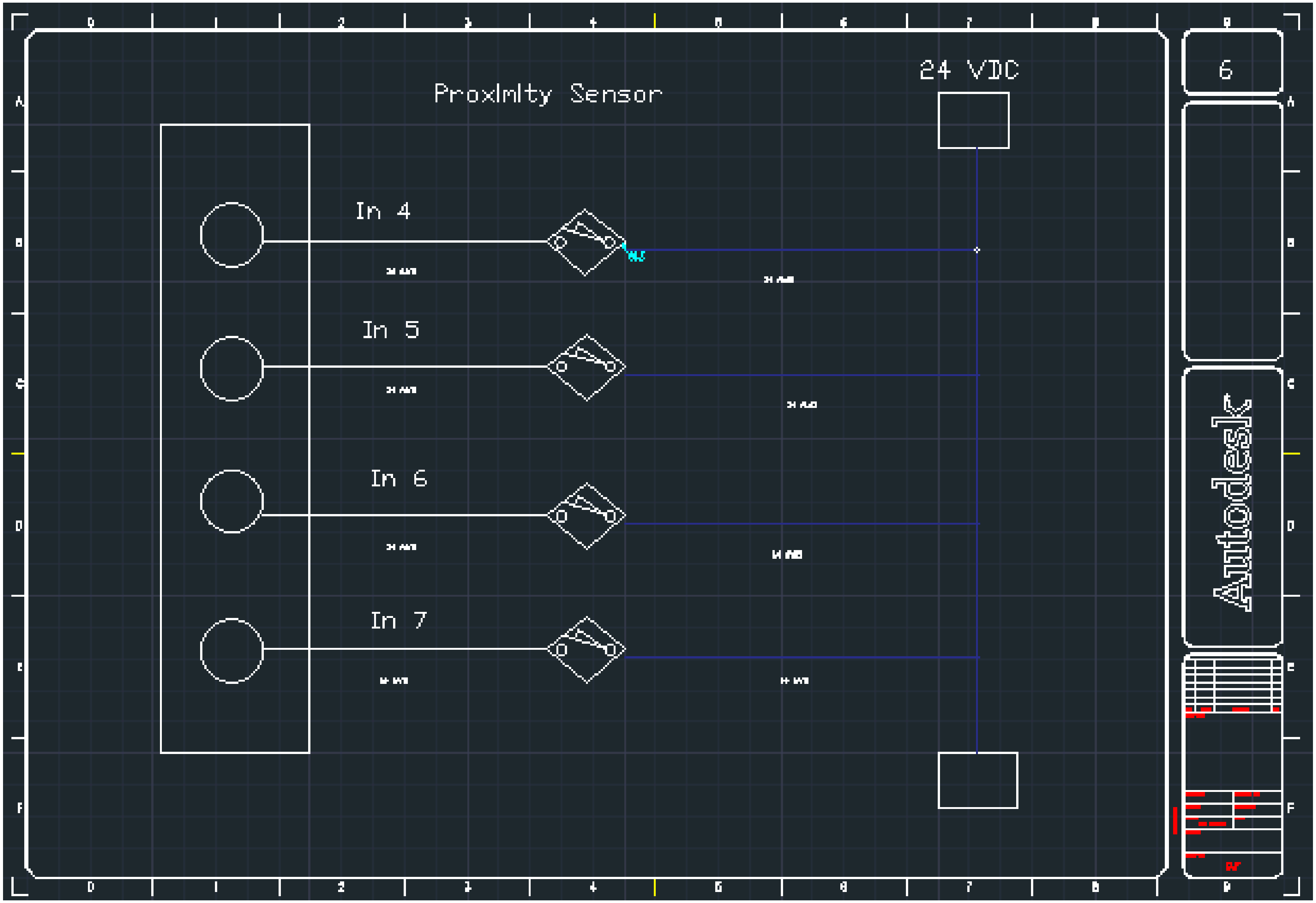


Figure 34: Proximity Sensors

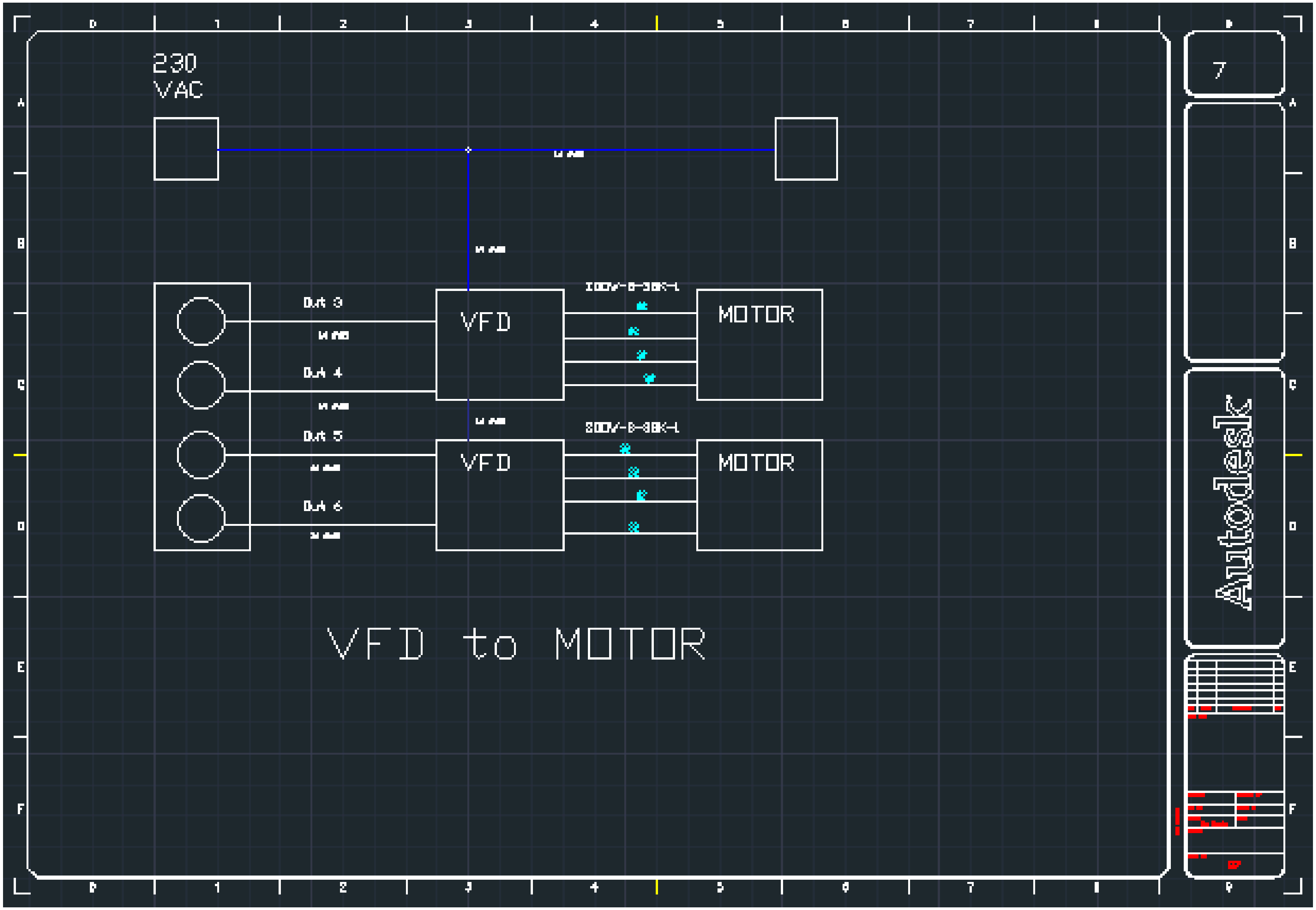


