Staking Machine User Manual

1815 - Connector Insert Stake Machine

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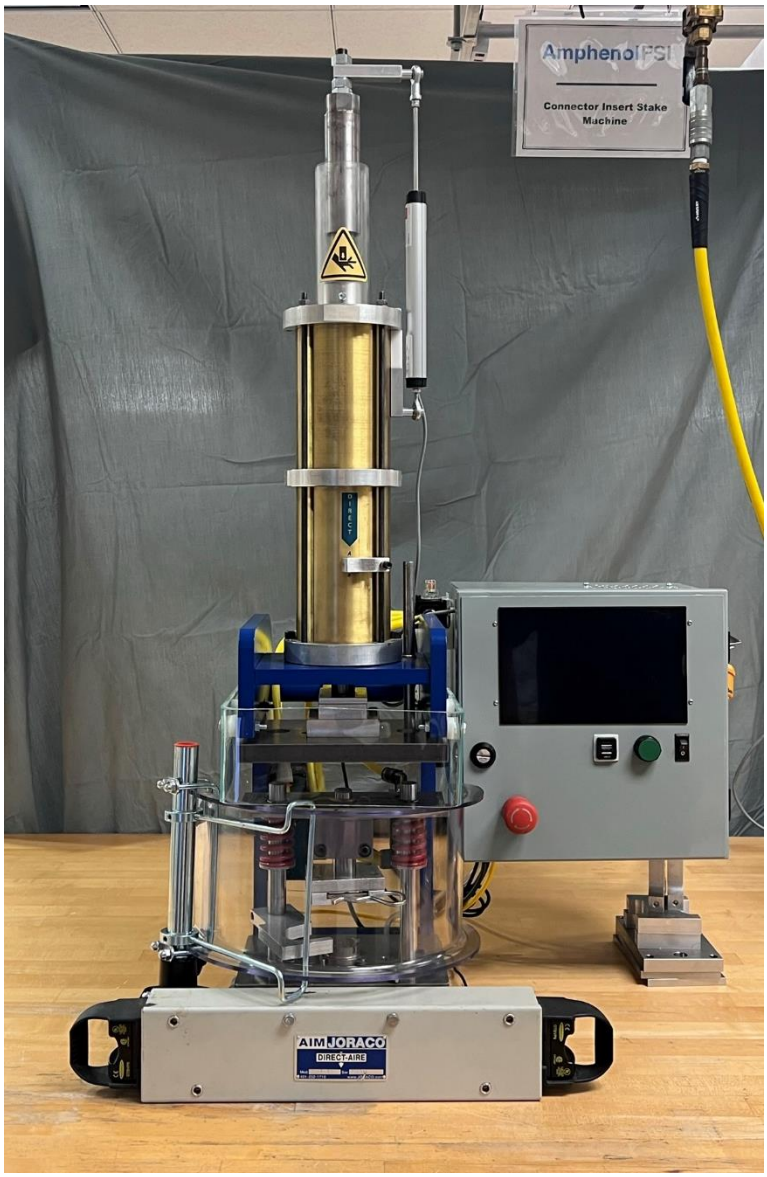
Introduction

This user manual provides a comprehensive guide for the Connector Insert Staking Machine produced by Fiber Focus – a student-led project within UTDesign from the University of Texas at Dallas. The Connector Insert Stake Machine was developed for Amphenol Fiber Systems International.

The Connector Insert Stake Machine is a pneumatic press equipped with a Programmable Logic Controller (PLC) and custom tooling designed for fixing inserts to connector shells. This manual aims to assist users in understanding the machine's functionalities, proper operation, maintenance procedures, and safety precautions.



Warnings and Safety Concerns

The installation and operation of electric and high-pressure systems, involving fluids and compressed gases, carry risks such as property damage, personal injury, or even death.

It is imperative that installers and users are adequately trained or certified and follow all necessary safety measures. Misuse or incorrect installation of this product can lead to serious consequences, including death, personal injury, or property damage.

The content of this document, along with additional information provided by Enfield Technologies and its authorized representatives, is designed for individuals with technical skills in selecting and utilizing these products. As a product owner, you are tasked with thoroughly assessing all technical and safety specifications pertinent to your application, including understanding the potential impacts of any failures. This product may not be appropriate for all scenarios, particularly those that involve human interaction. The responsibility to determine the product's appropriateness lies with you. Given that application requirements can differ significantly, you must conduct any necessary tests or analyses to confirm the product's suitability for your specific needs and verify that it meets all performance, safety, and warning criteria relevant to your situation.

Crush Hazard	The press exerts significant force and can crush fingers, hands, or other body parts if they are placed within the press during operation. Keep all body parts clear of the press area when it is in operation.
Pinch Points	Beware of pinch points in the press mechanism. Ensure that all guards are in place and properly secured to prevent accidental contact with moving parts.
High Pressure	Pneumatic systems operate under high pressure. Avoid contact with pneumatic hoses and components during operation to prevent injury from sudden releases of pressure or bursting hoses.
Electrical Hazard	The PLC controls the operation of the press and is powered by electricity. Avoid contact with electrical components and wiring to prevent electric shock.
Noise Exposure	Pneumatic presses can generate high levels of noise during operation. Wear hearing protection when working near the press for extended periods to prevent hearing damage.
Programming Error	Errors in serial communication between the HMI and PLC may result unexpected press movements or malfunctions. In the case of unexpected behavior, make sure that all operator users are aware of the e-stop and the power switch to the staking machine.

Table of Contents

1 Staking Machine Overview

Hardware/Terminology

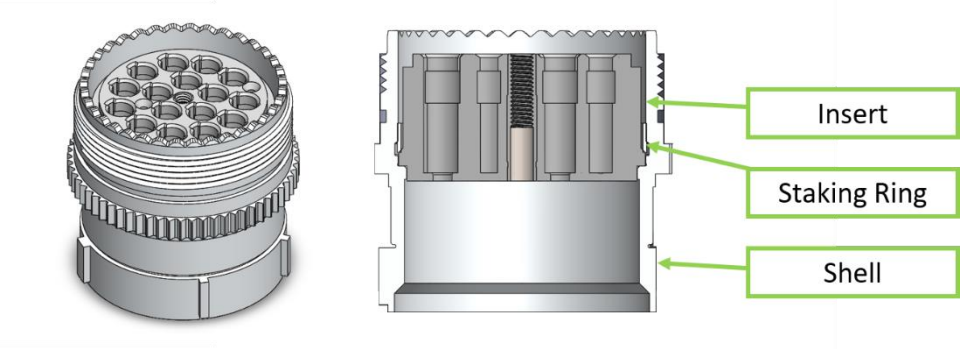
1.1.1 High-level terminology

This manual uses several terms throughout its copy that operators and technicians may be unfamiliar with. Some are established industry terms and others are specific to the Connector Stake Insert Machine. High-level terminology is defined in **Table 1**, with additional details for select terms following the table.

Table 1: High-level Terminology

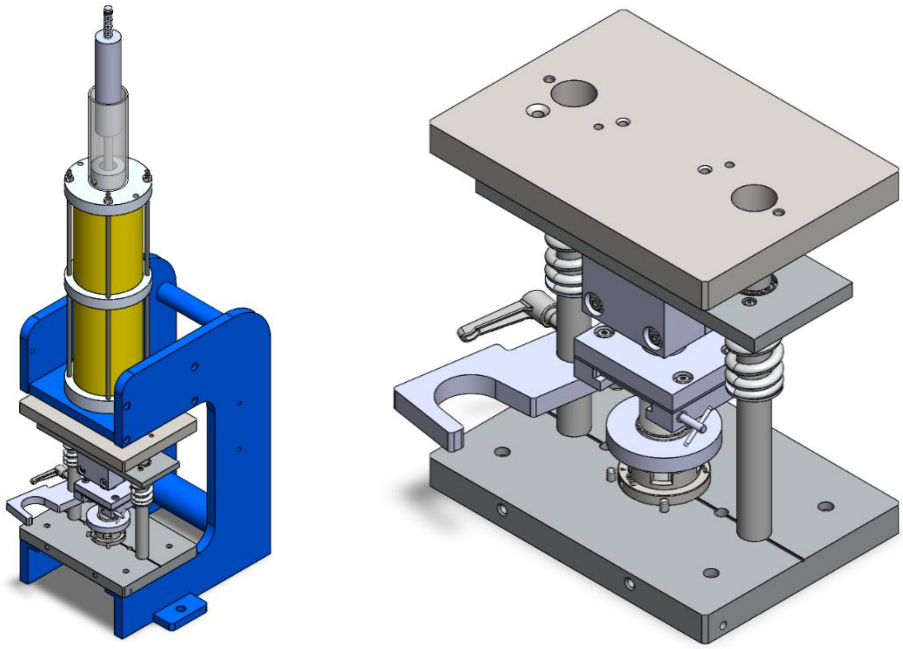
Term	**Meaning**
Connector	Physical contact component mating ends of two sets of optical fibers
Shell	Outer component of connector
Insert	Multichannel, inner component of connector
Staking Ring	Annealed aluminum ring used to fix shell and insert together
Staking	Process of deforming staking ring into gap between shell and insert to fix together
Staking machine	Whole machine
Tooling	Mechanical die set for staking
Press	Joraco DIRECT-AIRE Series Model 400T Benchtop Pneumatic Press
Press Cylinder	Primary pneumatic cylinder of press
Programmable Logic Controller (PLC)	Industrial computer adapted for controlling the staking process through input and outputs (I/O)
Human Machine Interface (HMI)	Touchscreen interface allowing operator to interact with PLC
Electrical Cabinet	Cabinet attached to press housing PLC, HMI, and other electrical components
Safety Switch	Emergency power stop
Pneumatic Filtration	PNEUMATICPLUG PPC3 Series Three Stage Air Drying System 1/8" NPT (High Flow)
Components-Off-the-Shelf (COTS)	Hardware products that are ready-made and available for sale to the public

Connector: Physical contact component mating ends of two sets of optical fibers, comprised of a shell (outer component), insert (inner component), and an annealed aluminum staking ring used to fix the shell and insert together.



Fiber optic connector with key components (shell, insert, and staking ring)

Staking Machine & Tooling: "Staking Machine" refers to the whole machine, including the press and the die-set, while "Tooling" refers to the mechanical die set that sits inside the press.



Staking machine (left) and tooling/die-set (right)

Press: The specific press referred to in this manual is the AIM Joraco DIRECT-AIRE Series Model 400T Benchtop Pneumatic Press.

AIM Joraco DIRECT-AIRE Series Model 400T Benchtop Pneumatic Press

Pneumatic Filtration: The specific pneumatic filtration system referred to in this manual is the PNEUMATICPLUG PPC3 Series Three Stage Air Drying System 1/8" NPT (High Flow).

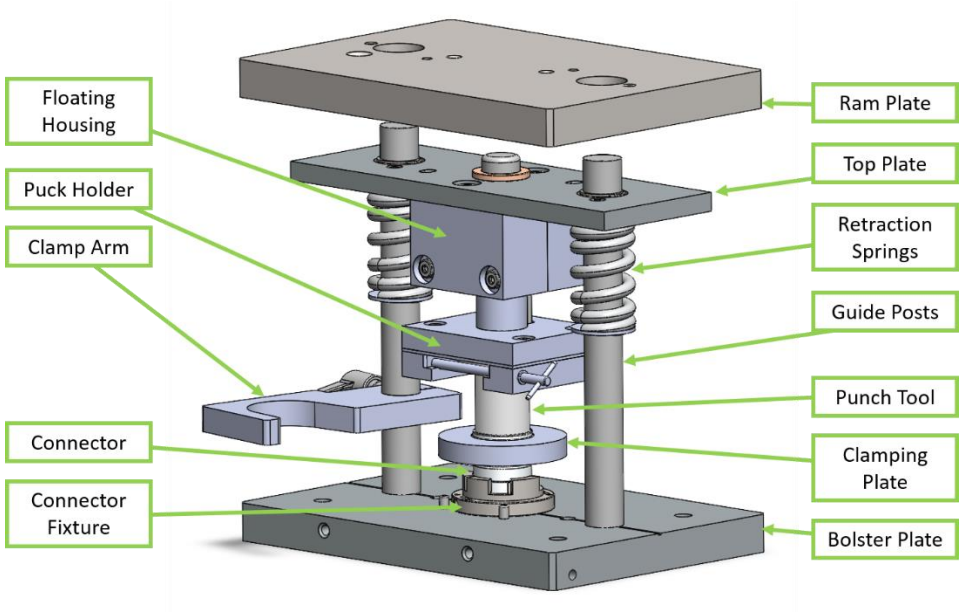
PNEUMATICPLUG PPC3 Series Three Stage Air Drying System 1/8" NPT (High Flow)

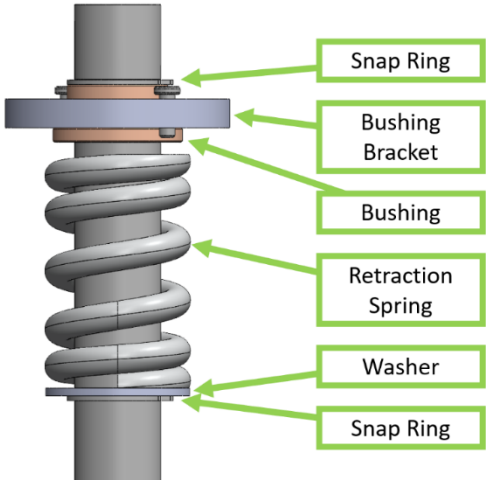
1.1.2 Staking Machine Component Terminology

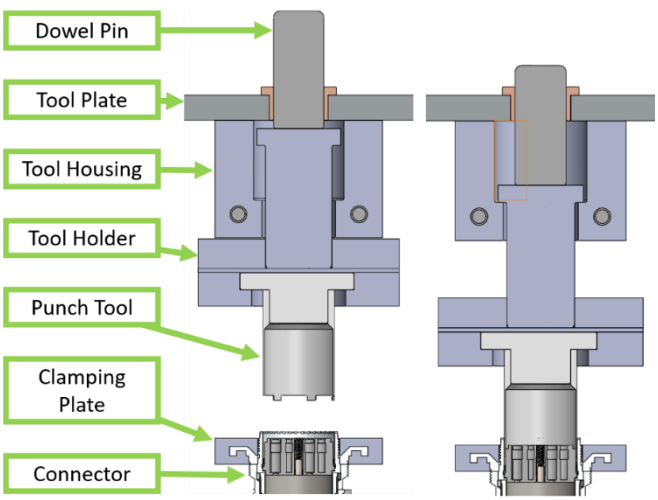
Staking machine component terminology is defined in **Table 2**, identified by part number where applicable.

Table 2: Staking Machine Component Terminology

Term	**Meaning**
Bolster Plate	Lower-most plate of die set (SD1815-01)
Top Plate	Upper-most plate of die set (SD1815-02)
Ram Plate	Plate connected to press cylinder (SD1815-03)
Guide Post	Dowel rods connecting bolster and top plate (SD1815-04 & -15)
Punch	Tool that deforms ring in shell to perform staking (AFSI pre-existing component)
Puck	Base which punch is pressed onto (SD1815-19-X)
Puck Holder	Assembly attaching punch to top plate (SD1815-A02)
Locking Pin	Pin securing punch base in tool holder (COTS)
Tool Holder Key	Machine key preventing rotation of puck cylinder (COTS)
Puck Holder Cylinder	Component connecting puck holder to floating housing (SD1815-07)
Floating Housing	Assembly attached to top plate allowing puck holder to float (SD1815-A03)
Clamp Arm	Plate connected to left guide post to prevent upward movement of connector during retraction (SD1815-11)
Clamp Plate	Connector specific plate bridging gap between shell flange and clamp arm (SD1815-12)
Connector Fixture	Fixture that holds connector, aligning with key / keyways of shell (AFSI pre-existing component)
Central Pin	Pin that connector fixture is placed onto (COTS)
Angle Pins	Pins that set the 90-degree rotation for the 2 loads (COTS)
Fixture Handle	Handle used for rotating connector fixture (COTS)
Reference block	Cylinder of known height used to zero position (SD1815-16)
Linear Potentiometer (POT)	Single axis position sensor tracking press cylinder movement (COTS)


Floating Housing
Puck Holder
Clamp Arm
Connector
Connector Fixture
Ram Plate
Top Plate
Retraction Springs
Guide Posts
Punch Tool
Clamping Plate
Bolster Plate


Snap Ring
Bushing Bracket
Bushing
Retraction Spring
Washer
Snap Ring


Dowel Pin
Tool Plate
Tool Housing
Tool Holder
Punch Tool
Clamping Plate
Connector

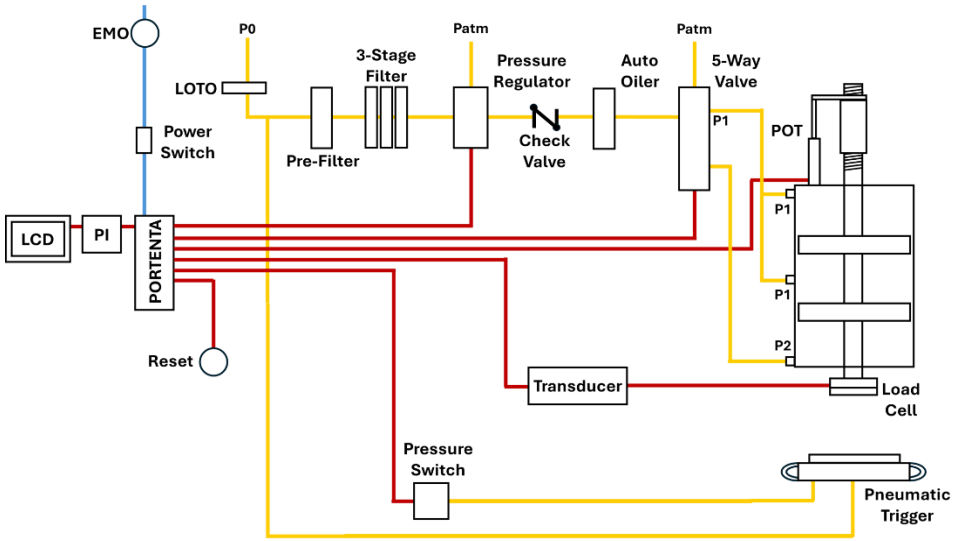
1.1.3 Operations Terminology

The staking machine has three main operations: Staking **(Section 5.2),** Retraction **(Section 5.3**), and Calibration **(Section 4)**.

- Staking Operation
  - The staking operation is the general operation for conducting the staking process. This process is public access and is meant for the end operator.
- Retraction operation
  - The retraction operation is an engineering technician operation meant as a backup retraction system in case of connector jamming. This operation is passcode protected.
- Calibration operation
  - The retraction operation is an engineering technician operation meant to calibrate the force-pressure look table used during actuation. This operation is passcode protected.

1.2 Systems Control Overview

This section will cover the control system of the modified press in the staking machine. The electrical components can be found in **section 2.4.1** and wiring diagrams of the staking machine electronics can be found in **section 2.4.6.** The pneumatics system will be discussed further in this section. For installation of pneumatics, see **section 2.4.2**. The system overview diagram can be seen below. The red line is electronics and sensors, the blue line is auxiliary power, and the yellow line is the pneumatics system.



Control System Diagram

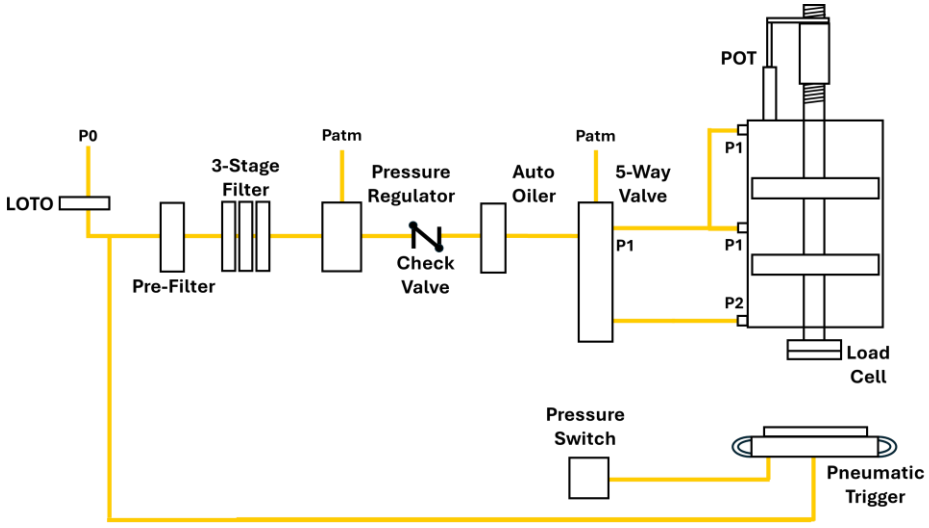
1.2.1 Pneumatics Overview

The press that is employed in the staking machine is the Joraco DIRECT-AIRE 400T pneumatic press, which encompasses a 3-chamber pneumatic cylinder. For pressure control, a pressure regulator, 5/2 valve, three-stage air filtration, pneumatic line auto-oiler, and a check valve are used. The filtration system regulates the input pressure to a maximum of 100 psi, dries, and filters the air down to 0.3 particulates to meet the pressure regulator's requirements. The pressure regulator then follows the filtration system, followed by the check valve. The check valve prevents the dirty air that is cycled out of the cylinder from backflowing and seizing the regulator. After the check valve there is an air lubricator to inject professional grade pneumatic oil into the air supply, this oil is needed by both the 5/2 valve and press cylinder. The air lubricator is set at the lowest drip rate possible; the DIRECT-AIRE press manual states that the press must be lubricated every 50 strokes. See **section 3** for maintenance details. Individual component manuals can be found in the provided total data package (TDP).

Pneumatic equipment includes the following:

- Joraco DIRECT-AIR 400T Pneumatic Press
- Enfield TR Electronic Pressure Regulator
- Unknown 5/2 valve
- PnuematicPlus PPF Series Particulate Air Filter
- PnuematicPlus PPC3C Series Three Stage Air Drying System
- SPEEDAIRE Compress Air Lubricator
- SMC Check Valve

Pneumatics Diagram:



1.3 Technical Specifications

The technical specifications for the staking machine are as follows:

Specification	Information
Dimensions (L x W x H):	2'x2.5'x3.5'
Power Inputs	Two 124 V AC Outlets
External Temperature Operating Range	0 ° - 40 °C
Internal Temperature Operating Range	0 ° - 60 °C
Air Pressure Operating Range	60 psi – 125 psi
Optimal Operating Pressure	100 psi
Minimum Accurate Load	250 lbs
Maximum Accurate Load	2000 lbs.
Stroke Length	4.5 in

2 Installation

The installation section refers to the general installation of the Staking Machine with Press configuration as well as the assembly of the staking machine die-set and subsystems. This section first discusses system requirements for using the staking machine, before providing the assembly instructions, and then installation. For general installation see **section 2.7.** The machine drawings for all custom parts can be found in the provided total data package.

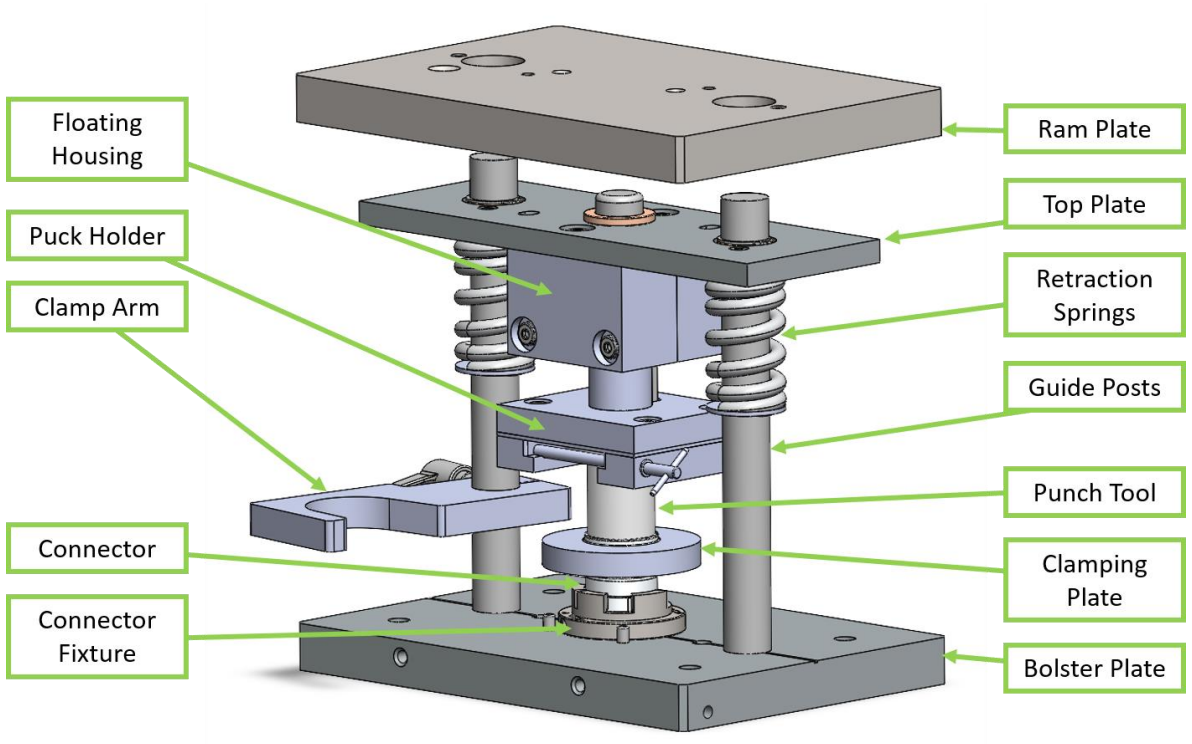
2.1 System Requirements

The staking machine has the following requirements for general operation:

- Two 120 V AC outlets
- 100 psi air supply
- 2.5 ft x 2 ft x 3.5 ft footprint

2.2 Assembly of Staking Machine Die-Set

The staking machine die-set is the mechanical system that aligns and retracts the tool punch with the connector shell during the staking operation. The assembled die-set can be seen below:



Die-Set Assembly

This subsection follows the assembly of the subsections of, as well as the final assembly of the staking machine die-set. For installation of the die-set, please see **section 2.5.**

Required Tools for Assembly:

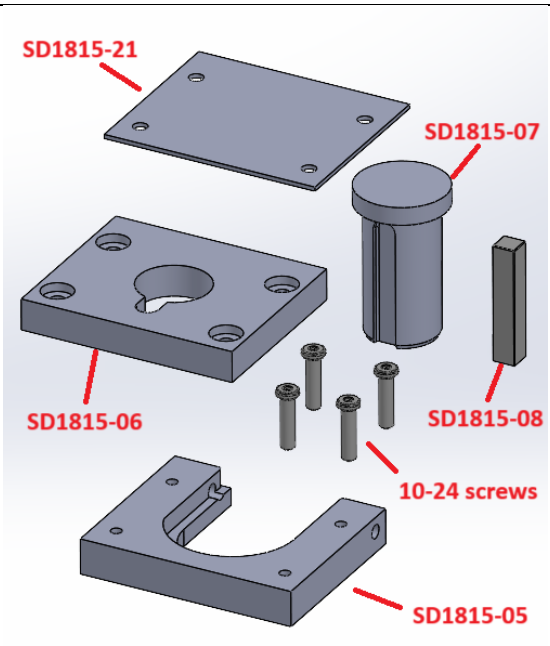
- Allen Wrench (Size 3/32")
- Flat Head Screwdriver
- Press* (Any type that can hold a sustained force is sufficient)
- Snap Ring Pliers
- Liquid Nitrogen

*Note that the assembly of the Staking Machine Die-Set uses shrink fits and press fits.

2.2.1 Tool Holder Subassembly

The tool holder is the plunging structure that holds the tool punch during staking. The tool holder has two main sections: the t-slot for tool punch bases and the core cylinder that connects the holder to the floating housing.

Parts needed to assemble the Tool Holder:

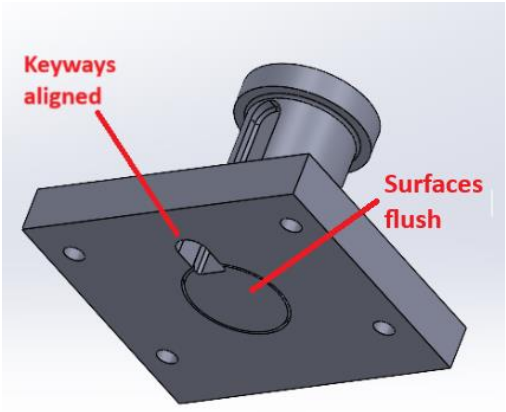


Tool-Holder Parts

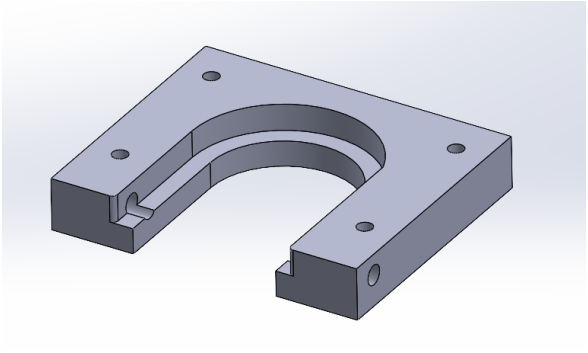
- (1x) SD1815-05 – Puck Holder Bottom Plate
- (1x) SD1815-06 – Puck Holder Top Plate
- (1xx) SD1815-07 – Puck Holder Cylinder
- (1xx) SD1815-21 – Tool Holder Sandwich Plate
- (1x) SD1815-08 – Tool Holder Key
- (4x) 10-24 Socket Head Screw, 3/4" Long

Assembly of the Tool Holder Subassembly:

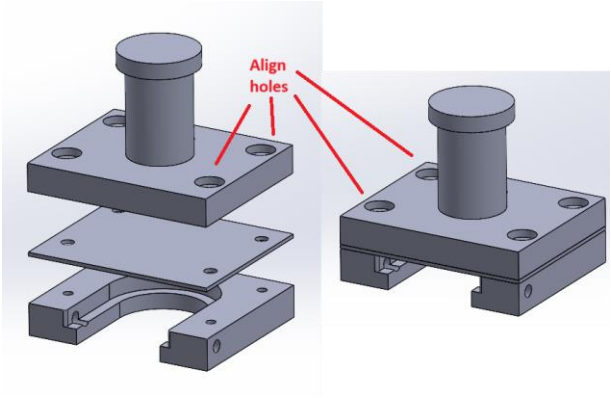
1. *Press SD1815-07 into SD1815-06 such that the bottom surfaces are flush, and the keyways are as shown below. The new part formed will be referenced as 07-06.*



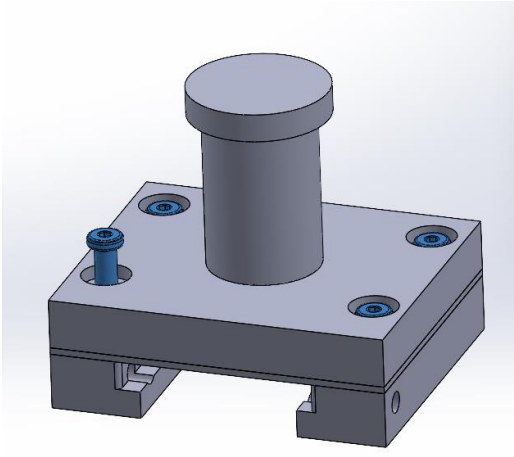
2. *Place SD1815-05 on flat surface with grooved pocket away from surface as shown:*



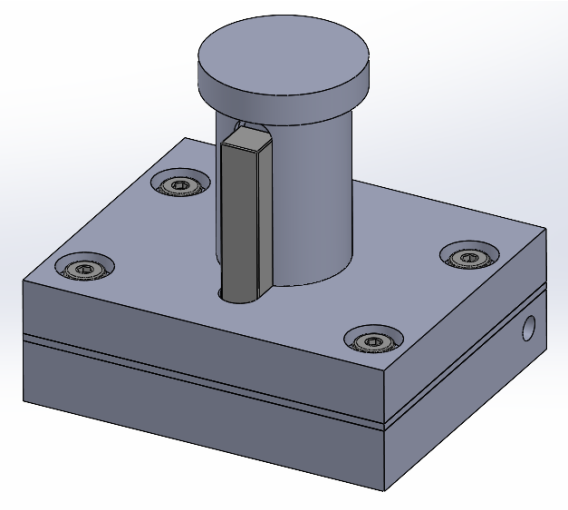
3. *Stack SD1815-21 and 07-06 onto SD1815-05. Align the 4 screw holes and surfaces to be flush:*



4. *Use Allen Wrench (size 3/32") to drive 4pcs 10-24 screws into bolt holes and secure the stack in place:*



5. *Insert SD1815-08 into keyway of assembly. The Tool Holder subassembly is now complete:*

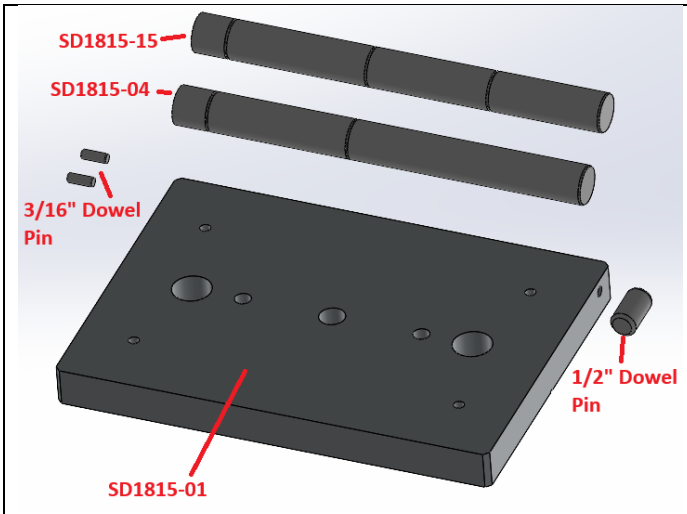


Tool Holder Assembly

2.2.2 Bolster Plate

The bolster plate is the base of the staking machine die-set and holds multiple press and shrink fits for guide posts and aligning pins.

Parts needed to assemble the Bolster Plate:

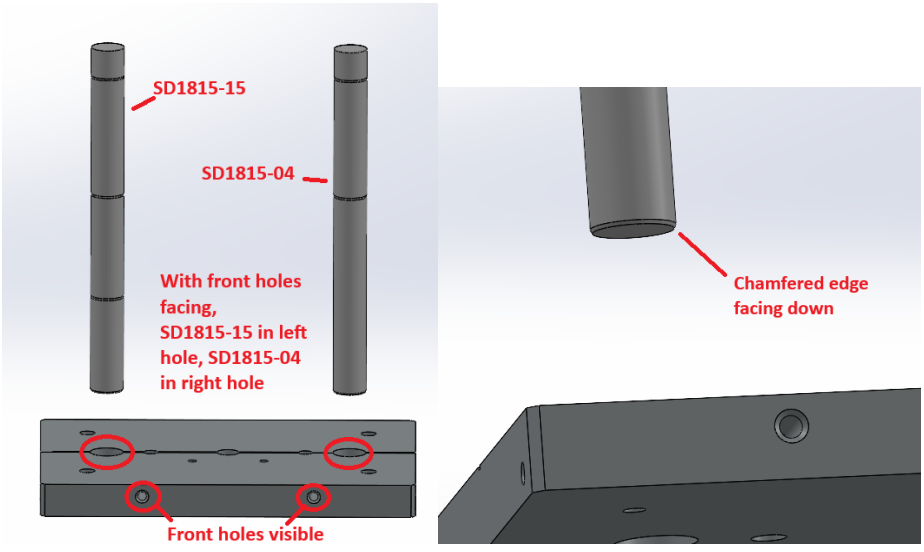


Bolster Plate and Inserted Parts

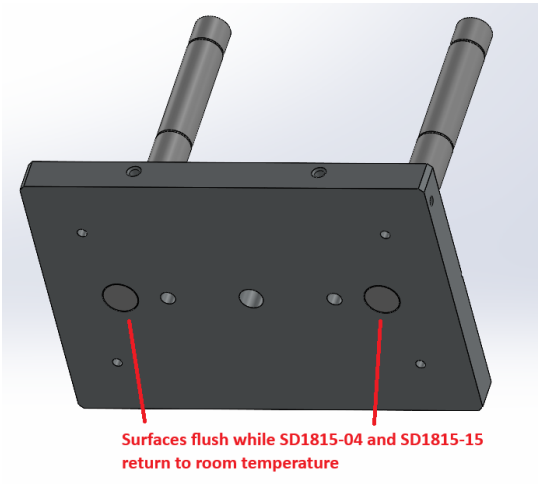
- *(1x) SD1815-01 – Bolster Plate*
- *(1x) SD1815-04 – Guide Post (Normal)*
- *(1x) SD1815-15 – Guide Post (Clamp Plate)*
- *(1x) Dowel Pin 1/2" Diameter, 7/8" Long*
- *(2x) Dowel Pin 3/16" Diameter, 7/16" Long*

All shrink fits and press fits can be seen in the diagram below for orientation. SD1815-04 and SD1815-15 are shrink fits. The 1/2"dowel pin is a press fit. The (2X) 3/16" dowel pins are sliding fits secured with Loctite.

Guide Posts SD1815-04 and SD1815-15 – Shrink Fits:

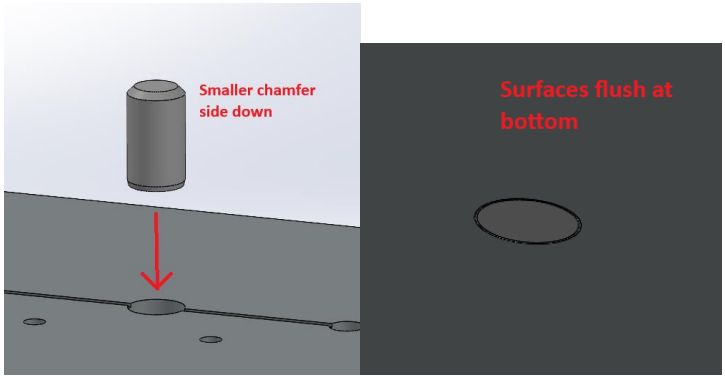


Guide post instructions.

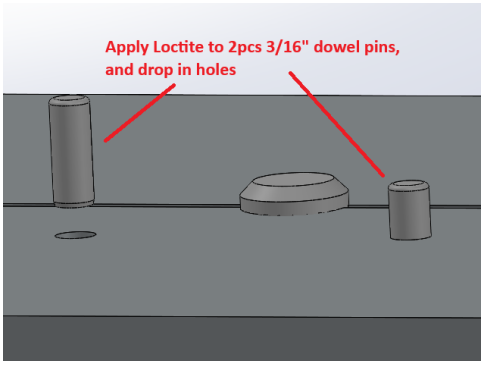


Guide Posts Positioning

Central Pin, 1/2" Dowel Pin – Press Fit:



Angle Pins, 3/16" Dowel Pin – Green Loctite:

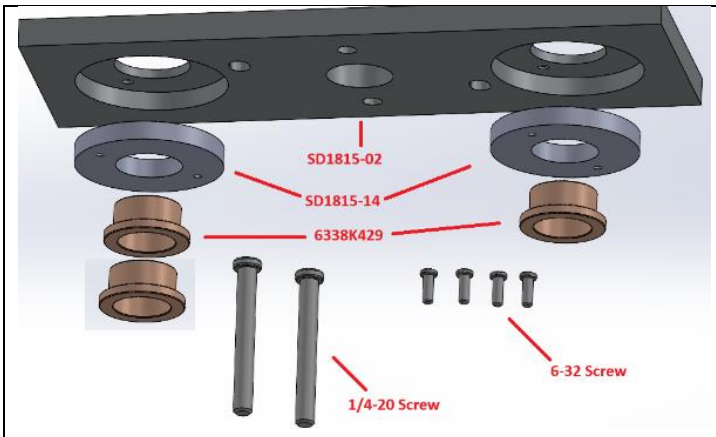


Central Posts and Pin Insertions

2.2.3 Top Plate

The top plate houses the bushings that maintain alignment and concentricity of the die-set. The top plate utilizes a bushing bracket sub-assembly to allow for smooth, controlled movement along the guide posts and prevent over constraining. The top plate and bushing brackets both contain press fits.

Parts needed to assemble the Top Plate:

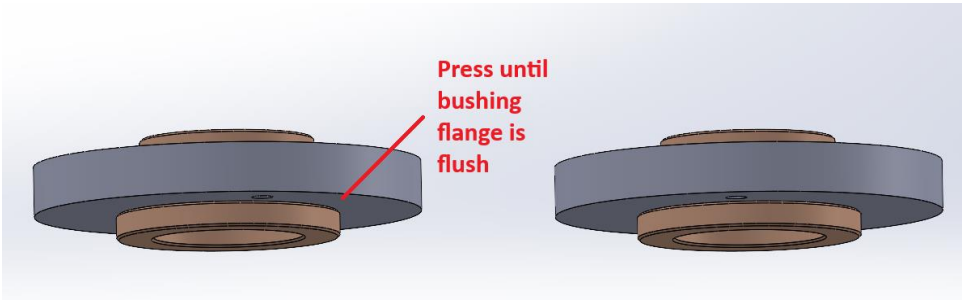


- (1x) SD1815-02 – Top Plate
- (2x) SD1815-14 – Bushing Bracket
- (3x) 6338K429 (McMaster) - 3/4" Oil-Embedded Bushing
- (4x) 6-32 Socket Head Screw, 3/8" Long
- Bolster Plate Subassembly

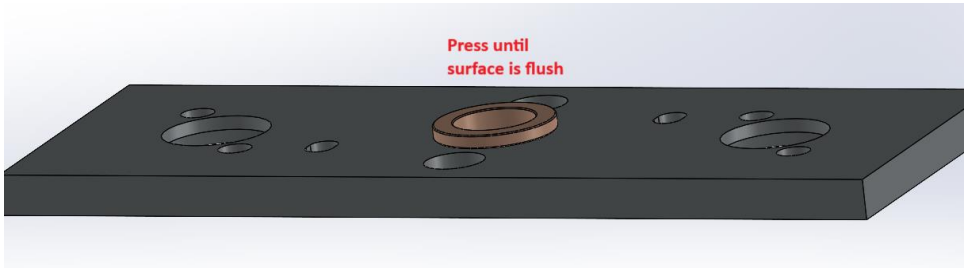
There are three press fits for the 3/4" Oil-Embedded Bushing *bushings in the top plate assembly: a central bushing in the middle of the top plate, and two bushings for the bushing brackets, one bushing for each bracket.*

Diagrams of press fits:

SD1815-14 to 6338K429 (x2):

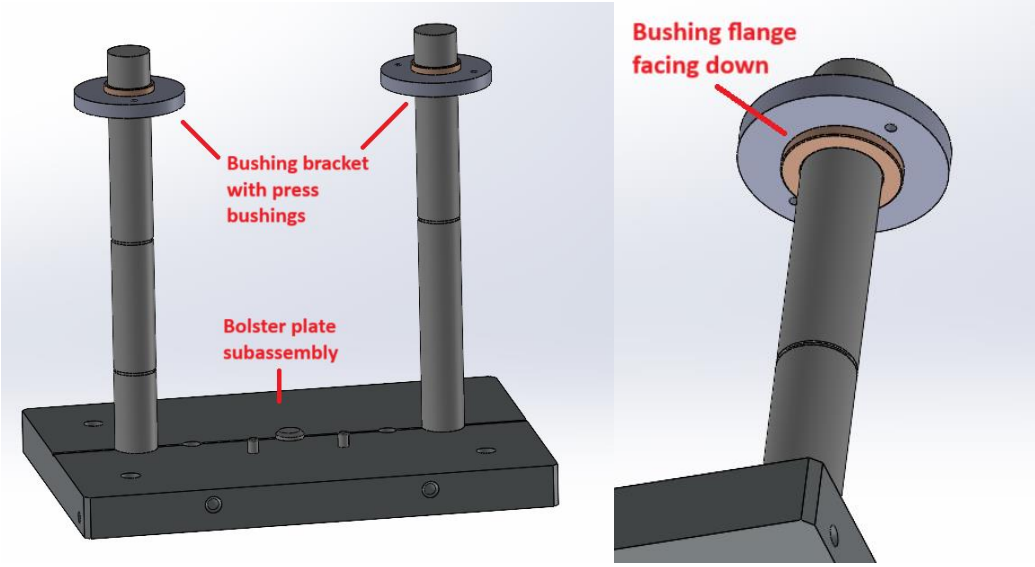


6338K429 to SD1815-02:

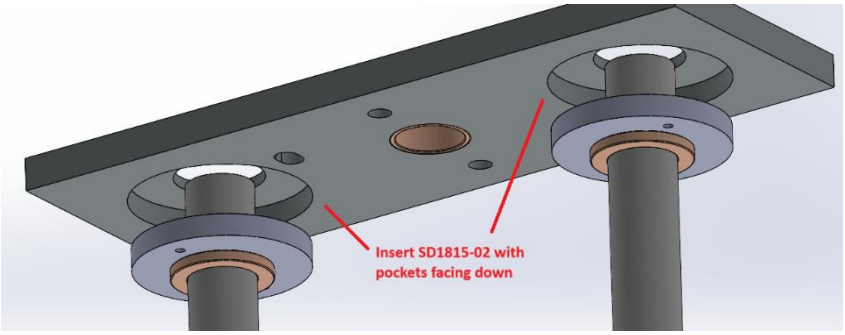


Assembly of the Top Plate:

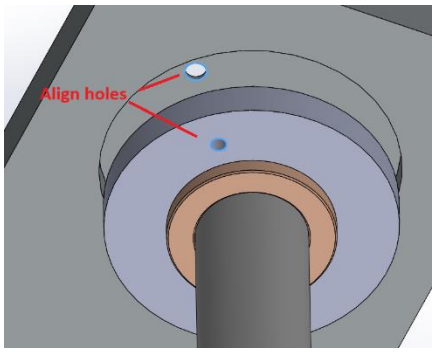
1. *Take the Bolster Plate Subassembly and set it on a flat surface. Insert SD1815-14 with pressed bushings (6338K429) onto guide posts. Bushings should be face down as shown:*

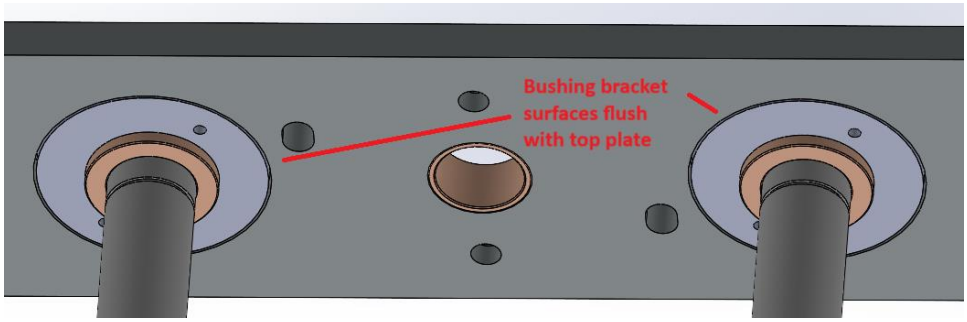


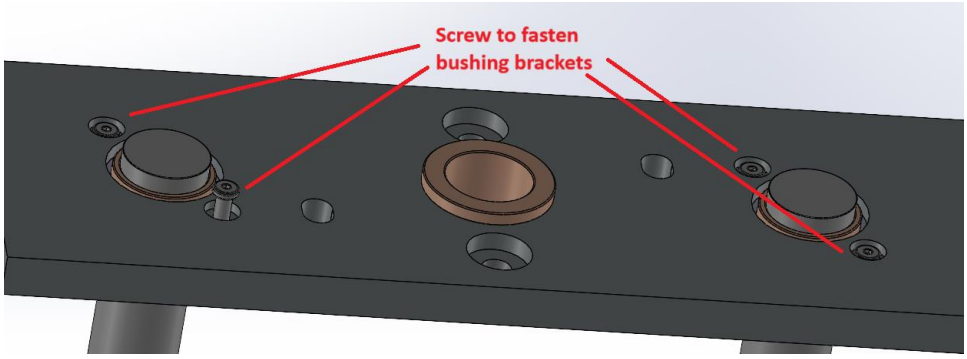
2. *Insert SD1815-02 onto guide posts in correct orientation.*



3. *Make sure that bushing brackets are flush inside of Top Plate. Screw. Insert 6-32 screws into 4 bolt holes to fix the bushing brackets to the top post:*





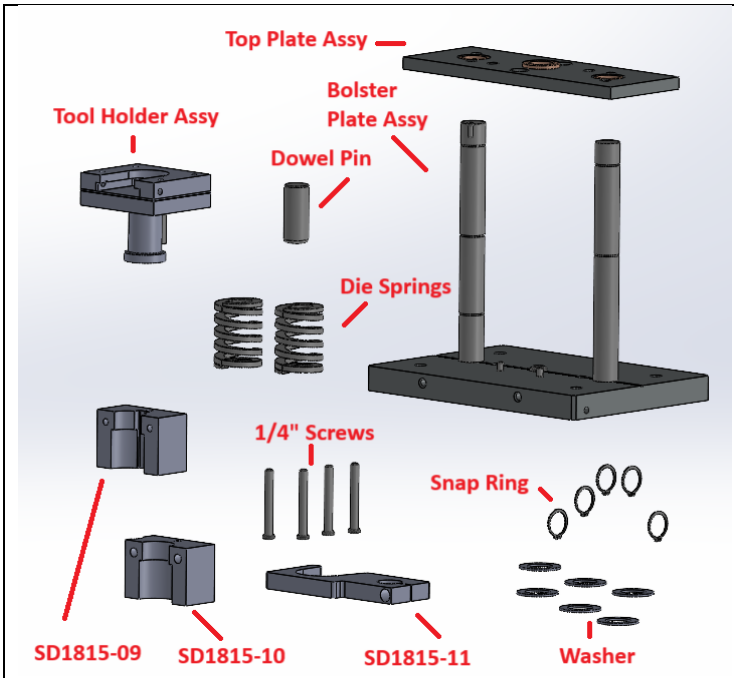


4. *The bushing brackets should now be aligned. The Top Plate is now assembled. Please remove the Top Plate assembly and set aside for now.*

2.2.4 Final Assembly of Die-Set

The Die-Set has three phases of assembly: set-up, pre-load, and final installations. Please note that the use of a press will be needed to assemble the Die-Set.

Parts needed to assemble the Die-Set:

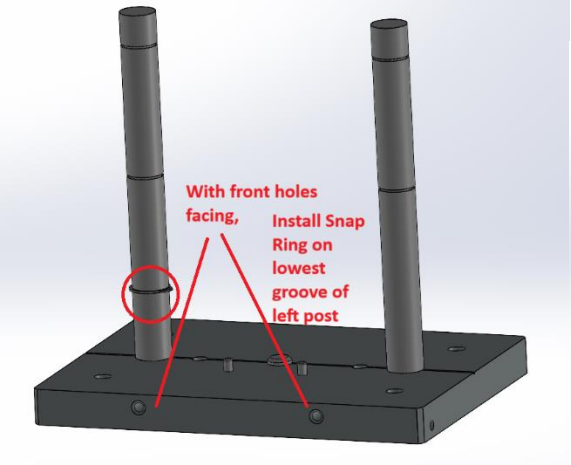


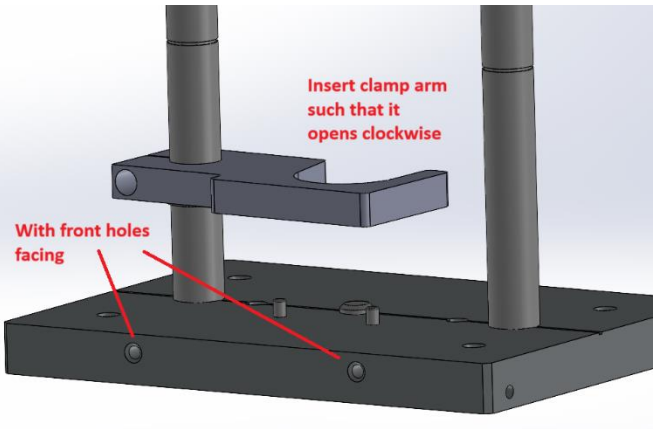
- (1x) SD1815-09– Tool Housing (Keyed)
- (1x) SD1815-10 – Tool Housing (Normal)
- (1x) SD1815-11 – Clamp Arm
- (5x) 3/4" ID Snap Ring
- (6x) Washers, 1/16" thickness, 0.750" ID 1.5" OD
- (2x) Die Springs (Spring Rate 1080 lbs./in)
- (4x) 1/4"-20 Socket Head Screw, 1-1/2" Long
- (1x) 3/4" Dowel Pin, 1-3/4" length
- (1x) Bolster Plate Assembly
- (1x) Top Plate Assembly
- (1x) Tool Holder Assembly
- (3x) Blocks of metal or 123 blocks

It is recommended that the Setup Phase is done in or near the press being used during the Pre-Load Phase to allow a smooth transition during assembly.

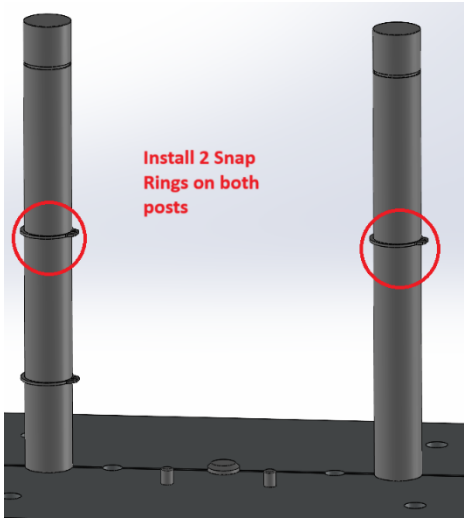
Setup Phase:

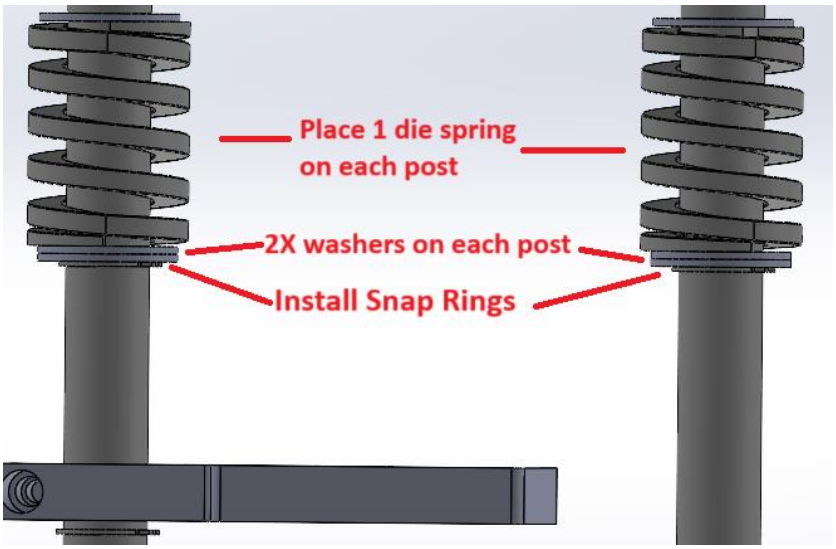
1. Place Bolster Plate on flat surface. Use snap ring pliers to insert Snap Ring on clamping guide post (left post) as shown. Slide Clamp Arm onto guide post:

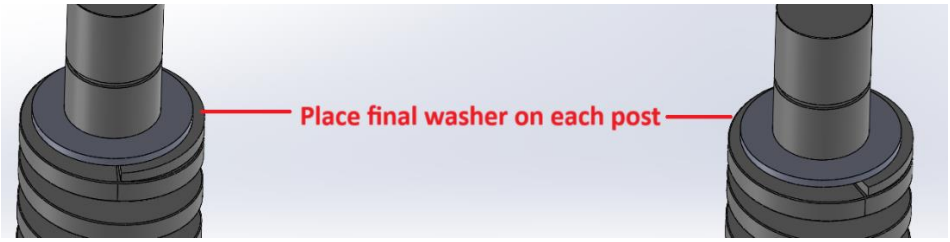




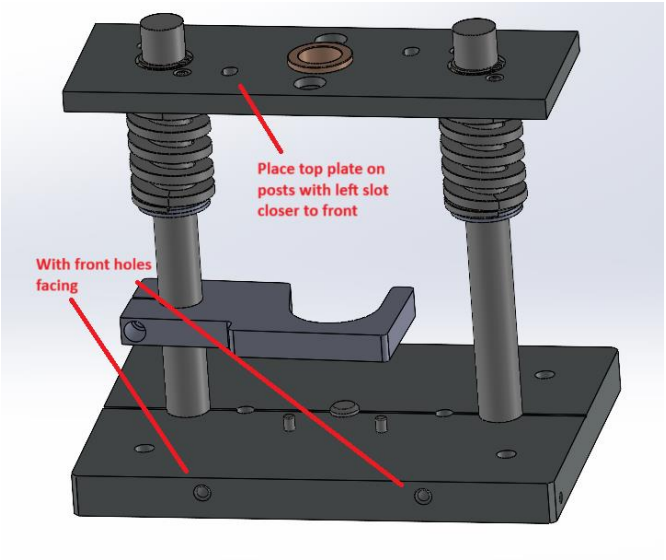
2. Insert Snap Rings onto both guide posts as shown. Slide one washer on top of each snap ring. Place die-springs on top of washers before sliding another set of washers on top of the springs:







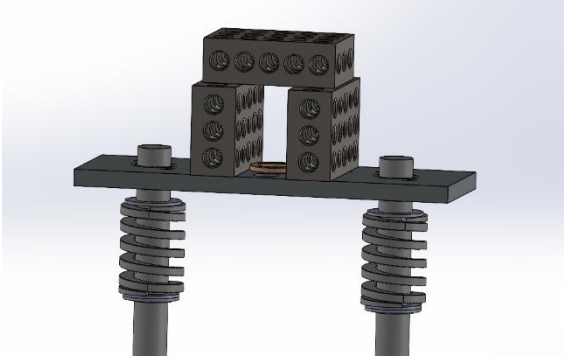
3. Place Top Plate Assembly onto the guide posts as shown. Ensure orientation is as shown.



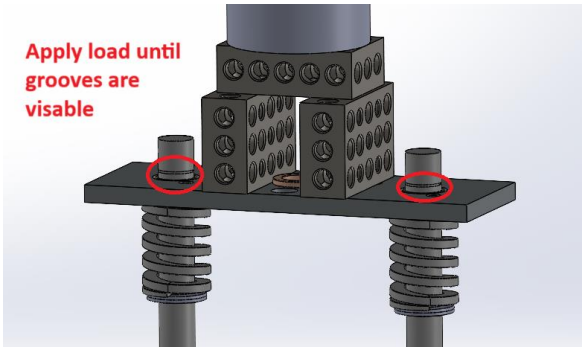
4. Continue to Pre-Load Phase.

Pre-Load Phase:

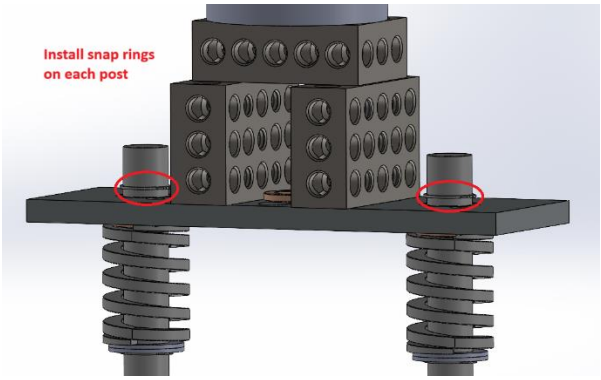
1. Place the setup bolster plate inside of a press.
2. Place blocks of metal onto the top plate as shown to prevent damage to bushing:



3. Actuate press to compress springs and lower the top plate beneath the top groove in guide posts. **Please note that the springs can only be compressed 0.6 inches.**



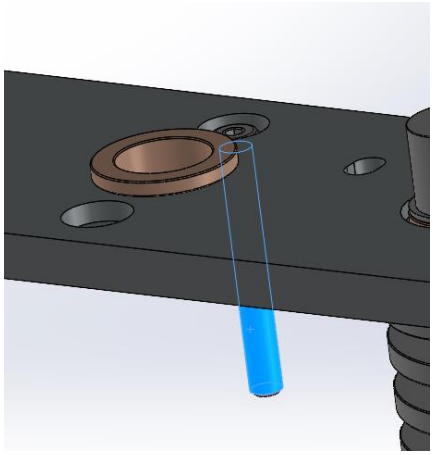
4. With load sustained, insert Snap Rings onto top groove of guide posts:

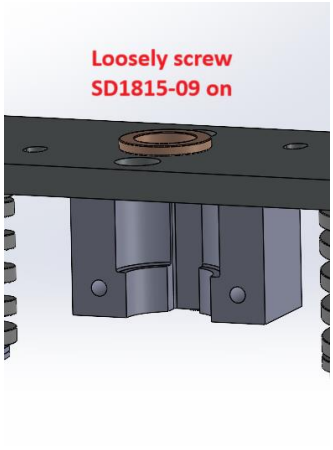


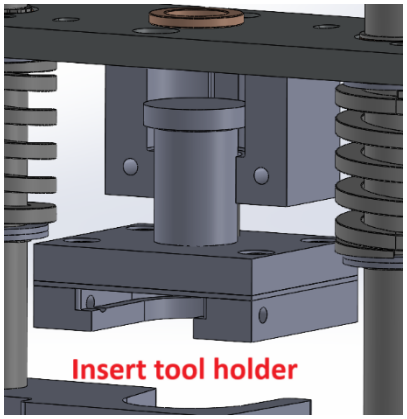
5. Remove press applied load, remove metal blocks, and remove assembly. Place the assembly onto a flat surface.
6. Continue to Final Installation Phase.

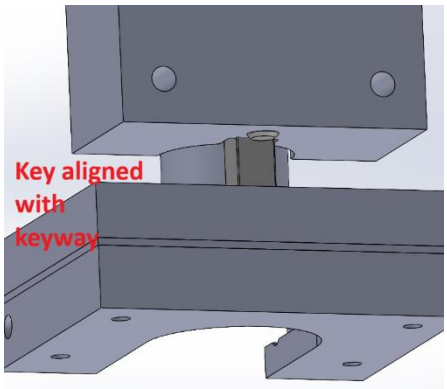
Final Installation Phase:

1. Use 1/4" screw to attach part 9 to the top plate. Insert Tool Holder Assembly into internal cavity of part 9 while aligning the key with the keyway.

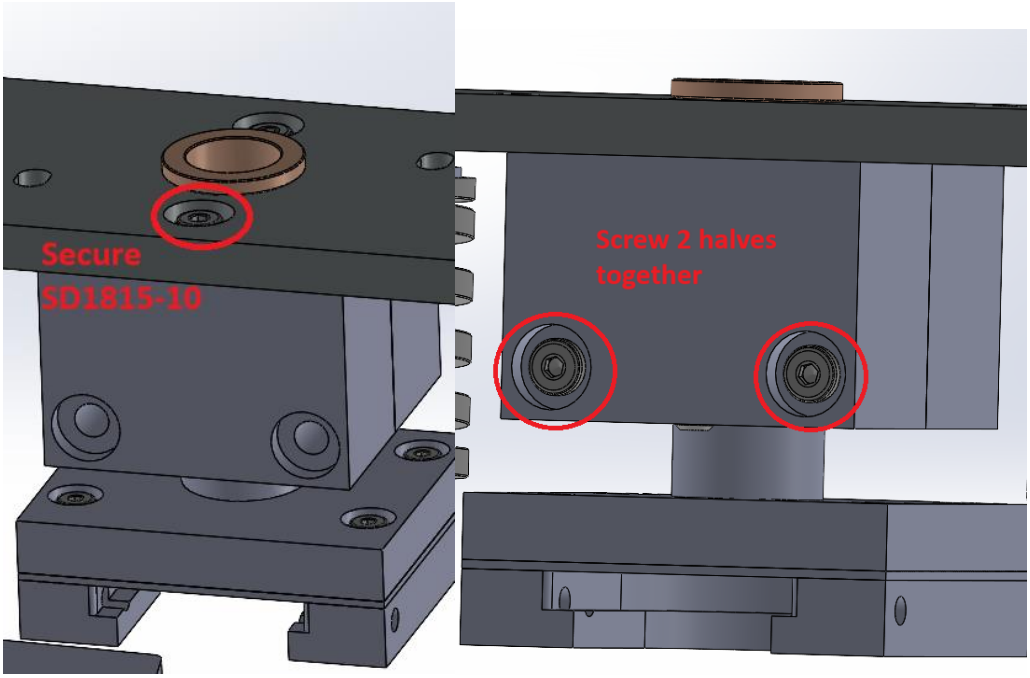




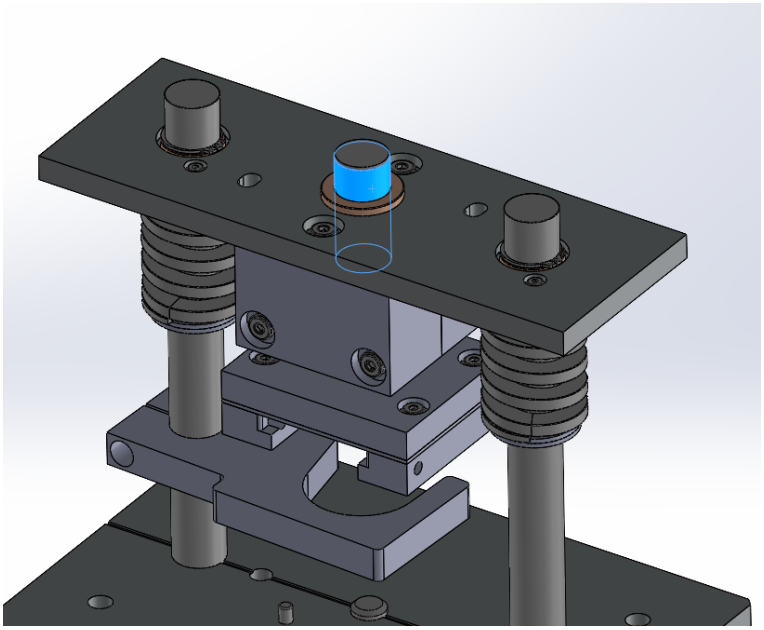




2. Use 1/4" screws to fix part 10 to part 9 to fix part 10 to the top plate. Tighten bolts going through tool holder The Tool Holder is now installed.