Fig 35: VFD to Motor

Appendix E - Future Expansion

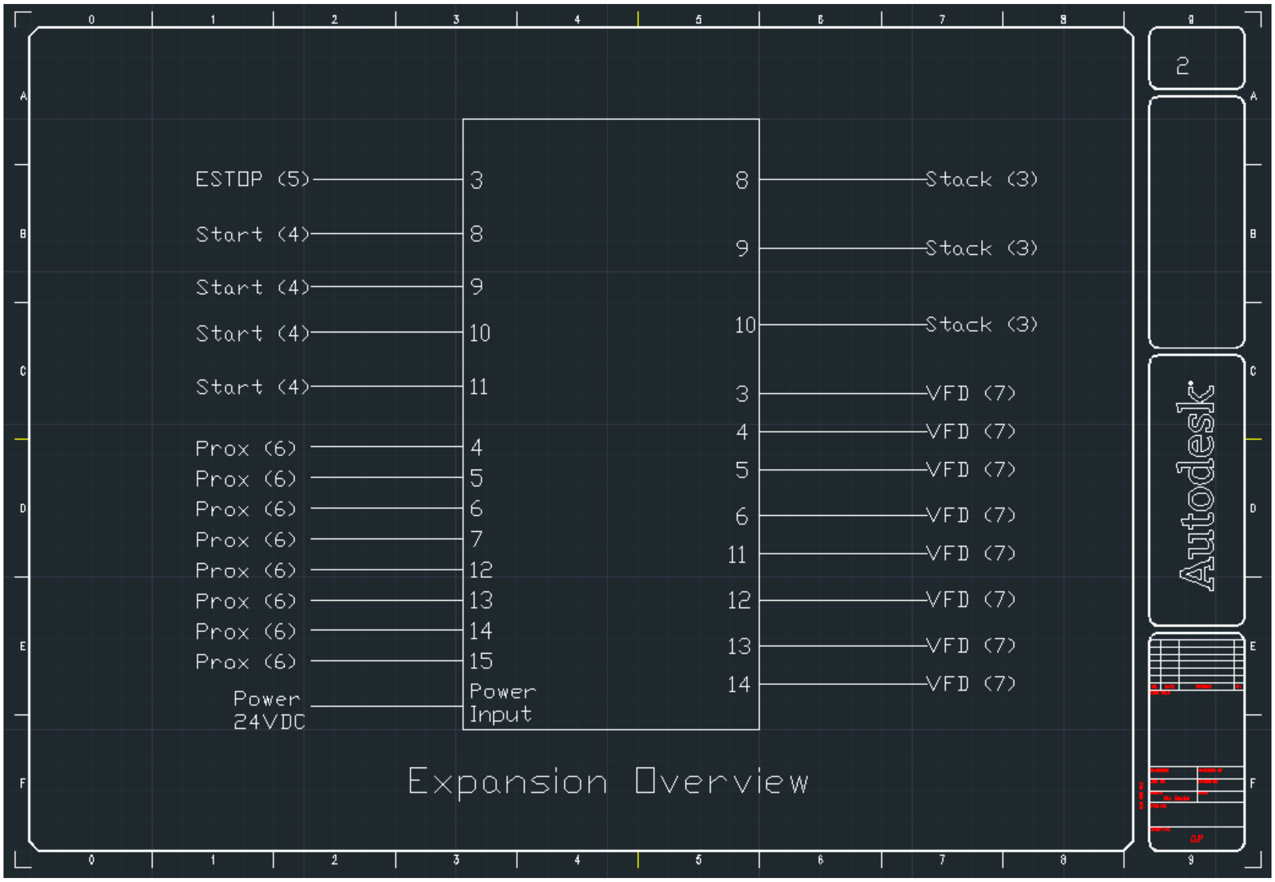


Figure 36: Expansion Overview

If the sponsor would like to expand in the future, this is an overview of what components would be needed, which are:

- 4 more proximity sensors for the upper and lower limits of the two extra boxes.
- 2 more start buttons for the two extra boxes.
- 2 more VFDs, (there are two wires from the PLC to each VFD for forward and reverse).
- 2 more motors are connected to the VFDs (Refer to figure 35 - VFD to Motor)
- 2 more proximity sensors to ensure the pins for the extra bays are in place

Appendix F - AWS B1.11 Welding Standard

Inspection of the welds will be performed in compliance with AWS B1.11M/B1.11:2015 in the following sections:

- Section 4.2.7 - Examination of Fit-Up and Alignment of Joints

4.2.7 Examine Fit-Up and Alignment of Joints. Joint fit-up and alignment are critical to the production of a sound weld. Items that may be considered prior to welding include:

(1) Groove angle

(2) Bevel depth

(3) Root opening

(4) Joint alignment and weld joint mismatch (see Figure 1)

(5) Backing

(6) Consumable insert

(7) Joint cleanliness

(8) Tack welds

(9) Preheat

- Section 4.3.3 - Examination of Weld Root Bead

4.3.3 Examine Weld Root Bead. The first weld deposited in a multiple pass weld, called the root bead, is susceptible to a number of weld discontinuities such as cracks, incomplete fusion, incomplete joint penetration, etc. A thorough visual examination of the root bead can detect many unacceptable conditions that should be corrected before depositing additional weld metal.

- Section 4.3.4 - Examination of Intermediate Weld Beads

4.3.4 Examine Intermediate Weld Beads. Examine intermediate weld beads as work progresses to ensure the weld beads are free of unacceptable conditions or discontinuities such as cracks, undercut, incomplete fusion, slag or oxides, etc., which if left uncorrected can result in unacceptable welds.

- Section 4.3.5 - Examination of Second Side before Welding

4.3.5 Examine Second Side Prior to Welding. Critical joint root conditions may exist on the second side of a double welded joint. This area should be examined after removal of slag and other irregularities. This is to assure that all discontinuities have been removed and that the contour and cleanliness of the excavation are suitable for subsequent welding.

- Section 4.4.1 through 4.4.4 - After Welding Examination

4.4.1 Examine Weld Surface Quality. Visually examine weld surface to verify the weld profile meets the acceptance criteria specified by the contract documents. Workmanship standards may address such items as surface roughness, weld spatter, and arc strikes. Most codes and specifications describe the type and size of discontinuities that are acceptable. Many of these discontinuities can be found by visual examination of the completed weld. The following are typical discontinuities found at the surface of welds:

(1) Porosity

(2) Incomplete fusion

(3) Incomplete joint penetration

(4) Undercut

(5) Underfill

(6) Overlap

(7) Cracks

(8) Metallic and nonmetallic inclusions

(9) Reinforcement

(10) Weld bead profile

(11) Root oxidation

4.4.2 Verify Weld Dimensions. All completed welds should be visually examined to verify the weld meets the drawing requirements for profile, size, length, and location. Fillet weld sizes can be determined by using one of several types of weld gauges to be discussed later. Groove welds should be filled to the full cross section of the joint, or as specified, and the weld reinforcement should not be excessive. Some conditions may require the use of special weld gauges to verify these dimensions.

4.4.3 Verify Dimensional Accuracy. Final examination of a fabricated weldment should verify that the dimensions are in accordance with the drawing.

4.4.4 Review Subsequent Requirements. Review the specification to determine if additional procedures are required. Such procedures may include postweld heat treatment, nondestructive testing, proof testing, or other operations.

- Section 5.1 - Weld Surface Conditions, General

5.1 General. This clause is concerned only with discontinuities, which may or may not be classed as defects (rejectable) depending on requirements of individual specifications or codes. The intent is informational and instructional, and meant to assist in the identification of discontinuities. Discontinuities can occur at any location in the weld. Visual examination after welding is limited to the surface condition of the weld. Discovery of subsurface discontinuities requires the visual examination be supplemented by a volumetric nondestructive test method such as ultrasonic or radiographic examination.