3. Insert 3/4"dowel pin into the bushing in the top plate. The Staking Machine Die-Set is now assembled.

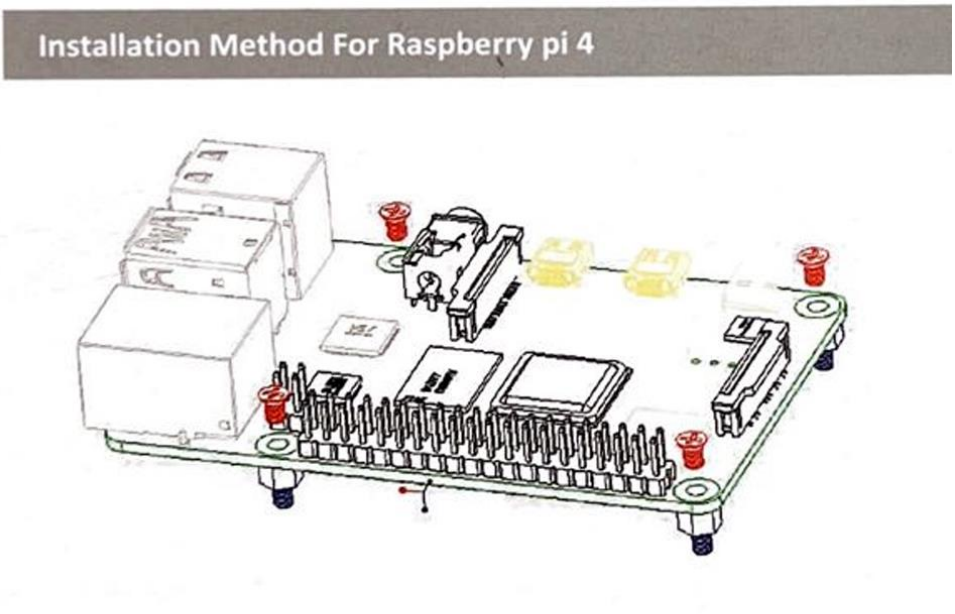


2.3 Assembly of HMI

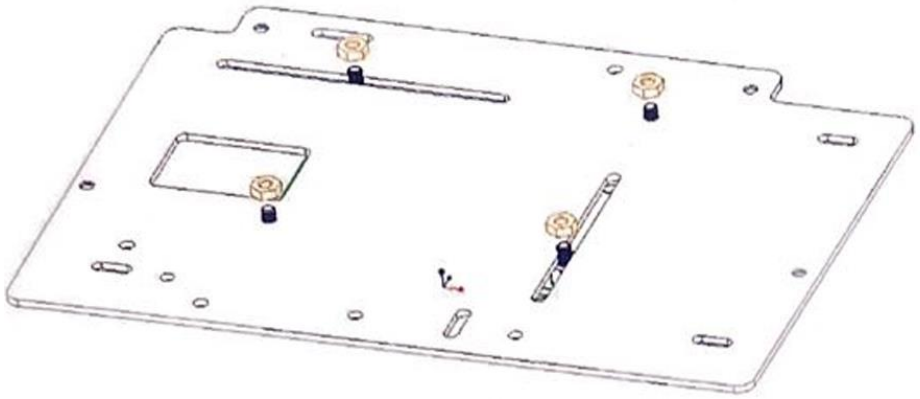
HMI stands for Human-Machine-Interface and consists of a Raspberry PI 4 connected to 9-inch Magedok Touchscreen display. The HMI is used to gather user input and communicate said input to the system's main PLC controller. The HMI then displays live user instruction and systems information during operation. This section covers the wiring and assembly of the HMI unit. For installation of the HMI, see **section 2.4.1.2.** For software and package libraries, see **section 8.3.**

2.3.1 Assembling the HMI

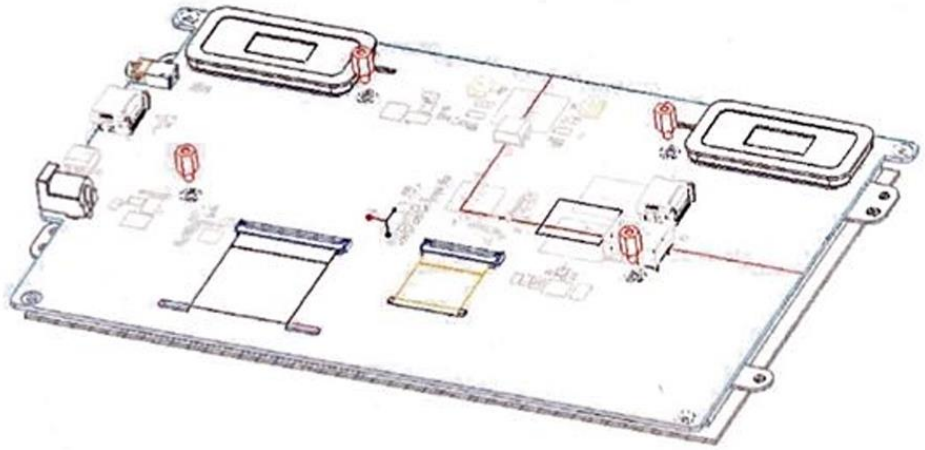
The HMI is comprised of three main areas: the touchscreen, the Raspberry Pi, and the cooling system. The instructions for mounting the Raspberry PI can be found in the operations manual for the 9in-touchscreen display on page 8. Copies of the instructions will also be found below. Note that it is recommended to flash the SD card and insert the card into PI before mounting electronics. See **section 8.3.4** for instructions on flashing the SD Card.



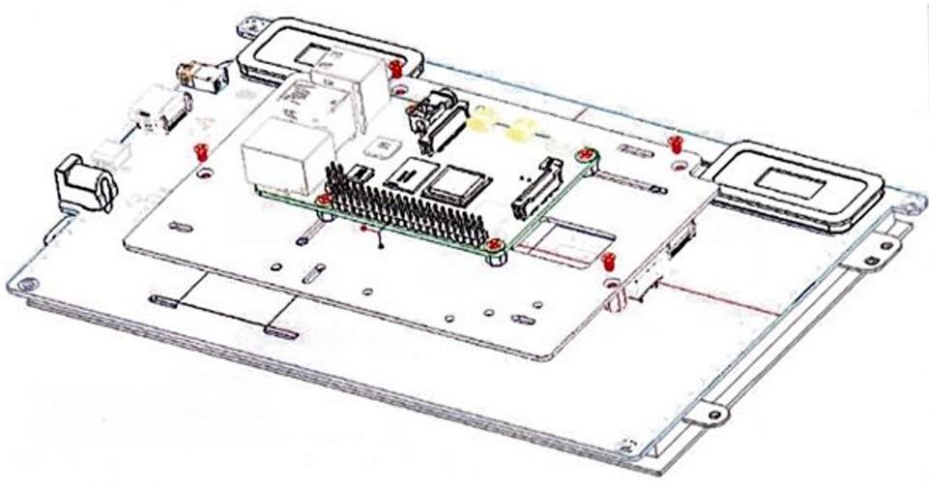
(1) .Install the screws(M2.5*10+4 and M2.5) in the Raspberry pi 4.



(2) .Put the installed Raspberry pi 4 on the aluminum plate,tighten the screw nut.



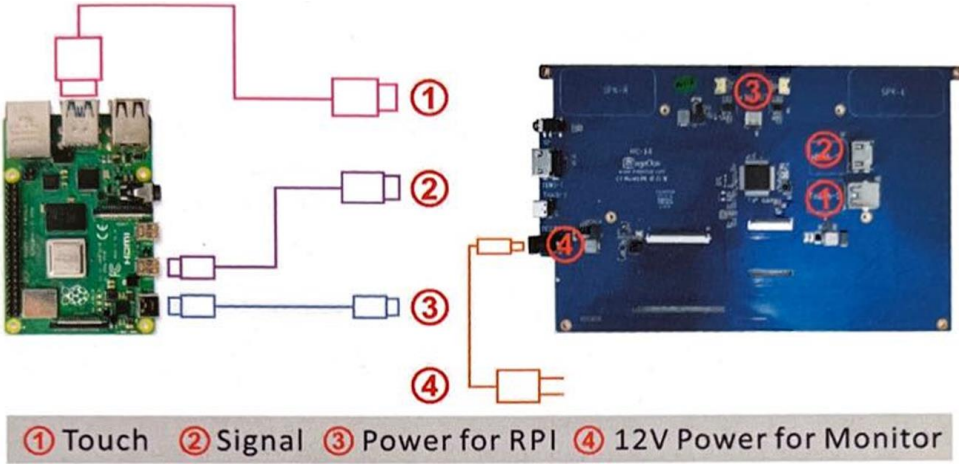
(3) .Install the screws(M2.5*10+4) in the back of the monitor's main board.



(4) .Install the screws(M2.5) ,Fixed the aluminum plate(step 2) in the back of the monitor's main board.

2.3.2 Wiring the HMI

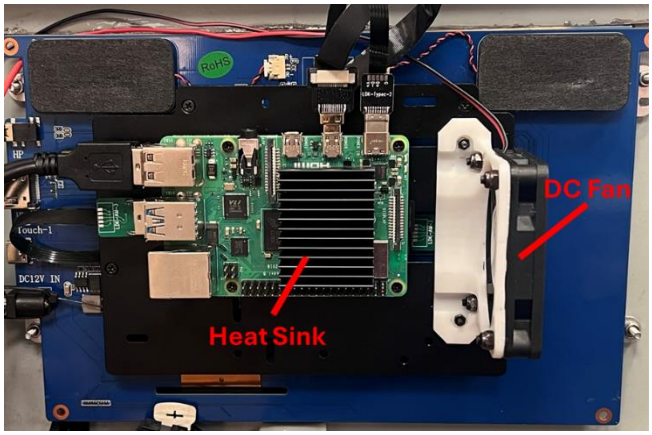
Once the Raspberry PI is mounted to the 9in-touchscreen display, the wires to connect the PI to the display can then be run. A basic wire diagram can be found below:

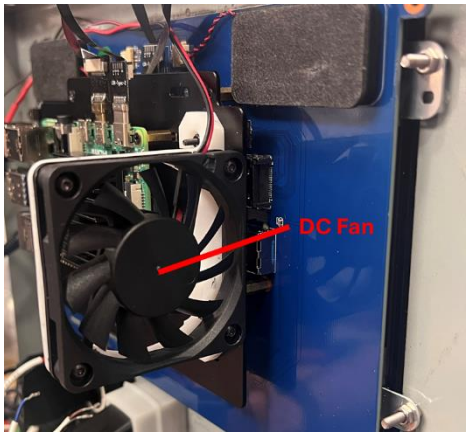


Note that the monitor uses a 12V2A power adapter (symbol 4) to get power to the monitor. The power cable is then routed into the electrical cabinet as explained in **section 2.4.6.** A micro-HDMI cable (symbol 2) is then used to connect the signal. A USB-C cable is then used to route power to the Raspberry PI from the monitor's motherboard. A USB-A to USB-Cable is used to connect the touch input of the monitor.

Mounting the Heatsink and Cooling Fan

The Raspberry PI and touch screen interface is prone to overheating if there is no cooling mechanism installed. To counter this a heatsink is mounted on top of the CPU on the Pi. A 24 V DC cooling fan is also mounted to the frame of the HMI using a provided 3D-printed bracket (part 27). The power for the fan will be wired into the PMC and will be discussed in **section 2.4.6.**





2.4 Assembly of Press

The press used for the staking machine is a Joraco Direct Aire 400T Series pneumatic press that is retrofitted to be a variable parameter digitally controlled closed-loop system. These upgrades include replacing the plc control system, pneumatics, and load cell, as well as installing an air filtration system, a pressure regulation system, a pneumatic line oiling system, a linear potentiometer for distance tracking, an HMI for user control, and safety guards. This section will cover these upgrades in order of assembly. For installation of the press see **section 2.7.**

2.4.1 Installing the Electrical Cabinet

The original electrical cabinet was replaced with a modified 12" x 12" x 12" electrical cabinet. This section will cover modifying the cabinet, installing components onto the cabinet panel, and installing components onto the cabinet door. For wiring the electronics, see **section 2.4.6**. For mounting the electrical cabinet, see **section 2.4.1.5**.

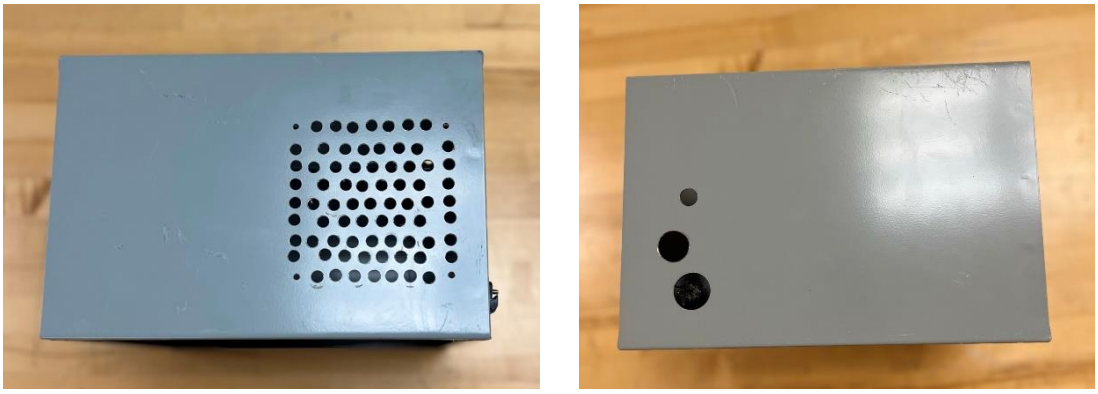
2.4.1.1 Cabinet Modifications.

The electrical cabinet has three main parts: the cabinet, cabinet panel, and the cabinet door. The cabinet and cabinet door are the only parts that are modified and will be discussed separately.

Modifying the Cabinet

The electrical cabinet is modified to have press mounting holes, bracket mounting holes for the pneumatic systems and the cabinet panel, and perforation holes for ventilation. The complete diagram can be seen below. The hole position diagrams can be found in the total data package provided. The cabinet modifications can be seen below:

Front view of cabinet (left); back view of cabinet (middle); left view of cabinet (right).



Top view of cabinet (left); bottom view of cabinet (right).

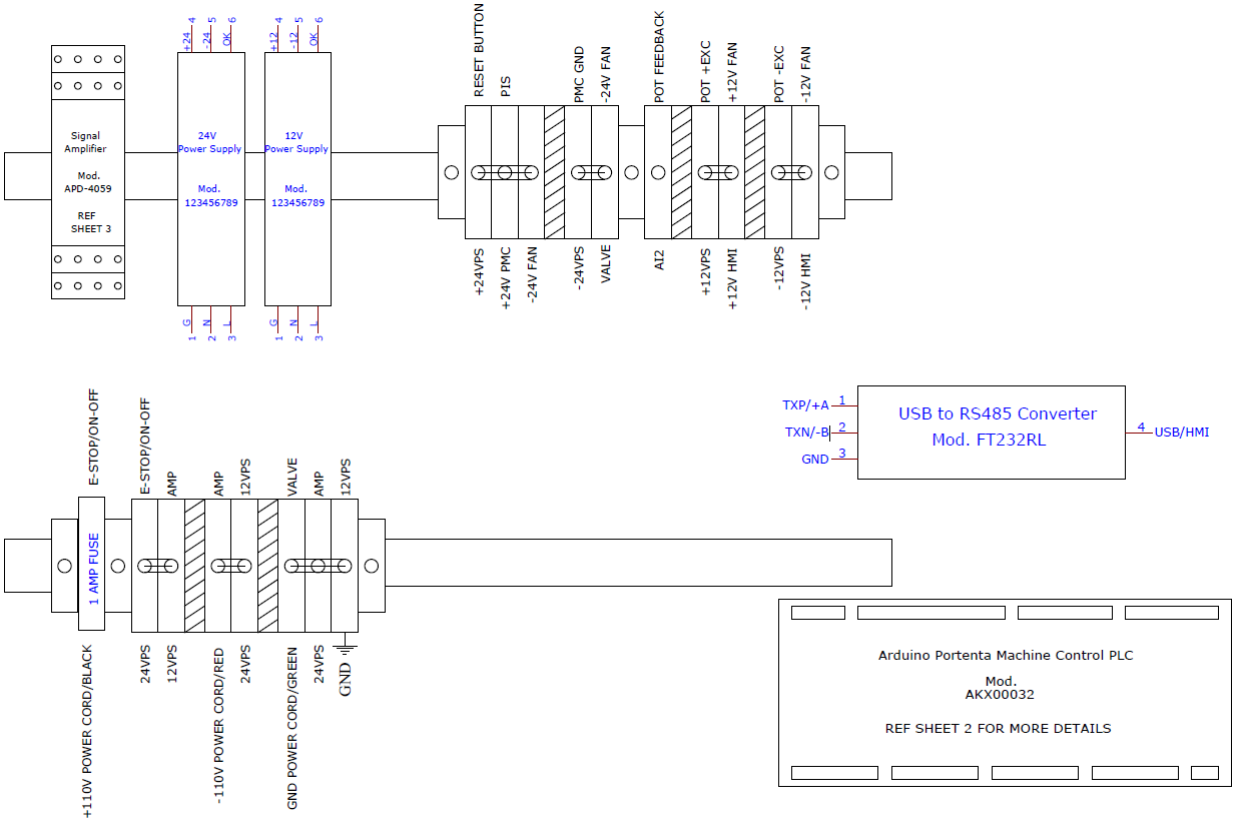
Modifying the Cabinet Door

The electrical cabinet door is modified to fit a custom layout panel that houses the HMI, electrical switches, and button controls for the press. The cut diagram for the cabinet door can is shown below. The HMI door Panel (part 20) is mounted to the cabinet door by epoxy.

Cabinet door with cut out (left); cabinet door with HMI door panel mounted (right).

2.4.1.2 Cabinet Panel Components Installation

The cabinet panel is a detachable electrical panel that is installed into the electrical cabinet. The panel houses the main power distribution system, voltage step-downs, load-cell transducer, and the fuse. The electrical component layout can be seen below. Part 34 is used to mount the USB RS 485 connector. For wiring, see **section 2.4.6.** Full-Scale layout and wire diagrams can be found in Appendix 1



Installing the Cabinet Panel

To install the cabinet panel, use the four screw mounts in the cabinet to attach the panel with a screwdriver.

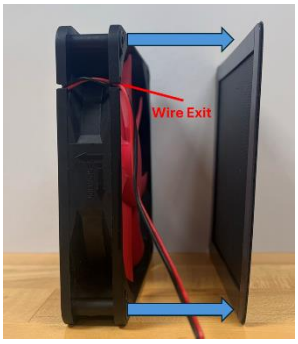
2.4.1.3 Cabinet Components Installation

The electrical cabinet has a few components that are mounted directly to the cabinet instead of the door or cabinet panel. These components include the vent filter, ventilation fan, and the two-hand safety switch.

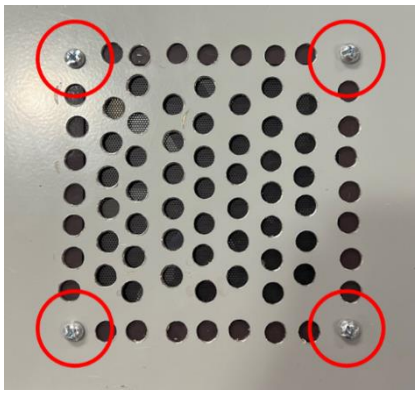
Installing the Vent Filter and Ventilation Fan

It is recommended to install the vent filter and ventilation fan after installing the electrical cabinet panel with the electronics. Further, the vent filter and ventilation fan are installed at the same time. Tools needed to install these components include a screwdriver and a pair of pliers.

1. Place vent filter on the side of the fan that has the wire. Air flow should flow outside the box.



2. Place fan and vent filter inside of cabinet with filter side facing the top wall with the perforations. Use 4 #8-32 x2 in screws to attach the fan and filter to the cabinet. The fan should sandwich the filter against the cabinet wall. Screws should come from the outside of the electrical cabinet as shown.



Installing the Two-Hand Safety Switch (Pneumatic Switch)

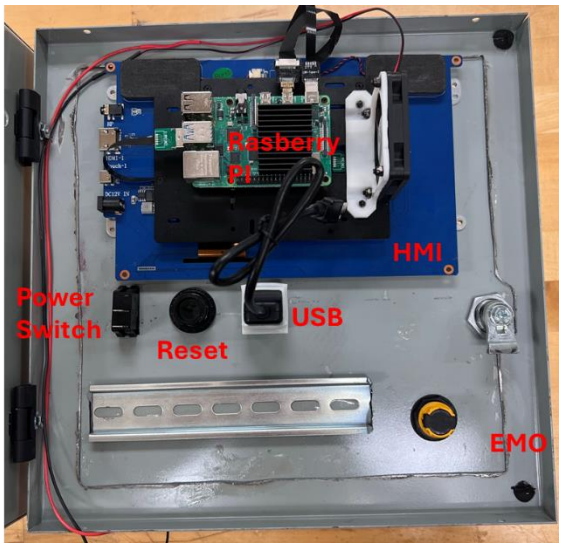
The Two-Hand Safety Switch uses a pneumatic switch that is housed inside the electrical cabinet. The switch is mounted with a Velcro command strip as shown in the diagram below.

2.4.1.4 Cabinet Door Components Installation

The Cabinet Door houses the HMI, E-Stop, Green Reset Button, Power Switch, USB ports, DIN-Rail, and cabinet lock. These components are installed using a variety of methods found in the table below. Internal Mechanism refers to two-piece component geometry that interlocks with its corresponding piece.

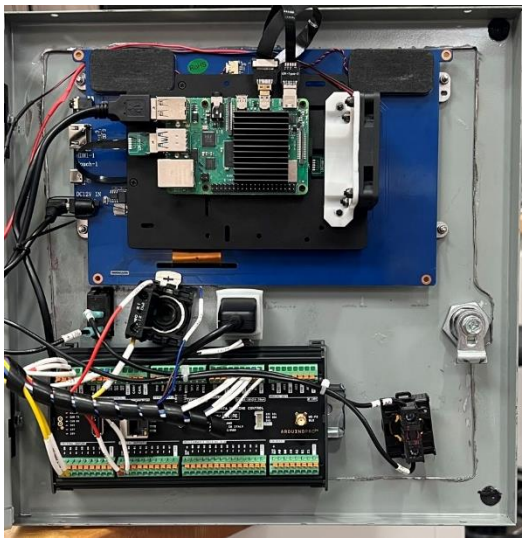
Component	Installation Method
HMI	Screws
E-Stop	Internal Mechanism
Green Reset Button	Internal Mechanism
Power Switch	Press Fit
USB Port	Screws
Cabinet Lock	Internal Mechanism
DIN-Rail	Epoxy

A picture of the installed component's locations can be seen below. Note that the DIN-Rail is mounted on the inside of the cabinet door via epoxy.



Installing the Arduino PLC

The Arduino PLC – Portenta Machine Control is mounted onto the DIN rail that is epoxied to the cabinet door. When installing orient the Portenta as shown.

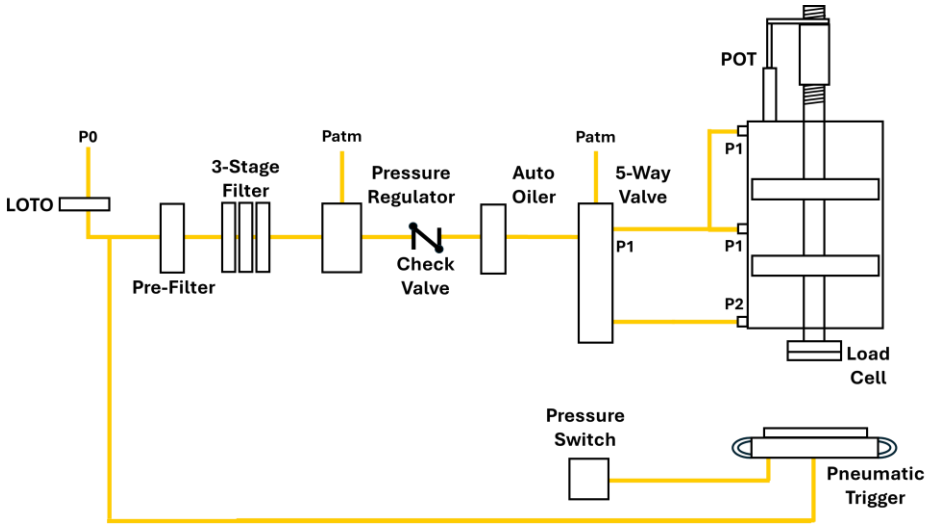


2.4.1.5 Mounting the Electrical Cabinet

The electrical cabinet can be mounted with two screws to the press. The mounting holes can be seen below.

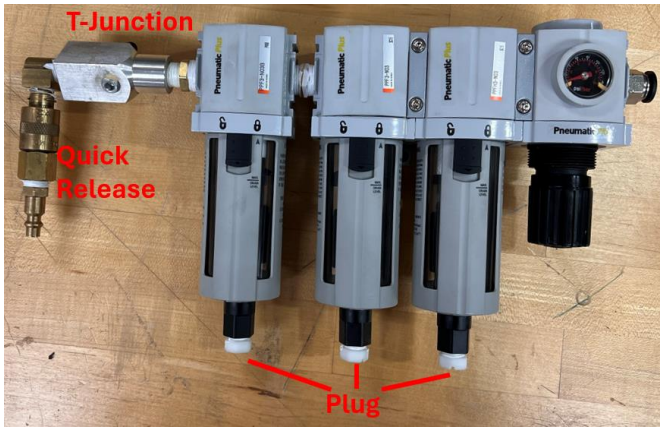
2.4.2 Installing the Pneumatics

The pneumatics system has several components including the air filtration, auto oiler, pressure regulator, check valve, 5-postion-2-way valve, safety switch, and cylinder. The pneumatics diagram can be seen below.



2.4.2.1 Filtration System

The air filtration system is critical to the operation of the press, preventing the pressure regulator from seizing. The filtration system is a three-stage filtration particulate and coalescing air filters, a dehumidifier, as well as an adjustable pressure regulator. The filtration system is first mounted together before being mounted directly to the back of the electrical cabinet. An air supply quick release valve and t-split adapter is then mounted to the filtration inlet side. Note, drain plugs (part 22) are used to plug the three glass bowls in the air filtration system.



2.4.2.2 Auto Oiler

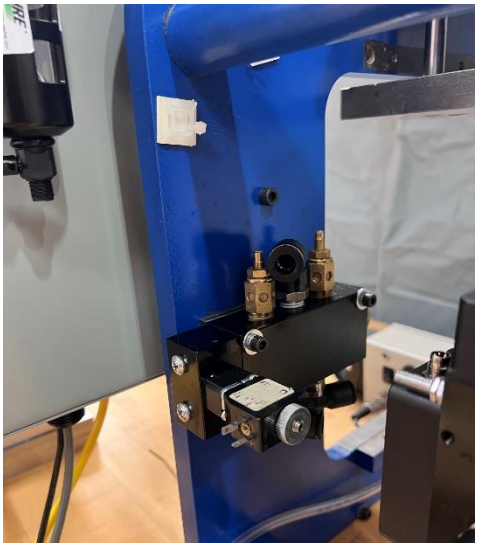
The auto oiler is used to lubricate the moving solenoid valves and cylinder inside the pressure system, as well as to minimize the frequency of maintenance. The auto oiler is mounted on the outside of the electrical cabinet on the side nearest the press using 3D printed parts 23 and 24. Note to mount the bracket (part 23) face the bolts inward to the cabinet and then insert the sleeve into the bracket. Finally insert the oiler into the sleeve and bracket.

2.4.2.3 Pressure Regulator

The pressure regulator is key to controlling the force in the press, providing a variable-digitally controlled output. The pressure regulator is rated for 145 psi and outputs a 10 V DC control signal. The pressure regulator is mounted on the right side of the interior of the press when facing the press from the back. For installation refer to the orientation and position below. Note the mount holes for the pressure regulator were drilled to match the regulator orientation shown.

2.4.2.4 5 Way – 2 Position Valve

The 5 way-2 position valve is used to direct pressure to either the top or bottom of the cylinder, directing the force being applied. The valve is installed on the left interior of the press, when facing the press from the backside:



2.4.3 Installing the Safety switch

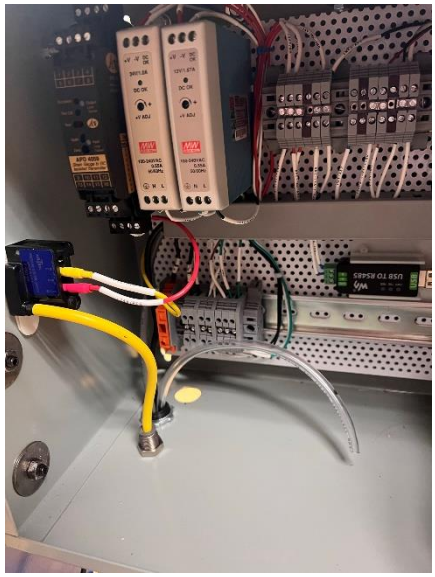
The two-hand safety switch is mounted at the front of the press. However, the bolts for the switch mount directly into the bolster plate of the Staking Machine Die-Set. Place the safety switch in position for later use. Route the pneumatics and wires for the safety switch as shown:

2.4.3.1 Safety Switch Pneumatics

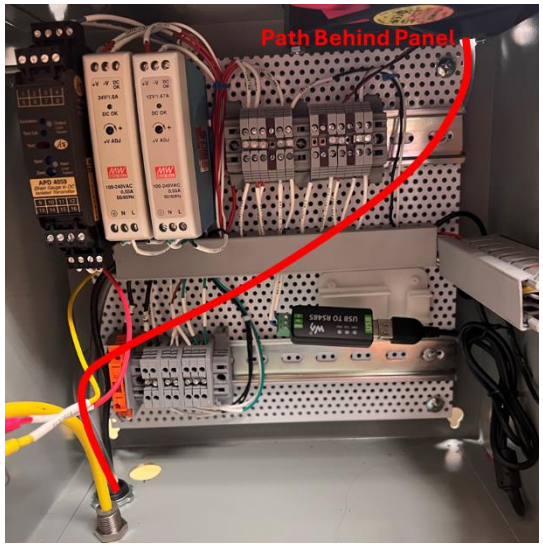
The two-hand safety switch pneumatic valve is mounted on the electrical cabinet and has its own air supply line from a custom split before the filtration system. The pneumatic line is installed as shown:

Routing the Safety Switch Pneumatic Line

1. Wrap clear tube over cross bar as shown above in 2.4.3.
2. Insert clear tube into electrical cabinet through wire coupler:



3. Wrap line behind cabinet panel and insert line into top-right hole in cabinet:



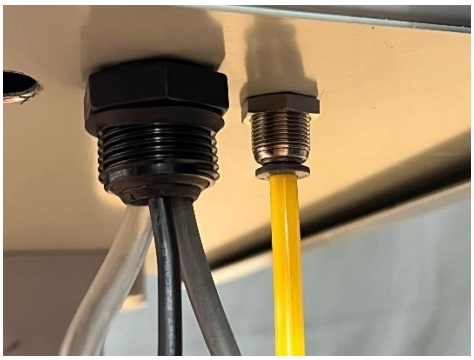
4. Insert pneumatic line outside of electrical cabinet and wrap tube around T-junction before connecting to T-Junction Valve:

Routing the Safety Switch Pneumatics Trigger

1. *Insert yellow connector tube from the pneumatic line coupler installed in the electrical cabinet:*

2. *Route the yellow pneumatic line from the safety switch over the crossbar as shown above in 2.4.3.*

3. *Insert yellow line in the bottom side of pneumatic coupler in electrical box:*



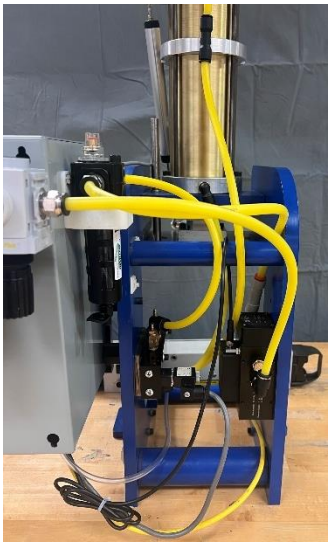
2.4.3.2 Configuring the Pneumatic Cylinder

The pneumatic cylinder sits at the top of the press and has three chambers, with two configurations. Either the top two chambers can be used for the down stroke, with the last chamber for the upstroke, or the top and bottom chambers are used for actuation with the central chamber vented to air. The configuration used for operation is the former and a diagram of this configuration can be seen in the pneumatics diagram at the start of **section 2.4.2.**

Routing the pneumatics

All pneumatic lines are 3/8 in diameter tubing. The pressure regulator, air filtration, auto oiler, and 5-way-2-position valve all have NPT 1/4 in inlets and outlets and uses 0.25 to 3/8 adapters to fit the tubing. The tube routing can be seen as follows.

Back and Top View:



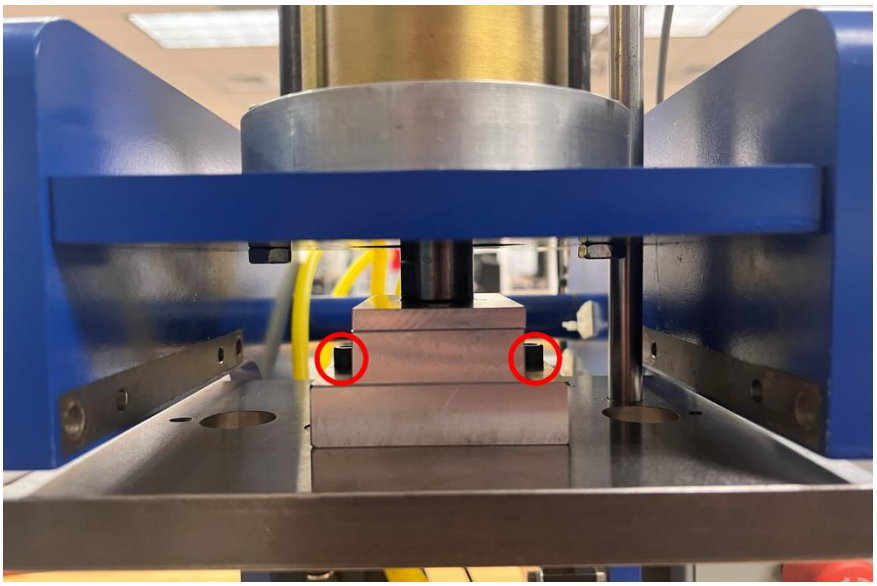
Piston and Alternative Top View:

Front View:

2.4.4 Installing the Load cell

A load cell can be used to read the applied forces of the press and is mounted between the cylinder and ram plate. To access the load cell, remove the staking machine die-set from the press if mounted, lower the press, and then unscrew the mounting block from the top of ram plate. Note the ram plate will fall out if not careful. Also note, the current configuration of the staking does not have a load cell in use.

To access the load cell, lower the press and then access the two bolts highlighted:

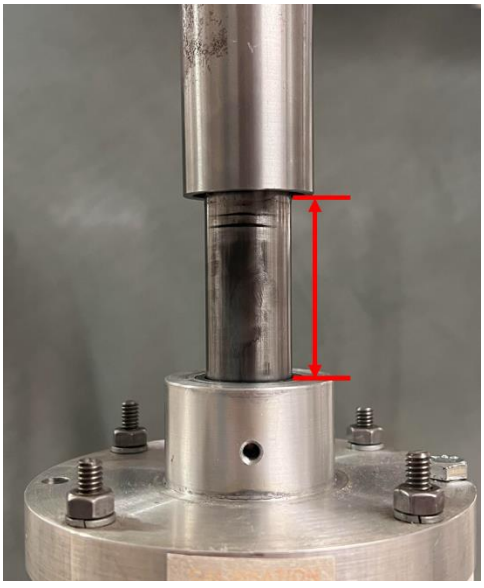


2.4.5 Installing the Potentiometer

The potentiometer is installed at the top of the press using machined parts 17 and parts 18, as well as the provided 3D printed spacer. To mount the potentiometer the following steps must be taken:

1. Remove the pinch guard from the press cylinder.

2. Measure and set the hard stop to 55 mm from the top of the cylinder.



3. Add the pinch guard back to the cylinder.
4. Bolt part 17 and the 3D printed spacer to the side of the cylinder as shown. Then fix the bottom of the potentiometer to part 17 with 1/4" bolt. Please make sure to use M5x0.50mm shoulder screws while mounting.

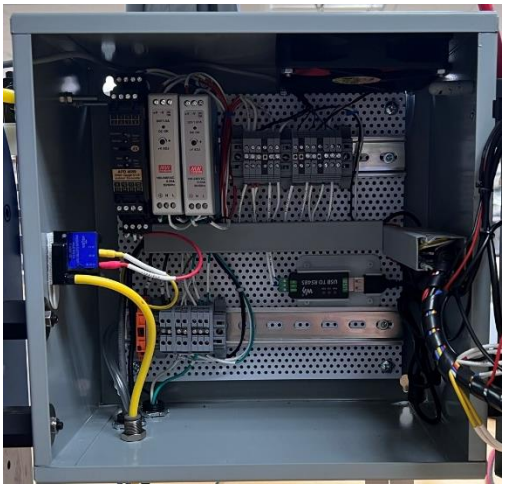
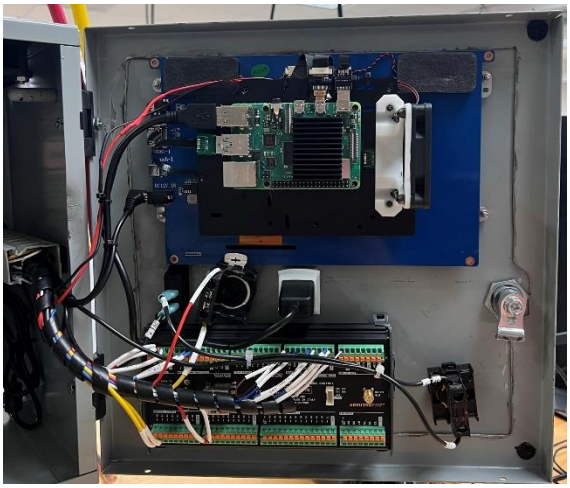
5. Insert part 18 onto the threaded bolt of the cylinder and put two nuts above the part on the threaded rod. Then mount the loose end of potentiometer to part 18 using the M5x0.50mm shoulder screws. Ensure that the potentiometer is straight and upright. The potentiometer is now installed.

6. Insert the potentiometer wire into electrical box as shown. This will be used to wire the sensor in **section 2.4.6.** Note that wrapping the wire under the top cross bar is optional depending on the length of the potentiometer wire.

2.4.6 Wiring the Electronics

Now that all the electronics are mounted to the press assembly, the wiring can be run throughout the machine. Please consult the wiring diagrams below for specific connections. Wires are under the bolster plate, on the interior of the press, away from the actuation area and to an access hole in the underside of the electrical cabinet as shown. For convenience, the electrical cabinet panel can be removed to wire the electronics and then remounted to complete running the wires to the cabinet door. Full-scale wiring diagrams can be found in Appendix 1.

Finished Electrical Cabinet:

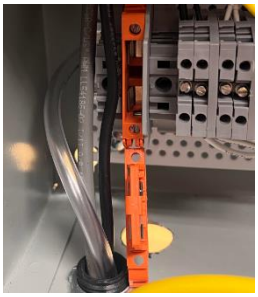



Route the Power Cable:

The remaining hole in the bottom of the electrical cabinet (the hole furthest from the front of the cabinet with the green, white, and black wires) is used to route the power cable. Use an electrical coupler to mount the wires and connect the wires to the inside of the electrical cabinet.

Installing/Replacing the Fuse

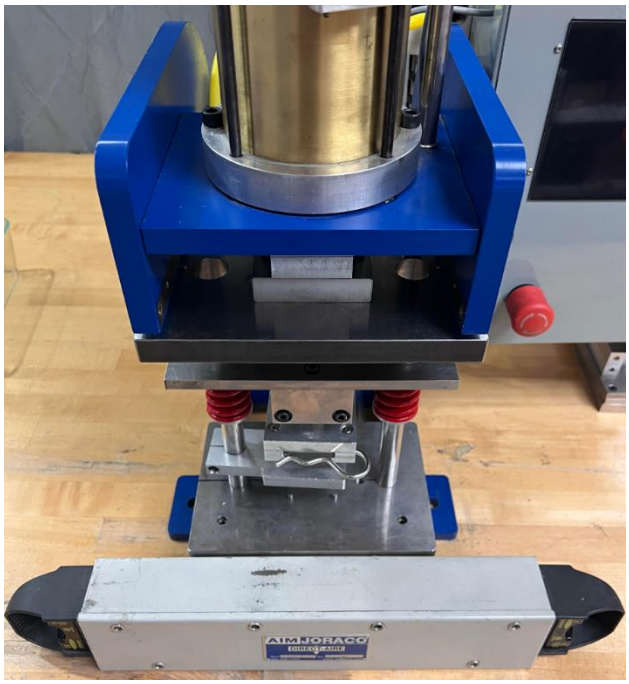
The electronics use a 5mm diameter – 20 mm length, 1A – 250V Fast acting Fuse that is inserted into the fuse holder as shown:



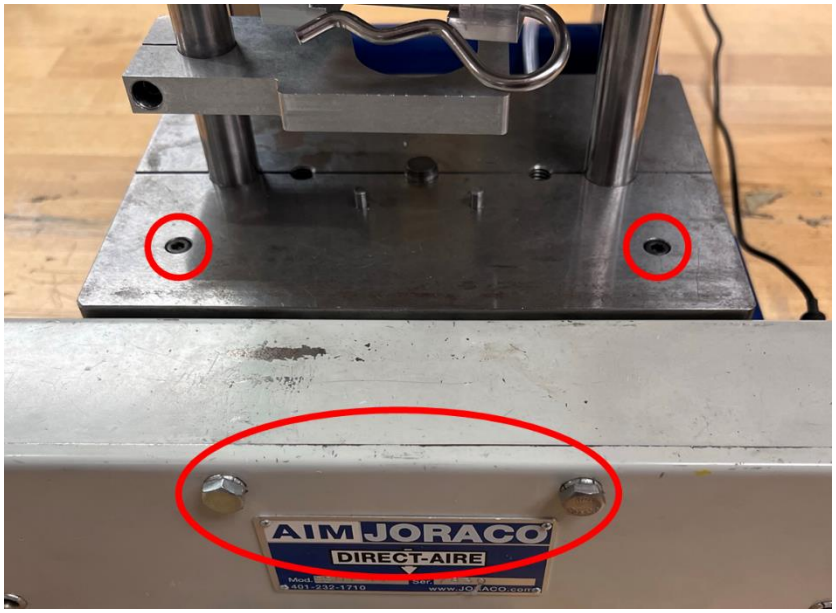

2.5 Installing Staking Machine Die-Set into Press

To install the Staking Machine Die-Set into the press, perform the following:

1. Place the die-set onto the press' work area as shown.



2. Bolt the die-set into place using the four top-side bolt holes. Then mount the two-hand safety switch onto the front side of the die-set bolster plate.