A discontinuity is an interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect. Discontinuities are rejectable only if they exceed specification requirements in terms of type, size, distribution, or location. A defect is a discontinuity or discontinuities that by nature or accumulated effect (for example, total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. The term *defect* designates rejectability.

Weld and base-metal discontinuities of specific types are more common when certain welding processes and joint details are used. Attendant conditions, such as high restraint and limited access to portions of a weld joint, may lead to a higher than normal incidence of weld or base-metal discontinuities. For example, highly restrained weld joints are more prone to cracking.

Each general type of discontinuity is discussed in detail in this clause (see also Table 1 and Figures 2 through 7). Other documents may use different terminology for some of these discontinuities; however, whenever possible, the approved AWS terminology, as found in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, should be used to eliminate confusion. An example of additional terminology occurs in AWS D1.1/D1.1M, *Structural Welding Code—Steel*. There, *fusion-type discontinuity* is a general term which is used to describe a number of discontinuities, including: slag inclusions, incomplete fusion, incomplete joint penetration, and similar elongated discontinuities in fusion welds.

- Section 5.10 - Weld Surface Conditions, Cracks

5.10 Cracks [see Table 1(12)]. Cracks are defined as fracture-type discontinuities characterized by a sharp tip and high ratio of length and/or width to thickness. They can occur in weld metal, heat-affected zone (HAZ), and base metal.

Cracking often initiates at stress concentrations caused by other discontinuities or near mechanical notches associated with the weldment design. Stresses that cause cracking may be either residual or service-induced. Residual stresses develop as a result of restraint provided by the weld joint and thermal contraction of the weld following solidification. Some crack types are illustrated in Figure 27.

If a crack is found during welding, it should be completely removed prior to additional welding. Welding over a crack rarely eliminates the crack.

5.10.2 Crack Types. Cracks can generally be classified as either hot cracks or cold cracks. Hot cracks occur in a metal during solidification or at elevated temperatures. Hot cracks can occur in both heat-affected (HAZ) and weld metal zones (WMZ), and are the result of insufficient ductility at high temperature. Hot cracks propagate between grains in the weld metal or at the weld interface.

Cold cracks occur in a metal at or near ambient temperatures. Cold cracks can occur in base metal (BMZ), heat-affected (HAZ), and weld metal zones (WMZ). They may result from improper welding practices or service conditions. Cold cracks propagate both between grains and through grains.

5.10.2.1 Throat Cracks [see Table 1(12) (c)]. Throat cracks are longitudinal cracks oriented along the throat of fillet welds. A throat crack is shown in Figure 31. They are generally, but not always, hot cracks.

5.10.2.2 Face and Root Cracks [see Table 1(12)(d)]. Face cracks are cracks that occur on the face of the weld and that can be oriented longitudinally or transversely. Root cracks are longitudinal cracks at the weld root or in the root surface. They may be hot or cold cracks. Face and root cracks are illustrated in Figure 27 and a face crack is illustrated in Figure 29.

5.10.2.3 Crater Cracks [see Table 1(12)(e)]. Crater cracks occur in the crater of a weld when the welding is improperly terminated. They are sometimes referred to as *star cracks*, though they may have other configurations. A crater crack is shown in Figure 32. Crater cracks are hot cracks usually forming a pronged starlike network. Crater cracks are found most frequently in materials with high coefficients of thermal expansion, for example austenitic stainless steel and aluminum. However, the occurrence of any such cracks can be minimized or prevented by filling the crater to a slightly convex shape prior to terminating the arc. Longitudinal cracks may initiate from a crater crack. Such a crack is shown in Figure 33.

5.10.2.4 Toe Cracks [see Table 1(12)(f)]. Toe cracks (Figures 34 and 35) are generally cold cracks. They initiate and propagate from the weld toe where shrinkage stresses are concentrated. Toe cracks initiate approximately normal to the base-metal surface. These cracks are generally the result of thermal shrinkage stresses acting on a weld heat-affected zone. Some toe cracks occur because the ductility of the base metal cannot accommodate the shrinkage stresses that are imposed by welding. Figures 34 and 35 depict a toe crack at the toe of a fillet weld.

5.10.2.5 Underbead and Heat-Affected Zone Cracks [see Table 1(12)(g)]. Carbon and low alloy steels are susceptible to cracks due to the presence of diffusible (atomic) hydrogen. Since this type of cracking may not occur until after the welding is completed, a hold time may be required prior to examination. The cracks are also known as delayed cold cracks, underbead cracks, heat-affected zone cracks (HAZ cracks), hydrogen-induced cracks, and hydrogen-assisted cracks. Diffusible hydrogen can be introduced into the weld puddle by moisture in the flux covering, by the decomposition of the flux components in FCAW or SAW consumables, and the presence of hydrocarbons such as grease, oil, cutting fluids, paint, finger prints, etc. Underbead cracks are depicted in Figure 36. These are unlikely to be detected by visual examination.

- Section 5.16 - Melt-Through

5.16 Melt-Through. Melt-through is visible root reinforcement produced in a joint welded from one side. An example of melt-through is illustrated in Figure 43. Melt-through is generally acceptable unless it results in excessive root reinforcement. Excessive melt-through is known by other nonstandard terms such as "root protrusion."

- Section 5.17 - Weld Size

5.17 Weld Size. Weld size is a measure of a critical dimension, or a combination of critical dimensions of a weld. The required weld size should be shown on the detail drawings. Weld size for various welds are defined and illustrated in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying.*

- Section 5.18 - Surface Oxidation

5.18 Surface Oxidation. Surface oxidation occurs when heated metals are exposed to atmospheric gases; this may be the result of insufficient shielding. It is also known by non-standard terms such as *sugaring*, *carburizing*, or *decarburizing*. Surface oxidation of stainless steels and nickel alloys can vary from iridescent colors of light straw, red, or blue when exposed to the atmosphere at temperatures above 540°C [1000°F]. When titanium and zirconium are exposed to the atmosphere at high temperature, they may develop discoloration from straw color to blue to black. Any discoloration darker than slight yellowing indicates extreme contamination of the base metal. These conditions may be avoided by keeping these metals protected by an inert gas anytime they are heated above 430°C [800°F]. In piping, this is called purging, and specific direction on how to do purging of piping is covered in AWS D10.11M/D10.11, *Guide for Root Pass Welding of Pipe Without Backing*. Surface oxidation occurs during gas shielded arc welding when the gas shield is lost or inadequate. Excessive surface oxidation, sometimes called sugaring, is shown in Figure 44.

Appendix G - OSHA 1910.147 LOTO Standards

(a) Scope, application, and purpose—(1) Scope.

(i) This standard covers the servicing and maintenance of machines and equipment in which the unexpected energization or startup of the machines or equipment, or release of stored energy could cause injury to employees. This standard establishes minimum performance requirements for the control of such hazardous energy.

(ii) This standard does not cover the following:

(A) Construction and agriculture employment;

(B) Employment covered by parts 1915, 1917, and 1918 of this title;

(C) Installations under the exclusive control of electric utilities for power generation, transmission, and distribution, including related equipment for communication or metering;

(D) Exposure to electrical hazards from work on, near, or with conductors or equipment in electric-utilization installations, which is covered by subpart S of this part; and

(E) Oil and gas well drilling and servicing.

(2) Application.

(i) This standard applies to the control of energy during servicing and/or maintenance of machines and equipment.

(ii) Normal production operations are not covered by this standard. Servicing and/or maintenance that takes place during normal production operations is covered by this standard only if:

> (A) An employee is required to remove or bypass a guard or other safety device; or
>
> (B) An employee is required to place any part of his or her body into an area on a machine or piece of equipment where work is performed upon the material being processed (point of operation) or where an associated danger zone exists during a machine operating cycle.