2.6 Installing Safety Guards

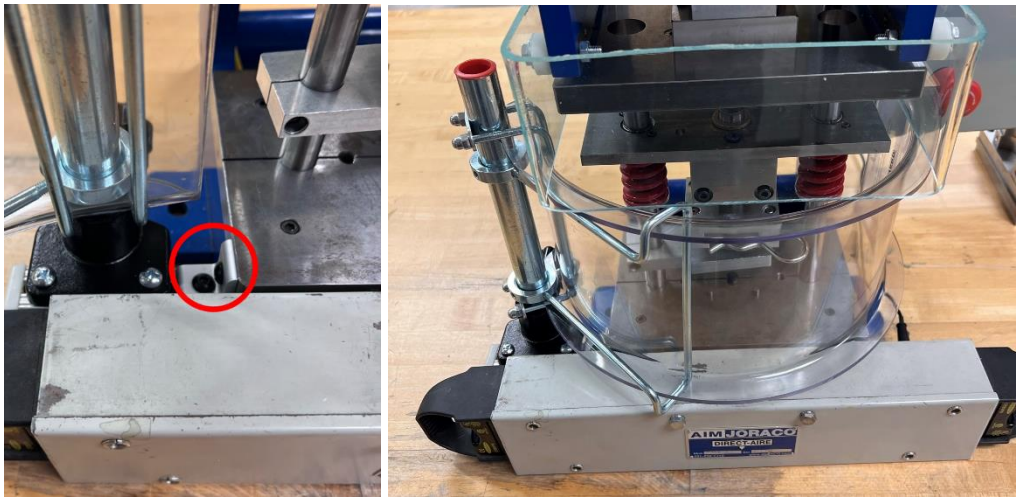
There are three safety guards for the staking machine: the press guard, the safety skirt, and the pinch guard.

2.6.1 Safety Skirt

The safety skirt is used to prevent pinching between the ram plate and the top of the Die-Set. To mount the safety skirt, orient the mounting holes to be on the top side of the skirt. Then use the provided 3D-printed spacers and bolts to mount the safety skirt as shown. Note that the skirt is mounted with a total of 4 bolts, 2 bolts on each side of the press.

2.6.2 Press Guard

The press guard is the primary guard on the press, covering the die-set during operation. To mount the press guard, align the guard to the left side of the Die-Set bolster plate and use a bolt to secure the press guard in place.

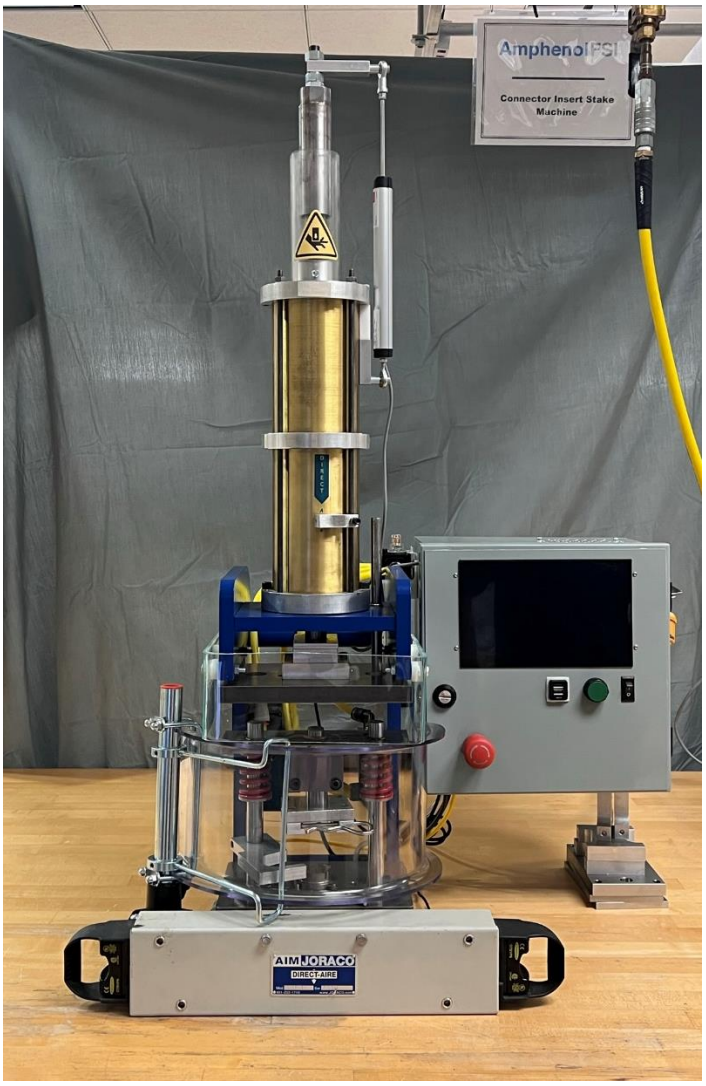


2.6.3 Pneumatic Cylinder Pinch Guard

The pinch guard is installed in tandem with the potentiometer. See **section 2.4.5** for more details.

2.7 Installing and Preparing Staking Machine for Operation

The staking machine has a footprint of 2.5 ft x 2 ft x 3.5 ft and weighs over 100 lbs. Before transporting the press, first secure a viable area that meets the volume requirement as well as the system requirements in **section 1.3.** Please make sure that both the press electrical box and the safety switch are plugged in. Further, the press will not operate with an air supply under 60 psi and needs at least 100 psi air supply to be fully operational.



3 Maintenance

3.1 Drain Air Filtration

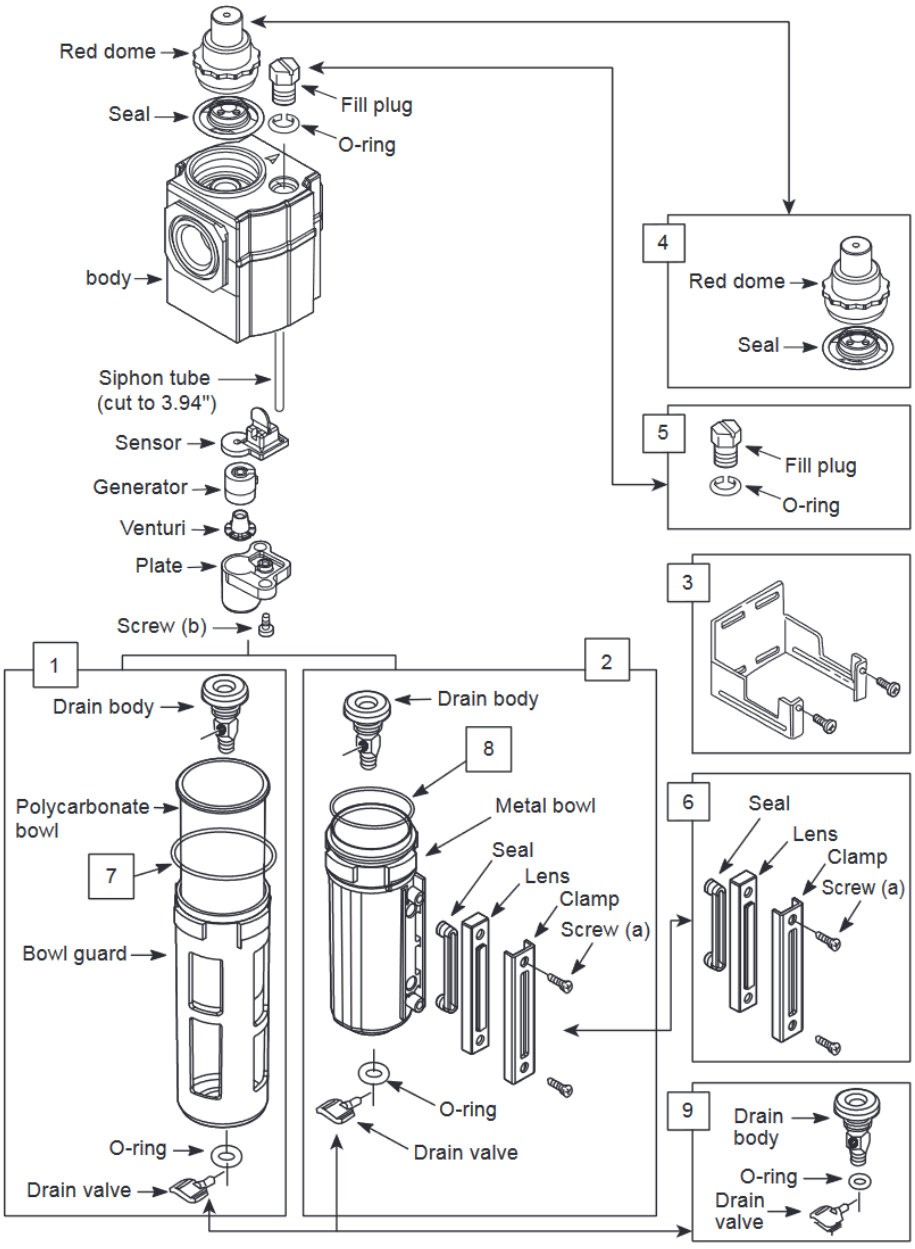
There are three catch buckets for the air-drying and particulate filters, each of which will need to be released from the depressurized system and emptied periodically. Marked on the exterior of each bucket, there is a max fill indicator that is visible in the observation window of each filter stage. To drain each bucket there is a 3D printed plug that unscrews from the bottom of each bowl. Remove the plug to drain the bowl into a receiving container and then reinsert the plug for the bowl. It is recommended to visually inspect the drain bowls at the end of operation or every 3-6 months as needed.

3.2 Auto-Oiler

The Auto-Oiler will need to be periodically refilled with 3-in-1 professional grade pneumatic tool oil via the small fill plug located on top of the oiler. On the body of the auto-oiler is a max fill line which should be followed. Any and all maintenance to the oiler, including refilling, MUST be conducted after the pressure from the inlet and outlet lines is reduced to zero.

Detailed maintenance instructions can be found in the Auto-Oiler User manual. Other pertinent maintenance may include:

- Replacing the polycarbonate bowl with a metal one if cracking or cloudiness occurs.
- Cleaning of the auto-oiler when sludge or contaminants are spotted in the bowl. Note, the polycarbonate bowl should be cleaned with warm water only, and all parts must be thoroughly dried and blown with dried air before re-assembly, as moisture can cause the press to fail. Follow disassembly instructions via diagram below, as per the user manual of the oiler.
- The drip-rate of the auto-oiler can be adjusted via the red dial on top of the oiler and must be sight-adjusted by counting the drops per minute. This measurement should be adjusted according to the flow rate of the air through the oiler and should match 1 drop every 50 strokes of the press or 0.5 drops per minute at 0.08 CFM. Additionally, poor device operation can be due to under-feeding oil to the press and should be adjusted as seen necessary.



3.3 Replace Cabinet Filter

The magnetic dust filter on the cabinet should be regularly cleaned or replaced every 3 - 6 months to ensure the removal of dust from the cabinet, which may be harmful to the electronics inside. See **section 2.4.1.3** for instructions on installing and removing the electrical cabinet fan and filter.

4 Calibration

4.1 Load Cell Calibration

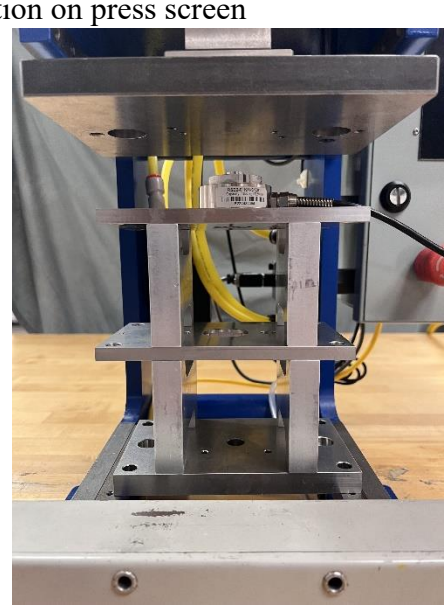
This calibration process involves a 5-point calibration test with an external load cell to update the parameters within the PLC software. The external loadcell that was used in this process was the Loadstar RSB2 2000kg paired with the LV-1000 software to read it; however, this specific loadcell is not required, any loadcell with a maximum load of at least 2000 lbs. will do. To implement the calibration in to the Arduino PMC a laptop with the calibration excel sheet located in the total data package and a Micro USB cable will be needed. Below are the steps you will need to take to find the force curve:

Computer setup:

1. Boot laptop.
2. Plug external load cell into
3. Start LV-1000 program on laptop.
4. Open calibration Excel sheet

Hardware setup:

1. Remove die-set.
2. Place metal blocks to raise platform roughly 5" from the bottom of workspace (top of press legs)
3. Place load cell in the middle of the platform.
4. Open calibration operation on press screen



Data collection:

1. Press the start button in the LV-1000 program to begin reading live forces.
2. On press screen go to "calibration point 1"
3. In Excel record voltage displayed on press screen
4. In Excel record live load displayed on LV-1000 program
5. On press screen go to "calibration point 2"
6. In Excel record voltage displayed on press screen
7. In Excel record live load displayed on LV-1000 program
8. On press screen go to "calibration point 3"
9. In Excel record voltage displayed on press screen
10. In Excel record live load displayed on LV-1000 program
11. On press screen go to "calibration point 4"
12. In Excel record voltage displayed on press screen
13. In Excel record live load displayed on LV-1000 program
14. Press the green reset button if ram plate is in down actuation position.
15. Exit calibration program on press screen.

PMC calibration point update:

1. Open Arduino PLC IDE
2. Open ***Press program name***
3. Go to "Project tab"
4. Open "IO Control FB" folder in project tab
5. Open "AI Loadcell Scale" function block
6. Update load points to the values given by the Excel sheet.
7. Connect to the PMC
8. Upload updated program to PMC.
9. Disconnect from PMC

Turn power off to the press.

4.2 Potentiometer calibration

The repeatability of the potentiometer was discovered to be within 0.0004" and was determined to be insignificant in variation of height measurement. During the staking operation, the linear potentiometer is calibrated via a touch-off sequence in the beginning of the operation. This touch off sequence records the voltage output of a known reference calibration block that is inserted into the machine. The in/V ratio is then calculated and used as reference for the staking actuation and force calibrations for the desired shell selection. The touch off procedure can be found in **section 5.2.**

5 Operation

The Staking Machine has three main operations: the staking operation, a manual retraction operation, and a calibration operation. This section will cover the staking and retraction operations, while the calibration operation section is discussed in full detail in **section 4.**

5.1 General Setup

Before any of the operations can be conducted the following setup guidelines should be conducted:

Turning Machine on:

- The power switch is located on the right most side of the electrical cabinet. When flipped on, the display screen will turn on and begin displaying the bootup sequence.

Bootup Sequence:

- Upon bootup, the HMI may flash the desktop of the Raspbian OS software before opening the HMI software and displaying the interfacing menu. If the HMI software does not run, then please try rebooting the system. If after reboot the error persists, please see troubleshooting **section 3** for further information.

Waiting for Press to Warm Up:

- The current APD 4059 Load Cell Transducer takes one hour to bootup to minimize noise in the system when in use. However, the current configuration of the press operates using the pressure regulator and does not need to wait for the Warm-Up period. It is recommended to turn the machine on while preparing the connector shells for staking.

5.2 Staking Operation

A staking operation refers to the act of using a tool punch to physically deform a staking ring inside of a connector shell. The act of deforming the ring is called "staking" and is conducted a desired "Staking Force" (**Table 1**) to ensure that enough deformation in the staking ring occurs. This deformation then permanently locks the connector insert inside of the shell. The staking operation is comprised of two rounds of staking, with a rotation of the entire connector assembly by 90 degrees relative to its origin position between each staking.

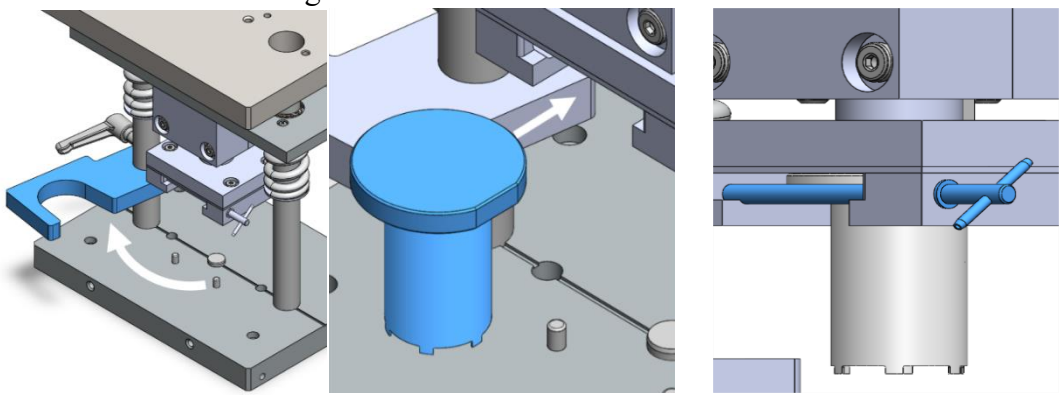
Table 1: Staking Force by Shell Size

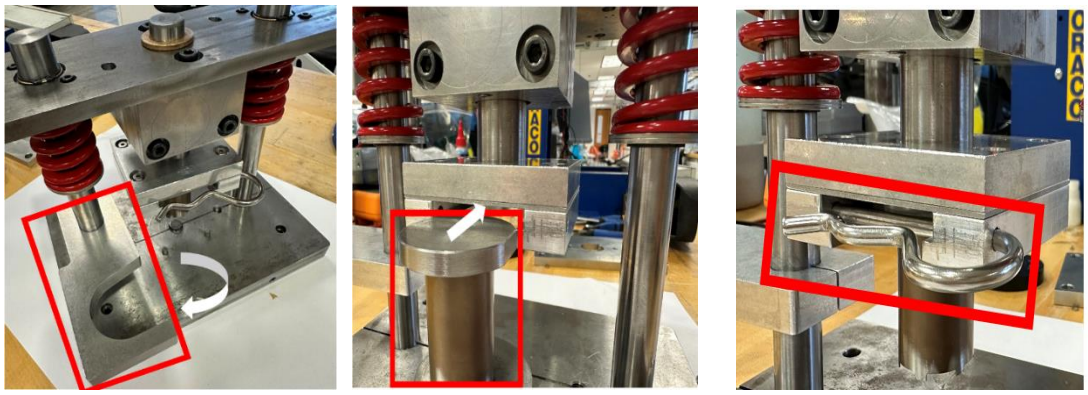
Staking Force	
Shell Size	**Force (lb.)**
11	330
13	410
15	500
17	587
19	780
21	888
23	995
25	1250

In terms of the prototype staking refers to the process of inserting the assembled, unstaked connector into the prototype, aligning the tool punch into the connector, conducting the staking operation using the human machine interface (HMI) display, and retrieving the now staked connector from the machine. The instructions to conduct the Staking Operation can be seen below:

On display screen, select Staking Operation and follow the instructions on the display screen:

1. Touch off procedure and tool punch installation:
    a. Open press guard door
    b. Unlock swing clamp arm by rotating handle counter-clockwise.
    c. Swing clamp arm out of the way of the tool holder and central post (clockwise)
    d. Select and insert tool punch.
        i. Select the labeled tool punch for the corresponding shell size to be staked.
        ii. Pull out locking pin from tool holder.
        iii. Insert selected tool punch and locking pin to secure tool punch in tool punch holder. Please make sure the flat face of the tool punch is facing the right side of the tool holder as shown.





Open clamp arm (left), insert punch tool into tool holder (center), and lock punch tool with pin (right)

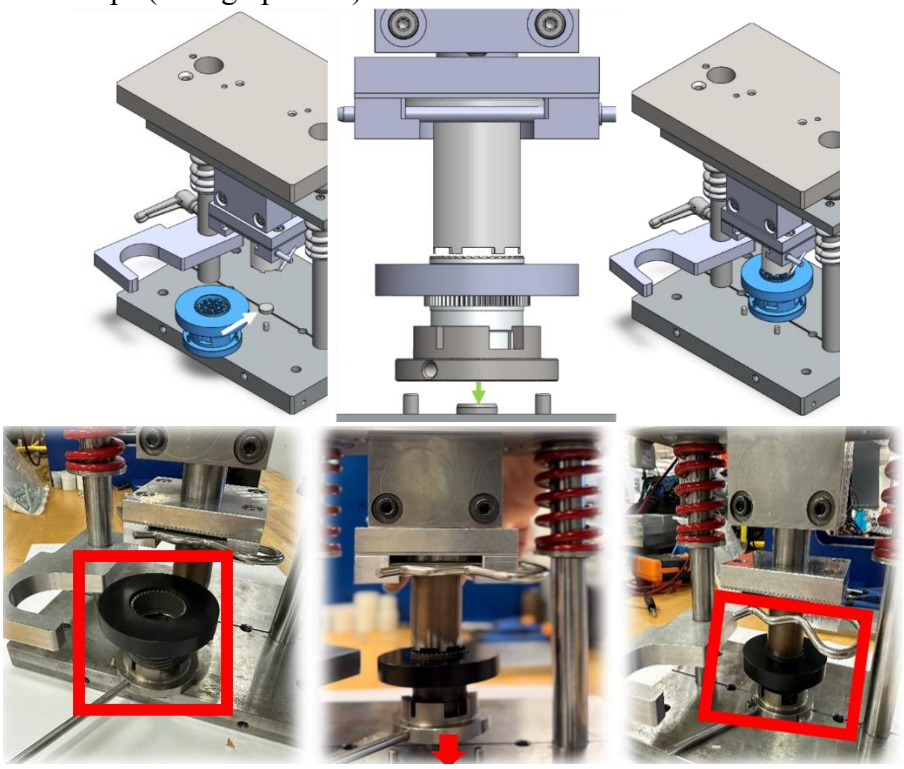
e. Insert labeled touch off block onto central post on the bottom plate of the staking machine.
f. Swing clamp arm inward (counterclockwise) until clamp arm rests on top of clamping plate.
g. Lock clamp arm position by rotating handle clockwise.
h. Close press guard door
i. Use both hands to activate the two-hand safety switch to begin touch off actuation.

Operator engaging two-finger trigger.

j. Keep hands inside safety switch until display screen says operation success.
k. Press "continue" to go to next steps.

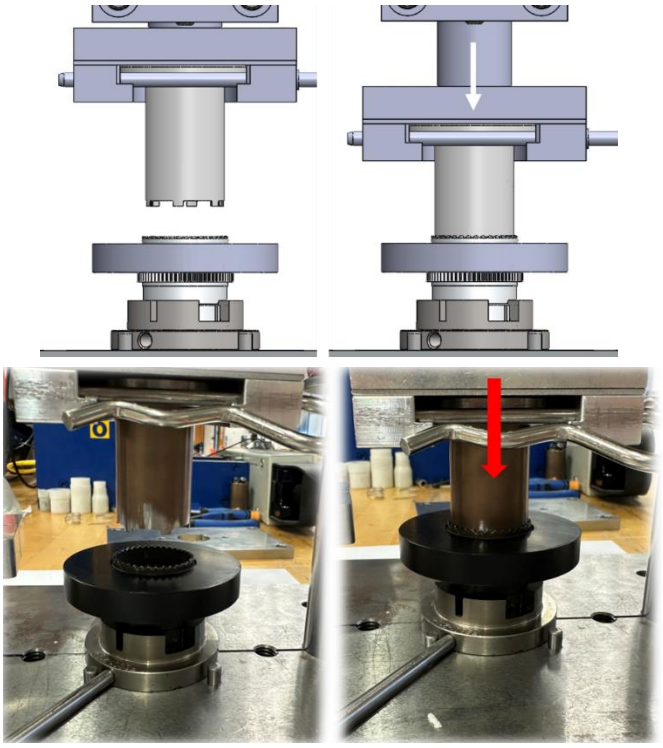
2. Open press guard door
3. Unlock swing clamp arm by rotating handle counter-clockwise.
4. Swing clamp arm out of the way of the tool holder (clockwise)
5. Remove the touch off block from the staking machine.
6. Select and insert connector shell.
   a. Select the connector shell, insert, and staking ring to be staked and assemble as defined in **section 1.3.1.**

b. Select the labeled connector fixture and clamp plate for the shell size and type to be staked.
c. Insert the connector on the connector fixture with connector shell castellations (teeth) pointing upward.
d. Insert clamp plate onto the connector shell until plate is flush against flange on the connector shell.
e. Raise the tool punch inside the staking machine and with the other hand insert the connector fixture, connector shell, and clamp plate assembly onto central post on bottom plate of press, ensure that rotation arm is between the 90° hard stops (facing operator)



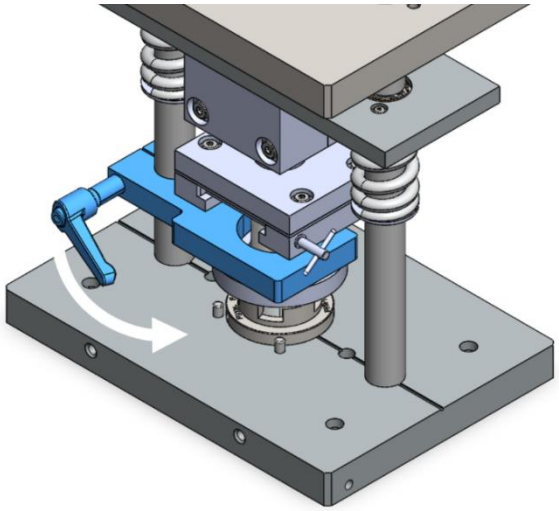
Insert connector fixture into machine.

f. Rotate connector fixture until rotation arm on connector fixture is flush against one of the 90° hard stops.
g. Lower tool punch and align the tool punch into the connector shell, until tool punch reaches hard stop and cannot move further downwards.



Pre-align punch tool and lower into connector.

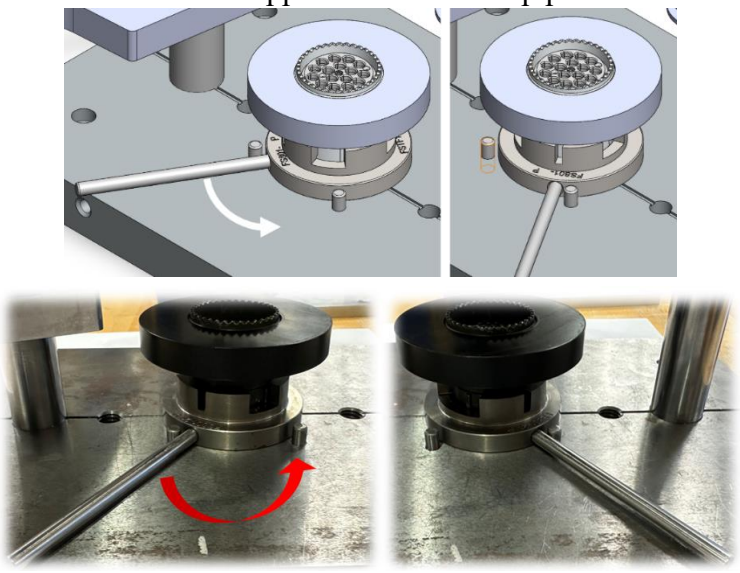
h. Swing clamp arm inward (counterclockwise) until clamp arm rests on top of clamping plate.



Close clamp arm

i. Lock clamp arm position by rotating handle clockwise.

7. Close press guard
8. Staking Selection
    a. On display screen press continue to go to staking selection
    b. Input the correct staking size and type into display screen and press continue.
9. Staking Actuation
    a. Use both hands to activate the two-hand safety switch to begin touch off actuation.
    b. Keep fingers on safety switch until display screen says operation success.
    c. Release safety switch and press continue on HMI to go to next steps.
    d. Open press guard door and use connector fixture rotating arm to rotate connector fixture to opposite 90° hard stop post.



90° rotation of connector between hard stops

    e. Close press guard door
    f. Press "continue" to go to second staking actuation.
    g. Repeat steps 9a – 9c.
10. Open press guard door
11. Unlock swing clamp arm by rotating handle counter-clockwise.
12. Swing clamp arm out of the way of the tool holder and central post (clockwise)
13. Removing Connector Shell
    a. With one hand lift the tool punch and with the other hand remove the connector fixture, connector shell, and clamp plate assembly from the staking machine.
14. Repeat steps 6-13 as necessary for connectors of the same size.
15. Removing Tool punch

a. Unlock tool punch by removing locking pin from tool punch holder.
b. Remove tool punch from tool punch holder.
c. Insert locking pin back into tool punch holder.

16. Swing clamp arm inward (counterclockwise) to not interfere with press guard.
17. Lock clamp arm position by rotating handle clockwise.
18. Close press guard door. The staking operation is complete.

5.3 Retraction Operation

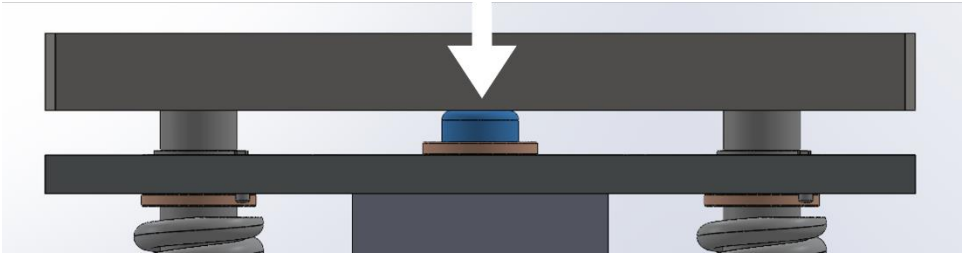
The retraction operation is a backup system used in the case of a jammed connector. If a connector jams and the tool punch cannot be easily removed from the shell with the troubleshooting of **section 6**, then use the retraction operation.

Retraction Overview

The retraction operation works by lowering the ram plate of the press to the top of the die-set if it is not already there. Then, once the ram plate is in position, mount the top of the die-set to the ram plate using the provided retraction operation bolts. Once mounted, use the HMI screen to select a desired direction and actuate using the two-hand safety switch.

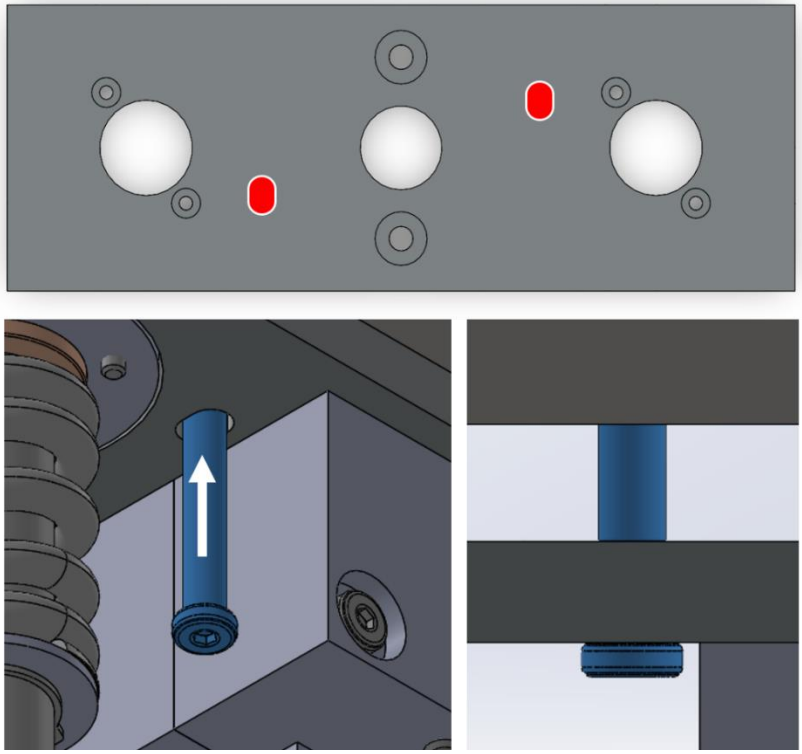
Retraction Operation Instructions

1. Reboot the staking machine and select the "Retraction Operation."
    - Enter the passcode "AFSI."
2. Select the "Down" direction on the HMI Screen. Once selected, use the two-hand safety switch to actuate the press, such that the ram plate touches the dowel pin in the center of the top plate.



Ram plate (top) lowered until contacting dowel pin (blue) in top plate.

3. Use the provided retraction bolts (Black-Oxide Alloy Steel Socket Head Screw 1/4"-20 Thread Size, 1-1/2" Long, Fully Threaded) to mount the die-set to the ram plate.
    - Insert the bolts through the retraction holes in the top plate.
    - Screw the bolts into the corresponding threaded holes in the ram plate.



Bolts inserted into retraction holes in top plate (top, in red) and threaded into ram plate (bottom right)

4. After securing the top plate, select the "Up" direction on the HMI Screen. Once selected use the safety switch to slowly actuate the press upward until the connector is unjammed. Please note that after the connector is unjammed the press will want to continue to actuate upward, please let go of the safety switch to prevent further actuation.
5. Select the "Down" Direction on the HMI and actuate the press until the die-set barely starts to move.
6. Remove the retraction bolts from the die-set and then push the green reset button.
7. Retraction Operation Complete. Press "Continue" to return to operation selection.

6 Troubleshooting

6.1 Failed Retraction and using the reset button

If the press loses power, has a serial communication issue, or does not have enough pressure, the ram plate may be stuck in the lower position for the cylinder. To resolve this, open the staking, if not already open, and press the reset button. This will cause the system to trigger the retraction process and return the ram plate to its normal starting position.

6.2 Resolving Jams

In the event the top plate does not return to the upright position after the press cylinder raises, the tooling is likely jammed in some way. There a several ways a jam can occur, that are detailed below. The retraction operation described in **section 5.3** was designed with these failure modes in mind. Use of the retraction operation is restricted to technicians. The technician will need to access the retraction operation through the HMI using the passcode "AFSI."

6.2.1 Top Plate Jammed on Guide Posts

If the top plate is jammed on the guide posts, this indicates an operation failure impacting the reliability of the die-set due to misalignment. The technician should perform the retraction operation detailed in **section 5.3** to dislodge the jam.

6.2.2 Punch Jammed in Connector

Should the staking ring jam the tool punch into the connector, the operator will not be able to remove the punch from the connector due to castellation defects or improperly applied forces. The retraction operation from **section 5.3**, can be employed to pull the punch out of the connector using the force from the press. The technician should ensure that the clamp arm is properly positioned and tightened so that the connector cannot move upward during the retraction operation.

6.2.3 Puck Holder Cylinder Jammed in Floating Housing

Should the technician be unable to raise the tool holder, first they should engage the retraction operation from **section 5.3** in order to remove the connector from the punch tool. From there, the operator would need to detach the ram plate from the top plate and then remove one half of the floating housing structure by unscrewing the two screws holding it to the other half, and then removing the screw fixing the first half to the top plate. Once half of the housing is removed, the jam will be dislodged and the housing can be reassembled.

6.3 Frozen or Stuck Screen

6.3.1 Reboot the Staking Machine (Turning it on and off again)

The HMI software can occasionally have an error due to mistimed serial communications or loose connections. The following are common errors:

HMI Software does not open. Error "/dev/ttyUSB0 directory not found":

Loose USB connector. Check connection and try again.

HMI displays the desktop image of Raspbian OS on Bootup:

Something is wrong with the software. Try running the software directly from visual studio code. If it works, then the auto bootup is broken and needs to be rebuilt (see **section 8.3**). If the software still does not run, then there is an error, a package issue may have occurred with the PI and python. The code will need to be altered to exit Fullscreen and then rerun to see the command line terminal error.

Warning: Spamming E-Stop or the power switch will pop the fuse.

7 Safety Guidelines

This section will discuss the potential hazards and recommendations during assembly, installation, and operation. It is recommended that eye protection and PPE is worn during the assembly of the staking machine.

7.1 Hazards

Crush Hazard	The press exerts significant force and can crush fingers, hands, or other body parts if they are placed within the press during operation. Keep all body parts clear of the press area when it is in operation.
Pinch Points	Beware of pinch points in the press mechanism. Ensure that all guards are in place and properly secured to prevent accidental contact with moving parts.
High Pressure	Pneumatic systems operate under high pressure. Avoid contact with pneumatic hoses and components during operation to prevent injury from sudden releases of pressure or bursting hoses.
Electrical Hazard	The PLC controls the operation of the press and is powered by electricity. Avoid contact with electrical components and wiring to prevent electric shock.
Noise Exposure	Pneumatic presses can generate high levels of noise during operation. Wear hearing protection when working near the press for extended periods to prevent hearing damage.
Programming Error	Errors in serial communication between the HMI and PLC may result in unexpected press movements or malfunctions. In the case of unexpected behavior, make sure that all operator users are aware of the e-stop and the power switch to the staking machine.

7.2 Precautions and Safety Recommendations

Operator	Ensure that personnel involved in operations and maintenance of the staking machine are adequately trained in working with pneumatic systems and PLC operations. They should have a clear understanding of safety procedures and protocols and **be made aware of the emergency stop button and the function of the two-hand safety switch.**
Proper Tooling	Ensure that the press is equipped with the correct tooling for the specific connector assembly being performed. Using incorrect or damaged tooling could result in improper assembly, damage to the connectors, and potential damage to the staking machine.
User Manuals	The component user manuals are in the total data package for the staking machine. For in depth questions, safety guidelines, and specifications of components, please review these manuals. This user manual takes the smallest operating range for all the components overall. Please review and understand the manuals provided by the pneumatic press and PLC manufacturers. Follow the assembly instructions and safety guidelines outlines in these documents if further questions are had.
Testing	Conduct comprehensive testing of the pneumatic press and PLC system after installation to ensure proper functionality and safety. Verify that all inputs and outputs are working as intended and that safety features respond appropriately.
Documentation and Labeling	Document the wiring, configuration, and setup of the PLC system for future reference. In addition, label components and connections clearly to aid in troubleshooting and maintenance. See **section 2.4.6** for details on labeling wiring.
Lockout Tagout (LOTO)	Before performing any maintenance or servicing on the press, follow proper lockout/tagout procedures to de-energize and isolate the press from its power source. Failure to do so could result in accidental activation of the press, causing serious injury.

Electronics Modifications	When working with the PLC, ensure that power to the system is completely turned off before handling any components. Follow LOTO procedures to prevent accidental startup.
Proper Wiring, Shielding, and Grounding	When wiring the PLC and associated electrical components, use properly shielded cables, and ensure that wiring is routed away from high-voltage sources to prevent interference or damage. In addition, properly ground all electrical components, including the PLC and any associated equipment, to avoid electrical hazards.
Maintenance Schedule	Follow the manufacturer's recommended maintenance schedule for the press and associated components. Regular maintenance helps ensure safe and reliable operation while minimizing the risk of unexpected failures. See **section 3** for an overview of staking machine maintenance.
Regular Inspections	Conduct regular inspections of the press and associated components to identify any signs of wear, damage, or potential hazards. Address any issues promptly to maintain safe operation. It is recommended to do inspections at the same time as maintenance.
Warning Labels	Display warning signs and labels in the vicinity of the press to remind operators of potential hazards and safe operating procedures.
Compliance with Regulations	Ensure that the installation and operation of the pneumatic press and PLC system comply with relevant safety regulations and standards in your jurisdiction.

8 Software

8.1 Introduction

The staking machine operates with the use of an Arduino Portenta Machine Control (PMC) for its PLC operations as well as a Raspberry PI for the HMI operations. The PMC and the HMI will be discussed separately in detail about the libraries and packages required for each program, a basic overview of the program and how to upload its codebase, as well as a brief explanation of how to modify both programs. Due to the open, published nature of the APIs for the libraries, links to tutorials will be provided as necessary as well as instructions as is appropriate. The codebases for both the PMC and the HMI can be found in the total data package provided alongside the manual and staking machine.

8.2 Portenta Machine Control

The Arduino Portenta Machine Control PLC (PMC) is a unit that takes the input user parameter from the HMI and executes a series of actions involving the connected sensors and controls equipment. The Arduino PMC will also report the active status and variables to the HMI using Modbus RTU.

8.2.1 Libraries and Packages

The basic mbed libraries and instructions to install them for the PMC can be found here: https://docs.arduino.cc/software/plc-ide/tutorials/plc-ide-setup-license/

For the program you will need the addition of the ArduinoModbus library, link found here: https://www.arduino.cc/reference/en/libraries/arduinomodbus/

8.2.1.1 List of libraries and packages with links

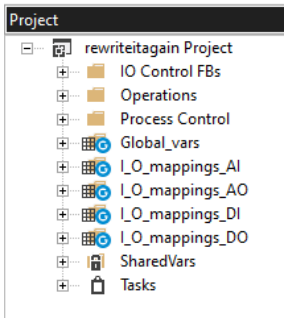
Library Name	Version	Link
AlPlc_PMC	1.0.3	https://reference.arduino.cc/reference/en/libraries/alplc_pmc/
Arduino_MachineControl	1.1.1	https://www.arduino.cc/reference/en/libraries/arduino_machinecontrol/
ArduinoRS485	1.0.5	https://www.arduino.cc/reference/en/libraries/arduinors485/
ArduinoModbus	1.0.9	https://www.arduino.cc/reference/en/libraries/arduinomodbus/

8.2.1.2 How to install libraries and packages

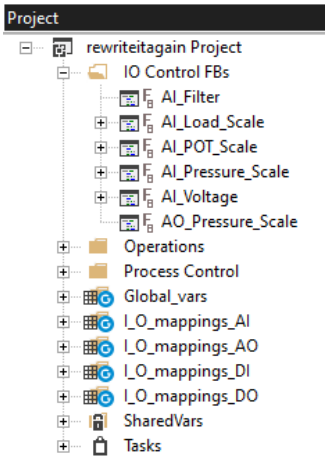
The following link is a step-by-step guide for installing libraries on the Arduino platform: https://docs.arduino.cc/software/ide-v1/tutorials/installing-libraries/

8.2.2 Basic software overview and how to upload codebase to PMC

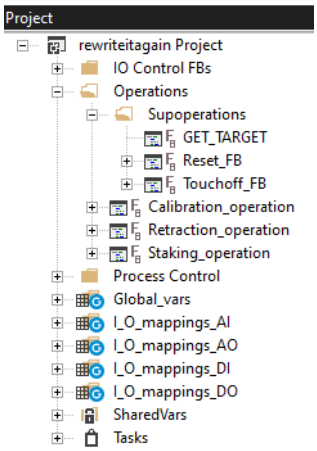
The PMC software is written between three different languages in the Arduino PLC IDE, those languages are C++, Structured Text (ST), and Function Block Diagrams (FBDs). The program in Arduino PLC IDE is separated into three different folders: IO Control FBs, Operations, and Process Control.



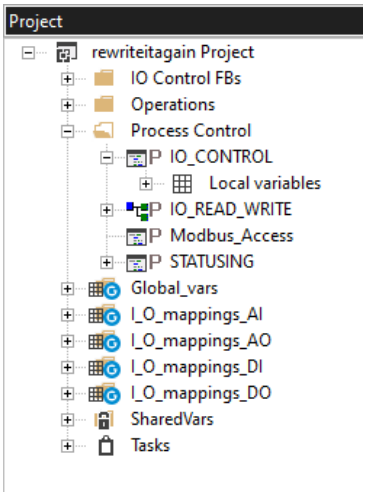
The IO Control FBs folder contains all of the custom function blocks that will be used to read the word value input by each of the sensors and scaling that inputted value to either a voltage value, pressure value, position value, or load value. This folder also contains the function block that will do the opposite by converting a desired output pressure value to a 0-10V value.



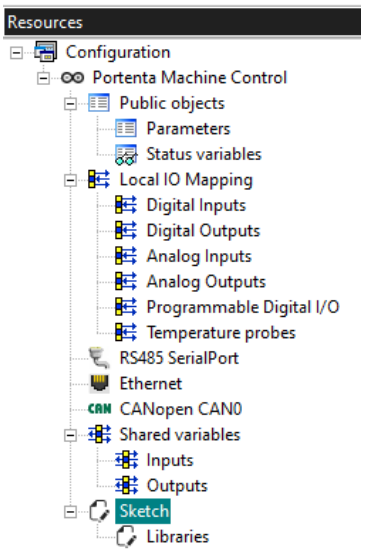
The Operations folder contains all the possible operations or sequences that the PMC might need to execute such as the Staking, Calibration, or Retraction operations. The Operations folder also has a sub folder for the suboperations such as Get Target, Reset, and Touchoff that may be called in the larger main operations.



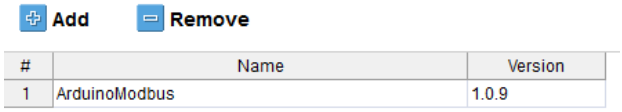
The Process Control folder contains all of the programs that execute the previously mentioned function blocks. IO_READ_WRITE is in FBD, and its purpose is to read and write all of the external sensors. IO_Control executes all the operations and suboperations based on the input parameters provided by the HMI such as shell size, shell type, and which operation to execute. Modbus_Access just connects the Modbus variables to the corresponding global variable, more information on Modbus in the next paragraph. STATUSING is a program that monitors various inputs and bit switches a single status variable that is read in the staking operation.



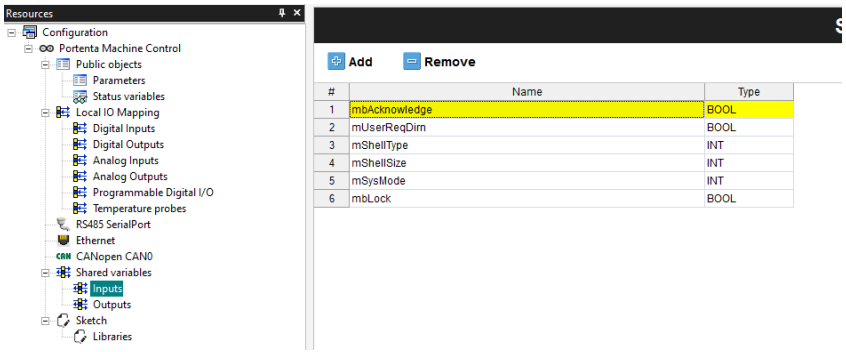
The PMC is currently using Modbus RTU over RS485 to communicate with the HMI, however, the built in function in the Arduino PLC IDE to enable Modbus RTU over RS485 at the time of development does not work so an Arduino sketch was added here in the Resources tab:



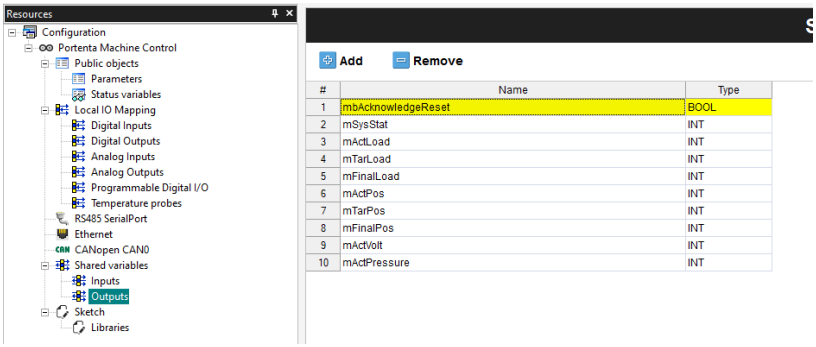
It is important to note that all libraries that the sketch calls must be included in the "Libraries" tab located under "Sketch" as shown:



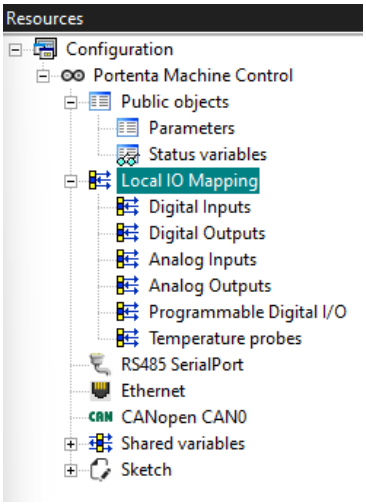
This includes libraries ONLY for the sketch and not the whole program. For the variables that are read from the HMI, the variables must be added to the "Shared variables" "Inputs" tab:



For the variables that are written to the HMI, the variables must be located in the "Outputs" tab:



All digital and analog IO can be added or modified here under "Local IO Mapping":



8.2.3 How to modify software/codebase.

Further documentation and online tutorials can be found here: https://docs.arduino.cc/tutorials/portenta-machine-control/user-manual/

8.3 Human Machine Interface (HMI)

The Human Machine Interface is a touch screen display that allows users to interact with the staking machine by selecting an operation program and following the corresponding displayed instructions to conduct the operation. Displayed instructions have pictures and guided steps on how the user should interact with the machine.

8.3.1 Libraries and Packages

The HMI uses the Raspbian OS, with the capabilities of a standalone computer that can run multiple applications, connect to the internet, and have Bluetooth applications. The current configuration has WI-FI and Bluetooth disabled and automatically runs the HMI program to display the interface.

8.3.1.1 List of libraries and packages with links

The HMI uses the following software:

- Raspbian OS
- Visual Studio Code

8.3.1.2 How to install libraries and packages

The HMI uses the following additional libraries and packages excluding the Raspbian OS. To run the command lines, make sure that the HMI is connected to the internet to allow the packages to download.

Package	Functionality	Command to install package in terminal
Visual Studio Code	Software to Edit Code	sudo apt install code
Visual Studio Code Python Extension	Python Extension for VS Code	Automatically prompted when opening VS Code python file.
tkinter	Base library to render graphics.	sudo apt install tk
customtkinter	Expands functionality of tkinter rendering library	pip3 install customtkinter –break-system-packages
PIL	Render Image Files	pip install Pillow –break-system-packages
minimalmodbus	Allows for serial communication in python.	pip3 install minimalmodbus–break-system-packages

8.3.2 Supplemental Scripts and Operations

OverheatDetection.py

The HMI has a background script running to ensure that overheating does not occur. This script automatically runs every 2 minutes and shuts down the HMI System at 60°C to prevent hardware burning out or corrupting. The task is called OverheatDetection.py and is scheduled using the Cron library that is native to Raspbian OS.

Enabling Cron Scheduler for OverheatDetection.py

To enable the Cron Scheduler, open the command terminal on the Raspberry PI and type the following lines of code:

crontab -e

This command opens the cron schedule editor, move to the bottom of the commented instruction overview and then type the following:

*/2 * * * * python3 /home/AFSI/documents/HMI_Program/OverheatDetection.py

The line of code represents the minute/hour/day of the month/ month/day of the week/ command to execute. This line runs the OverheatDetection.py script every 2-minute interval after bootup.

Press Ctrl+O , hit enter, then press Ctrl+X to save and exit.

8.3.3 Basic software overview and how to upload codebase to Raspberry PI

HMI.py

The main program for the HMI control is a python script called HMI.py that is edited inside of Visual Studio Code and runs using Python3 found native to the Raspbian OS. **The HMI script also has a supplemental assets library that must be in the same file location as HMI.py.** This assets folder contains the images used in the display instructions.

The HMI operates off a page menu system. Each page is its own function to change the display screen with its respective images, text, buttons, and interfacing controls. Each function is housed in a page dictionary and page array to allow for both sequential and nonsequential page rendering.

The graphics and button interfaces of HMI are rendered using the tkinter library to design and display the graphical elements of the interface by constructing a graphical structure called a frame. Each frame can then be drawn to the screen as well as deleted to display the appropriate

graphics and text. Each frame consists of the display images, instructional text, as well as interfaces such as buttons or text inputs. Helper functions are commented to describe their function in the codebase.

Serial Communications and Live Updating

The HMI uses multi-threading to read/write data to the PMC as well as update any local variables for the display screen. The touch off and live update pages use their own updating logic to minimize unused read calls. These sections of the code are commented to describe their function in the codebase. Serial communication to the PMC is done by using a rs485 serial USB converter.

Enabling Auto-Bootup

Auto-bootup is disabled by default. For the HMI to run correctly, the HMI.py script should be run on boot-up of the Raspberry Pi. To enable automatic start-up, do the following:

Open Terminal and type the following lines:

```
mkdir /home/AFSI/.config/autostart
nano /home/AFSI/.config/autostart/HMIBootUp.desktop
```

Inside the desktop file copy the following lines:

```
[Desktop Entry]
Type=Application
Name=HMIBootUp
Exec=/usr/bin/python3  /home/AFSI/Documents/HMI_Program/HMI.py
```

Press Ctrl+O , hit enter, then press Ctrl+X. The HMI.py script is now enabled for auto-bootup.

8.3.4 Cloning and Flashing Raspberry PI SD Card

The operating system and code for a Raspberry PI runs off of an SD Card and can be backed up in case of damage. The backup of the Raspberry PI is found in HMIBackup_Final.img and can be flashed to the SD Card using the software win32diskimager. Instructions and a link to the Win32DiskImager Software can be found at https://lifehacker.com/how-to-clone-your-raspberry-pi-sd-card-for-super-easy-r-1261113524 and are summarized as follows:

Cloning the SD Card

1. Insert SD Card into computer.
2. Create a text file in the designated folder to house backup. Rename file "HMIBackup.img".
3. Open Win32DiskImager and in the "Image File" box enter the path to "HMIBackup.img".
4. Under the "Device" box, select the SD Card.
5. Click "Read" and wait for the process to finish.

Flashing the Backup to the SD Card

1. Insert SD Card into computer. Clear contents and delete the partitions of SD Card.
2. Open Win32DiskImager and select the "HMIBackup.img" file. Select the SD Card in the Device drop down box.
3. Click "Write" and wait for the process to finish.

8.3.5 How to modify software/codebase.

To Modify the codebase, there is a settings icon on the operation selection page that is locked when you click on it. Enter the passcode "AFSI" to enter settings. The only option is to close the program or return to operation selection.

Once the program is closed, use Visual Studio Code to open the HMI script. It is recommended to enable develop mode in the code and disable Fullscreen to view errors in debugging. The software is commented and explains how to enable devMode to true.

To add additional shell sizes and types, simply open the HMI script and add the new selection criteria to the end of the corresponding dictionaries and arrays.

9 Future Recommendations and Modifications

Several items were outside the initial specifications and achievable scope for the allotted time and budget for the staking machine. While not present in the delivered prototype, it is recommended that these changes be implemented by AFSI to improve the machine's performance and functionality.

Light Curtain/Interlocking Press Guard

During the secondary safety inspection, it was strongly recommended by the UTD safety manager that an interlocking press guard be implemented so that the press cannot be operated with the press guard open, and the press guard cannot be opened while the press is in operation. The staking machine at AAO uses a light curtain that prevents operation of the machine if the threshold is broken. The current design uses a non-interlocked lathe guard and a simple pinch skirt for operator protection. For improved safety, we recommend that AFSI implements either an interlocked press guard or a light curtain similar to AAO.

Replacing Load Cell and Amplifier

The load cell purchased from Omega is out of calibration. While the return window has closed, it is still under warranty and Omega has offered to fix it. However, the lead time for recalibrating the load cell extended beyond the project timeline. To accomplish the project goal, a work around was devised to hit the target force using the readings from the pressure regulator. We recommend AFSI has Omega recalibrate the load cell while it is still under warranty, so the live force can be read more directly.

Associated, the amplifier for the load cell requires a warm-up period of at least one hour in order to reach the appropriate operating temperature for accurate readings. The current amplifier also produces a considerable amount of electrical noise. To improve the accuracy of the readings, it is recommended that AFSI replace the amplifier for the load cell with an Omega DRC-4710 or equivalent. However, the team recommends calling Omega to verify the compatibility and warm up time.

Updated Tool Holder Pin

The current design uses a cotter pin to secure the punch tooling inside the tool holder. For improved ergonomics and to prevent loss, it is recommended that this pin is replaced with a T-Handle Locking Quick-Release Pin with Lanyard (3/16" Diameter, 3" Usable Length) from McMaster-Carr.

Bushing Choice

A minor oversight on this project were the oil-impregnated bushings that were chosen. In the future, it is best practice to choose bushings whose length is greater than or equal to one diameter

of the post. That was not the case with these parts, and while there is no problem with the machine operation currently, there is some difficulty in the initial locating of the posts and attempting to manipulate the top plate by hand.

Surface Treatments

Much of the project is created from alloy steel parts, which can rust and corrode over time. Treating the surface of these and the aluminum parts will increase their toughness and longevity.

Clamp Arm Redesign

In our development of the clamp arm, we initially considered using a separate clamping shaft collar, though we could not find one with a high enough thrust load. It was then requested by the Client that the clamping mechanism be integrated into the clamp arm, and the design on the press is the result. It may be desirable to re-design the part so that it is removable without taking the die-set apart, or so that the required torque the user has to exert is lowered. The current design was achieved by copying much of the geometry from the considered McMaster part – some future considerations may be to texture the surface of the guide post or inside surface of the clamp plate holder for increased friction, or to select a larger diameter screw for lower torque.

Thermal Cycling Test for Raspberry Pi

During testing, the original Raspberry PI for the HMI thermally failed due to overheating, by running the HMI for an extended period. A fan and heatsink were added for thermal regulation and the onboard temperature sensor was set to shut down the Raspberry PI if dangerous temperatures are reached. It is recommended that a thermal cycling test is conducted to assess exactly how long the system can run before thermal limits are reached for the Raspberry PI so additional thermal regulation can be implemented as needed.

Exhaust Valve Instead of Check Valve

The current design utilizes a check valve to prevent dirty air from returning to the system. However, during an emergency situation where the e-stop is triggered, the press will hold pressure and continue moving until reaching an equilibrium position. To improve operator safety, the check valve should be replaced with an exhaust valve that vents pressure during power loss.

Air Filtration Drip Pan

The air filters chosen to clean the air supply to the press drip water that they filter from the supplied air. This water currently collects in a series of bowls that are plugged with 3D printed bolts (SD1815-22). These collection bowls need to be manually relieved. Replacing the bolts with a drip pan can decrease the labor associated with the air filtration system.

Replacing 3D-Printed Parts

As mentioned in **Section 5.2.3**, the current design requires a 3D printed spacer (SD1815-29) to secure the POT to the cylinder of the press. While this solution is satisfactory, if the machine were reproduced, the spacer could be eliminated by increasing the length of the POT bracket (SD1815-17) 1.60 inches (new total length: 3.60 inches).

The section also mentions the staking ring insert tools (SD1815-30-X). The leading edge on the outer component that drives the staking ring in between the connector shell and insert is made of very thin walls, the same thickness as the punch tool. UV Tough resin was used to increase the allowable strain, and their inward deformation is intrinsically limited by the inner component. However, the walls of this leading edge are not immune to breaking. New insert tools can be printed for less than $1.00 of material cost provided a mSLA printer is available. For the sake of longevity, AFSI may consider having replacements machined out of aluminum. However, the tools cannot be machined with traditional methods as drawn and would need to be redesigned into three parts that can be assembled after machining.

Optimizing the Retraction Springs

As mentioned in **section 3.5**, the retraction springs currently apply a 200 lb retraction force. This 200 lb. value was based on calculations of a slide hammer discussed in the design justification. The team recommends that AFSI uses the existing tool holding rig provided by the client to manually stake a connector and measure the necessary retraction force. The measured retraction force can then be used to optimize the spring constant of the die-springs in the staking machine.

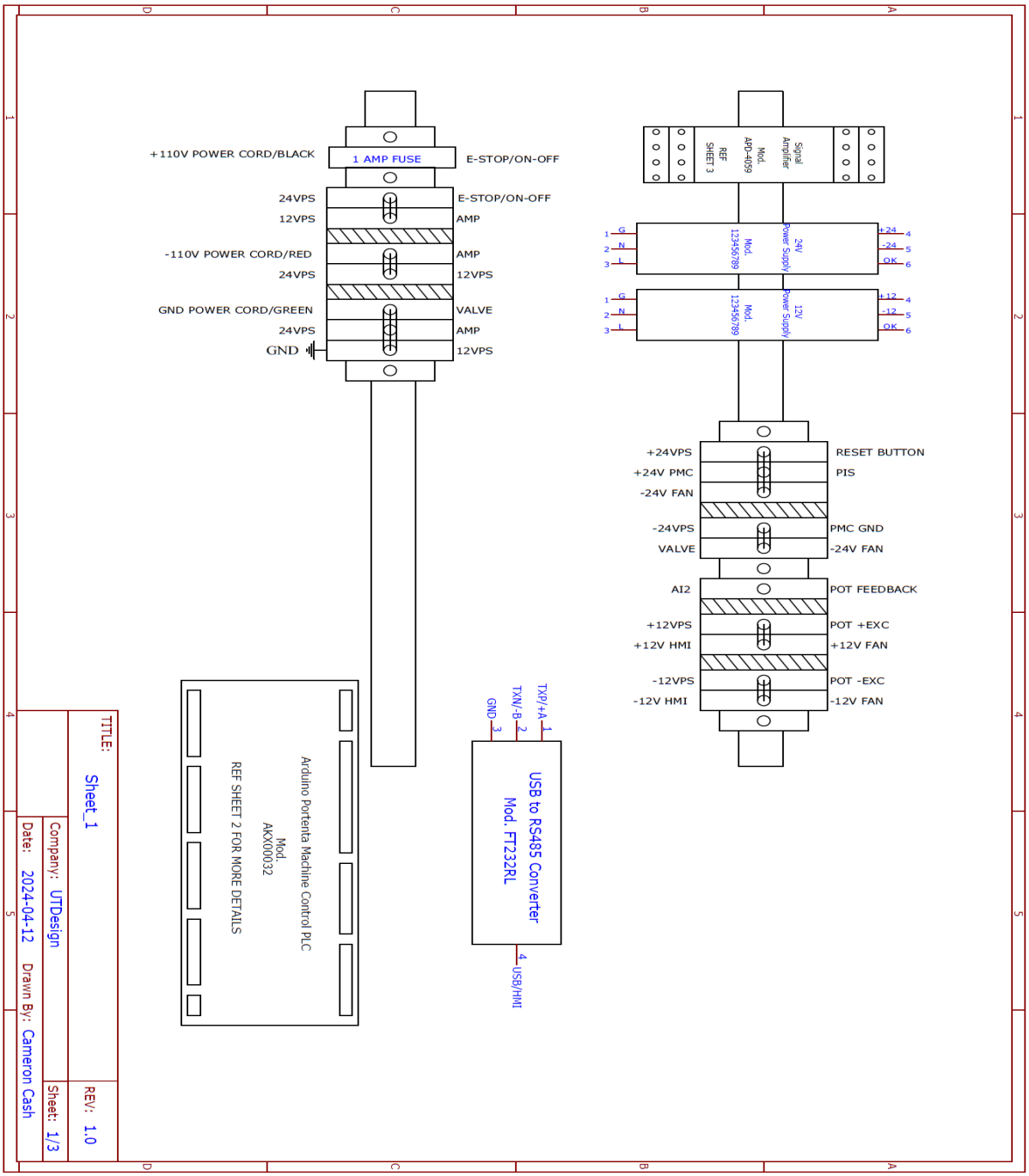
Waterjet the Cabinet Door

If the HMI panel is unsatisfactory or if the use of epoxy is not desired. The electrical cabinet door can be replaced with an identical door. Due to the detachable hinges, the cabinet door can be laid flat on a waterjet. It is recommended for future doors to use the HMI panel design as the foundation for a waterjet sequence to precision cut the holes in the cabinet door. Please note that if switching to this manufacturing method, the position of the lock will need to be modified to match its dimension specifications.

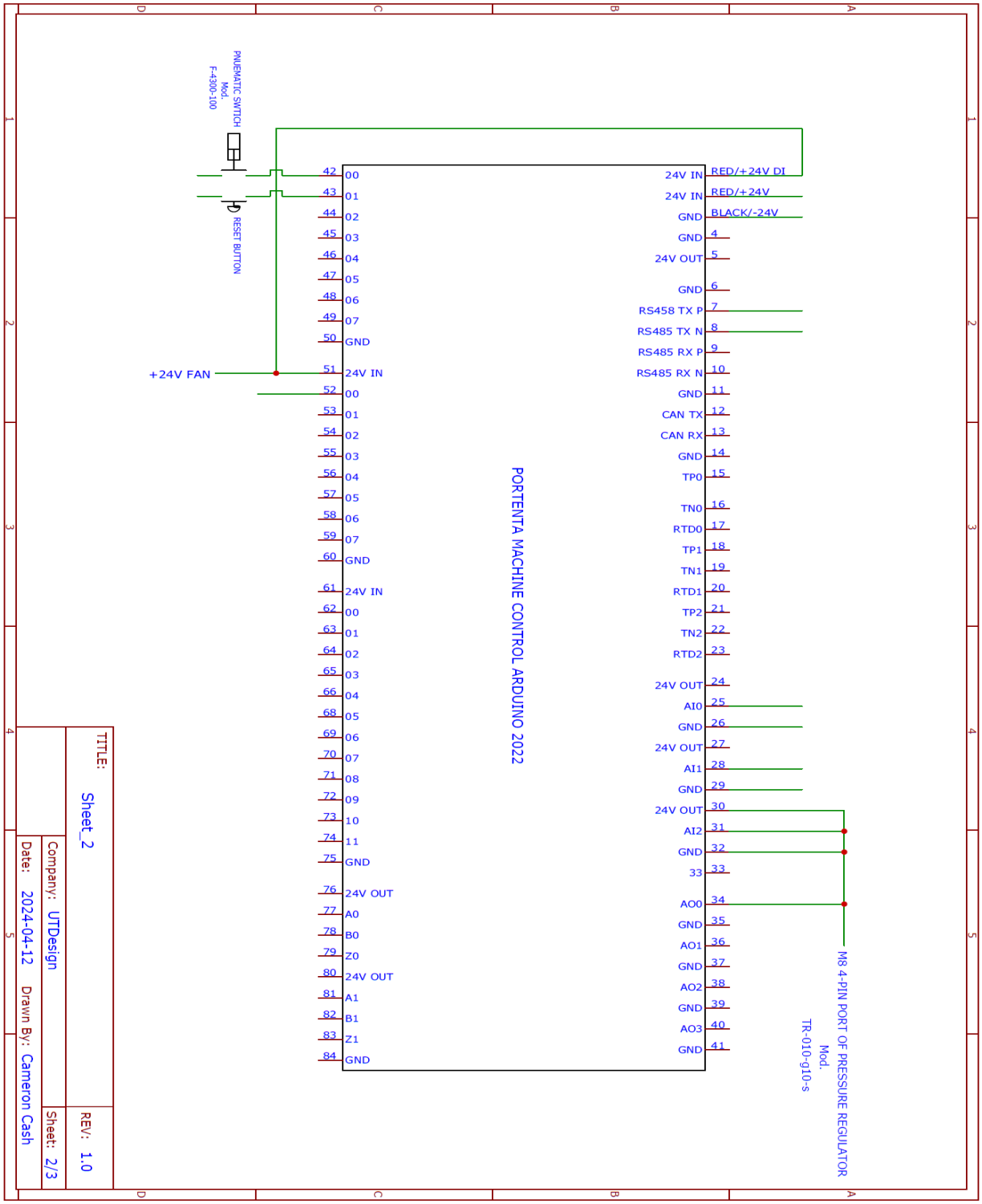
Appendix

9.1 Wire Diagrams

Electrical Cabinet



Portenta Machine Control:



Load Cell Amplifier: