

TORMACH® 1500MX®



Copyright

Notice

Information is subject to change without notice by Tormach, Inc. For the most recent version of this document, see tormach.com/support.

You're welcome to make copies of this document for evaluating, learning about, and/or using the machine.

You may not charge for any copies you make beyond the cost of printing.

Unless otherwise noted, companies, names, and various data used in examples are fictitious.

To the Reader

We're dedicated to continually improving our documentation and products, and welcome any clarifications, corrections, or suggestions.

Credits

Tormach®, 1500MX®, and PathPilot® are trademarks or registered trademarks of Tormach, Inc. Our milling machines and accessories are covered by one or more of the following U.S. Patents: 7,386,362; D606,568; D612,406; D621,859; and other patent(s) pending.

Other product or company names may be the trademarks of their respective owners.

Copyright © Tormach, Inc. 2026

IMPORTANT INFORMATION: PLEASE READ FIRST

INSPECT THE ITEMS DELIVERED

Before installing your machine, carefully inspect all delivered items. Complete the following steps upon receiving your shipment to ensure that everything is in proper condition and that any issues are promptly addressed.

1. Inspect the item(s):
 - Photograph any damage that may have occurred during shipping.
 - Note any damage on the delivery receipt before signing for the shipment. If there is extensive visible damage to the machine, refuse to accept the shipment.
 - Verify the received goods against the packing list. If there is any damage or shortages, you must contact Tormach within 30 days of receipt. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.
2. If there are any items that have not yet been delivered, we recommend waiting until you've received all shipments to begin installing the machine. Depending on the product and options ordered, the system may arrive in one or more shipments of:
 - Accessories (if applicable)
 - Machine



Note: The machine system and large accessories are sent by freight carrier. Smaller accessories may be sent by parcel service.

SAVE THESE INSTRUCTIONS!

This document contains important safety warnings and operating instructions for your machine. Before operating this machine in any way, you and all other operators must read and understand all instructions. If you don't, there's a risk of voided warranty, property damage, serious injury, or death. Keep these instructions with your machine so that they're readily accessible.

PURPOSE AND SCOPE OF THIS DOCUMENT

This document is intended to provide sufficient information to allow you to install, configure, and use your machine. It assumes that you have appropriate experience and/or access to training for any computer-aided design or manufacturing software for use with the machine.

GETTING HELP

We provide no-cost technical support through multiple channels. The quickest way to get the answers you need is normally in this order:

1. Read this document.
2. Read related documents and watch related videos at tormach.com/support.
3. If you still need answers, gather the following information so that we may help you as quickly as possible:
 - Your phone number, address, and company name (if applicable).
 - Machine model and serial number, which are located on the side of the electrical cabinet, next to the Main Disconnect switch.
 - The version of PathPilot that you're running.
 - Any accessories that you have for your machine.
 - A clear and concise description of the issue.
 - Any supporting media and information that you can share with us. For example, you could:
 - Analyze what might have changed since the machine last worked correctly.
 - Record a short video.
 - Take a picture of a part.
 - For software, share log data .zip files, screen captures, or program files.
For information, see "Share Log Data .zip Files" (on the next page).
 - From the PathPilot interface, on the Status tab, record any available information.
 - Use a digital multimeter for voltage readings.

4. Once you've gathered the information in Step 3, contact us in the following ways:
 - a. Create a support ticket: Go to tormach.com/how-to-submit-a-support-ticket
 - b. Phone: (608) 849-8381 (Monday through Friday, 8 a.m. to 5 p.m. U.S. Central Standard Time)

SHARE LOG DATA .ZIP FILES

The controller keeps log data on how the machine has been working, which you can export as a .zip file. This information helps us troubleshoot software situations much faster.

To share log data .zip files:

1. Put a USB drive into the PathPilot controller.
2. From the PathPilot controller, on the **Status** tab, select **Log Data**.
PathPilot creates a file called **logdata_[TODAY'S-DATE].zip**, and saves it on your USB drive.
3. Remove the USB drive from the controller. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

LIABILITY DISCLAIMER

We've made every effort to provide comprehensive and accurate information, but no warranty or fitness is claimed or implied. All information provided is on an as is basis. The authors, publisher, and Tormach, Inc. ("we", "us", and so on) shall not have any liability for, or responsibility to, any person or entity for any reason for any loss or damage arising from the information contained in this document.

This document provides guidance on safety precautions and techniques, but because the specifics of any one workshop or other local conditions can vary greatly, we accept no responsibility for machine performance or any damage or injury caused by its use. It's your responsibility to verify that you fully understand the implications of what you're doing and comply with any legislation and codes of practice applicable to your city, state, or nation.

IMPORTANT INFORMATION: PLEASE READ FIRST.....	3
SAFETY.....	21
1.1 Intended Use	22
1.2 Machine Standards	23
1.2.1 American National Safety Institute (ANSI).....	23
1.2.2 Occupational Safety and Health Administration (OSHA).....	23
1.3 Safety Overview.....	24
1.3.1 Safety Messages.....	24
<i>Personal Injury.....</i>	24
<i>Property Damage.....</i>	24
1.3.2 Safety Decals.....	24
<i>On the Electrical Cabinet Door.....</i>	24
<i>Next to the Main Disconnect.....</i>	25
<i>On the Spindle Nose.....</i>	26
1.3.3 Information Decals.....	26
<i>Serial Number Plate.....</i>	26
1.4 Machine Safety.....	27
1.4.1 General Shop Safety.....	27
1.4.2 Operational Safety.....	27
<i>General.....</i>	27
<i>Tooling.....</i>	28
<i>Workholding.....</i>	28
1.4.3 Electrical Safety.....	28
1.5 Noise Exposure.....	30
1.6 Operating Modes Reference.....	31
1.6.1 Run Mode (Mode 1).....	31
1.6.2 Setup Mode (Mode 2).....	31
1.6.3 Mode Constraints.....	32
1.6.4 Automatic Tool Changer (ATC) Constraints.....	32
ABOUT YOUR MACHINE.....	35
2.1 Machine Specifications.....	36
SITE REQUIREMENTS.....	39
3.1 General Site and Space Requirements.....	40
3.1.1 Site Requirements.....	40
3.1.2 Space Requirements.....	40
3.1.3 Operator Workstation Reference.....	40
3.2 Electrical and Power Requirements.....	41

TABLE OF CONTENTS

3.2.1 Electrical Requirements	41
3.2.2 Power Requirements	41
3.3 Air Requirements	42
3.4 Space Planning Drawings	43
3.4.1 Space Planning	44
3.4.2 Minimum Transport Height	46
3.4.3 Table Clearance	47
3.4.4 Table Details	48
3.5 Electrical Site Plan Drawings	49
3.5.1 Electrical Site Plan	50
INSTALLATION	51
4.1 Pre-Installation Checklist	52
4.2 Installation Tools and Items	53
4.3 Move the Pallet	54
4.4 Unpack the Machine Crate	55
4.5 Self-Assembled Installation	58
4.5.1 Install the Enclosure	58
<i>Before You Begin Assembly</i>	58
<i>Required Tools and Items</i>	59
<i>Unpack the Shipping Crate</i>	59
<i>Prepare the Enclosure Panels</i>	59
Assemble the Left Top Panel	59
Assemble the Right Top Panel	59
Assemble the Chip Tray Center Kick Plate	60
Assemble the Chip Trays	60
Prepare the Panels for Sealant	61
<i>Set up the Operator Console</i>	61
<i>Install the Chip Trays</i>	62
<i>Install the Enclosure Panels</i>	64
Secure Panel Screws	68
Clean Excess Sealant	68
<i>Assemble the Door</i>	68
Install the Door Latch	70
Install the Door Latch Push Button	70
<i>Connect the Enclosure Lights</i>	70
<i>Mount the Operator Console</i>	71
<i>Install the Chip Tray Center Kick Plate</i>	72
<i>Install the Windows</i>	73
4.5.2 Set Up the PathPilot Controller	73
<i>Specify the Date and Time</i>	73
<i>Specify the Keyboard Language</i>	73
<i>Update PathPilot</i>	73
4.5.3 Set Up the Automatic Oiler	74
<i>Specify the Interval Time</i>	74

Specify the Actuation Time.....	75
About the Automatic Oiler.....	75
About Actuation Time.....	75
4.6 Factory-Assembled Machine Setup.....	76
4.6.1 Set Up the PathPilot Controller.....	76
Specify the Date and Time.....	76
Specify the Keyboard Language.....	76
Update PathPilot.....	76
4.6.2 Set Up the Automatic Oiler.....	77
Specify the Interval Time.....	77
Specify the Actuation Time.....	77
About the Automatic Oiler.....	78
About Actuation Time.....	78
4.6.3 Set Up the Flood Coolant Tank.....	78
Required Tools.....	78
Unpack the Coolant Tank Crate.....	78
Install the Flood Coolant Pump.....	78
Install the Flood Coolant Filter.....	79
Make Coolant Connections.....	79
4.7 Verify the Installation.....	81
4.7.1 Power on the Machine.....	81
4.7.2 Verify Axes Function.....	82
4.7.3 Verify Spindle Function.....	82
4.7.4 Power off the Machine.....	83
4.8 Install Accessory Components.....	84
4.8.1 Install the Flood Coolant Kit.....	84
Required Tools.....	84
Unpack the Coolant Tank Crate.....	84
Install the Flood Coolant Pump.....	84
Install the Flood Coolant Filter.....	85
Install the Coolant Manifold.....	85
Install the Y-Axis Washdown Nozzle.....	86
Install the Flood Coolant Ring.....	88
Install the Manual Sprayer.....	89
Make Coolant Connections.....	92
4.8.2 Install the Automatic Chip Tray Washdown Kit.....	92
Before You Begin.....	92
Required Tools.....	93
Install the Washdown Pump.....	93
Install the Washdown Coolant Filter.....	93
Install the Coolant Hoses and Fittings.....	93
Install the Washdown Bars.....	94
Make Connections.....	95
4.8.3 Install the Through-Spindle Coolant (TSC) Kit.....	95
Before You Begin.....	95

TABLE OF CONTENTS

- Prerequisites 95
- Required Tools 95
- Unpack the Through-Spindle Coolant Kit 96
- Prepare the Machine for Installation 96
- Install the Coolant Pickup and Filter 96
- Install the Rotary Union 97
- Install the High-Pressure Hose 99
- Install the Hose Bracket 100
- Make Connections 100
- Securely Tighten Hose Clamps 101
- 4.8.4 Install the Chip Conveyor Kit 101
 - Before You Begin 101
 - Prerequisites 101
 - Required Tools 101
 - Unpack and Assemble the Chip Conveyor Kit 102
 - Prepare the Coolant Tank 102
 - Lift and Install the Chip Conveyor 103
 - Make Connections 104
 - Verify the Installation 105
- 4.8.5 Install the Oil Skimmer Kit 106
- 4.8.6 Install the Mist Collector Kit 108
 - Before You Begin 108
 - Prerequisites 108
 - Required Tools 108
 - Mechanical Installation 109
 - Top of Enclosure Installation (Recommended Location) 109
 - Floor Installation (Alternate Location) 110
 - Electrical Installation 111
- 4.8.7 Install the MQL Kit 111
 - Required Tools 111
 - Remove the Tubing from the Pump 111
 - Route the Tubing 112
 - Mount the Pump 113
- 4.8.8 Install the Automatic Tool Changer (ATC) 115
 - Required Tools 115
 - Unpack the ATC Box 115
 - Prepare the Machine 115
 - Assemble the ATC 117
 - Install the ATC Electrical Cabinet 118
 - Level and Align the ATC 122
 - Required Tools 122
 - Test Tool Changes 127
- 4.8.9 Install the microARC 6 127
 - Install the A-Axis Driver 127
 - Install the microARC 6 in the Machine 131

4.8.10 Install the Probe and Tool Setter.....	132
<i>Before You Begin</i>	132
Required Tools.....	132
Notes.....	132
<i>Wireless Receiver Installation</i>	132
<i>Tool Setter Installation and Setup</i>	134
Align the Tool Setter's Stylus.....	135
Reference the Tool Setter.....	135
Set G37 Position.....	136
<i>Wireless Probe Installation and Setup</i>	137
Adjust Probe Tip Concentricity.....	137
Set Probe Length and Diameter.....	138
Probe Status Lights Reference.....	139
SYSTEM BASICS.....	141
5.1 System Reference.....	142
5.1.1 Machine Table.....	142
5.1.2 Spindle.....	142
<i>About the Spindle</i>	142
5.1.3 Axes.....	142
5.2 Basic Controls Reference.....	143
5.2.1 Machine Controls.....	143
5.2.2 PathPilot Interface.....	143
PATHPILOT INTERFACE OVERVIEW.....	145
6.1 About PathPilot.....	146
6.2 Notebook Section.....	147
6.2.1 Main Tab.....	147
6.2.2 File Tab.....	147
6.2.3 Settings Tab.....	148
6.2.4 Offsets Tab.....	148
6.2.5 Conversational Tab.....	148
6.2.6 Probe/ETS Tab.....	148
6.2.7 Status Tab.....	149
6.3 Persistent Controls.....	150
6.3.1 Program Control Area.....	150
6.3.2 Position Status Area.....	150
6.3.3 Manual Control Area.....	151
6.4 Keyboard Shortcuts.....	152
6.5 Manage PathPilot Versions.....	153
6.5.1 Download and Install an Update File from the Controller.....	153
6.5.2 Install an Update File from a USB Drive.....	153
6.5.3 Install a Previous Version of an Update File.....	154
PATHPILOT TOOLS AND FEATURES.....	155

TABLE OF CONTENTS

- 7.1 Create and Load G-Code Files156
 - 7.1.1 Load G-Code156
 - Transfer Files to and From the Controller156
 - Preview G-Code Files156
 - Access Recent G-Code Files157
 - Close the Current Program157
 - 7.1.2 Edit G-Code157
 - Edit G-Code with a Text Editor157
 - Edit G-Code with Conversational Programming157
 - Change the Step Order158
 - Create a New Job Assignment158
 - Load an Existing G-Code File158
 - Edit a Job Assignment158
 - 7.1.3 Read G-Code158
 - Expand the G-Code Tab158
 - About the G-Code Tab158
 - Search in the Code159
 - Set a New Start Line159
 - Lead-In Moves160
 - Change the View of the Tool Path Display160
 - About the Tool Path Display161
 - 7.1.4 Use Conversational Programming161
 - About Conversational Programming161
 - Create a Face on a Part161
 - About Facing162
 - Facing in PathPilot162
 - Facing Reference163
 - Create a Profile on a Part163
 - About Profiling163
 - Profiling in PathPilot163
 - Profiling Reference164
 - Create a Pocket on a Part164
 - About Pockets165
 - Creating Pockets in PathPilot165
 - About Circular Pockets165
 - About Rectangular Pockets166
 - Create Hole Locations on a Part (Drill/Tap)166
 - About Drilling and Tapping167
 - Drilling and Tapping in PathPilot167
 - Create a Drilling Sequence167
 - Create a Tapping Sequence168
 - Drilling and Tapping Reference168
 - Create Threads on a Part169
 - About Thread Milling169
 - Thread Milling in PathPilot169

Thread Milling Reference.....	170
Create Text to Engrave on a Part.....	170
About Engraving.....	171
Import a DXF File.....	171
Working with Layers and Shapes.....	171
Change the Layer or Shape Cut Order.....	171
Adjust the Tree View Window.....	172
Working in the Preview Window.....	172
7.2 Machine Settings and Accessories.....	173
7.2.1 Enable an Internet Connection.....	173
Enable Automatic Updates.....	173
7.2.2 Change the Network Name.....	174
7.2.3 Select the Spindle Type.....	174
7.2.4 Change the Screen Orientation.....	174
About Portrait Screen Layout.....	174
7.2.5 Specify the Tool Change Method.....	175
About Automatic Tool Changes.....	176
About Manual Tool Changes.....	176
7.2.6 Limit G30 Moves.....	176
About G30.....	176
7.2.7 Enable the On-Screen Keyboard.....	176
About Soft Keyboards.....	176
7.2.8 Enable Tooltips.....	177
7.2.9 Enable the USB M-Code I/O Interface Kit.....	177
7.2.10 Enable Feeds and Speeds Suggestions in Conversational Routines.....	177
7.2.11 Specify Probing and Tool Measuring Options.....	177
7.2.12 Use a USB Camera.....	177
About USB Cameras.....	178
Manual Recording.....	178
Automatic E-Stop Loop Recording ("Dashcam").....	179
Review Video and Image Files.....	179
File Naming Convention.....	179
G-Code Commands.....	180
File Naming Conventions.....	180
Use M01 to Take Pictures.....	180
7.3 Set Up G-Code Programs.....	181
7.3.1 Use a Probe with PathPilot.....	181
Set Up the Probe.....	181
Use a Probe to Find a Feature's Location.....	181
Use a Probe to Set Work Offset Zeroes.....	181
Set the X and Y Work Offset Zero on the Corner of a Feature.....	181
Set the Work Offset Zeroes on a Feature.....	181
Use a Probe to Find the Center of a Feature.....	182
Find the Center of a Pocket.....	182
Find the Center of a Slot.....	182

TABLE OF CONTENTS

Find the Center of a Rectangular Boss.....	182
Find the Center of a Circular Boss.....	182
Find the Center Rotation of an A-Axis.....	183
7.3.2 Set Tool Length Offsets.....	183
<i>About Tool Offsets.....</i>	183
<i>Touch Off the Tool Length Offsets.....</i>	184
Set a Known Reference Height.....	184
Measure Tools Using a Known Reference Height.....	184
<i>Use an Electronic Tool Setter (ETS) to Measure Tools.....</i>	185
<i>Use a Tool Height Setter to Measure Tools.....</i>	185
Set a Known Reference Height.....	185
Verify the Calibration of the Tool Height Setter.....	186
7.3.3 Set Work Offsets.....	186
<i>About Work Offsets.....</i>	187
7.3.4 View Work Offsets.....	187
7.3.5 View Available G-Code Modes.....	187
7.4 Run G-Code Programs.....	188
7.4.1 Bring the Machine Out of Reset.....	188
<i>About Reset Mode.....</i>	188
7.4.2 View the Active Axis to Jog.....	188
7.4.3 Jog the Machine.....	188
<i>Jog in Continuous Velocity Mode.....</i>	189
<i>About Continuous Velocity Jogging.....</i>	189
<i>Jog in Step Mode.....</i>	189
<i>About Step Jogging.....</i>	189
7.4.4 View the Current Machine Position.....	189
7.4.5 Reference the Machine.....	190
<i>About Referencing.....</i>	190
7.4.6 Start a Program.....	190
<i>About Cycle Start.....</i>	190
<i>Cycle Start Reference.....</i>	190
7.4.7 Stop Machine Motion.....	191
7.4.8 Operate the Coolant Pump.....	191
<i>About Coolant.....</i>	191
7.4.9 View the Active G-Code Modes.....	191
7.4.10 View the Distance to Go.....	191
<i>About Distance to Go.....</i>	191
7.5 Control G-Code Programs.....	192
7.5.1 Use the Feed Hold Function.....	192
<i>About Feed Hold.....</i>	192
7.5.2 Use the Feed Rate Override Function.....	192
<i>About Feed Rate Override.....</i>	192
7.5.3 Use M01 Break Mode.....	193
<i>About M01 Break.....</i>	193
<i>Display Information and Capture Images During an M00 or M01 Break.....</i>	193

Display Information with Images.....	193
Display Information with Text.....	193
Capture Images with a USB Camera.....	193
7.5.4 Use the Maxvel Override Function.....	193
<i>About Maxvel Override.....</i>	194
7.5.5 Use Single Block Mode.....	194
<i>About Single Block.....</i>	194
7.5.6 Use the Spindle Override Function.....	194
<i>About Spindle Override.....</i>	194
7.5.7 Change the Feed Rate.....	195
<i>About Feed Rates.....</i>	195
7.5.8 Change the Spindle Speed.....	195
<i>About Spindle Controls.....</i>	195
7.5.9 Change the Tool Number.....	195
<i>About M6 G43.....</i>	195
7.5.10 Use a G30 Position.....	195
<i>About G30.....</i>	196
7.5.11 View the Tool Length.....	196
7.5.12 Manually Enter Commands.....	196
<i>About the MDI Line DRO Field.....</i>	196
<i>Admin Commands Reference.....</i>	196
7.5.13 Copy Recently Entered Commands.....	197
7.5.14 Use Feeds and Speeds Suggestions.....	197
<i>Refresh DRO Field Values.....</i>	198
<i>Use Additional Provided Information.....</i>	198
<i>Create Tool Descriptions.....</i>	199
Manually Enter Tool Descriptions.....	199
Automatically Generate Tool Descriptions.....	199
<i>Tool Keywords Reference.....</i>	200
7.5.15 Use Cycle Counters (M30 and M99).....	200
<i>Monitor Cycle Counters.....</i>	201
<i>Change Cycle Counter Values.....</i>	201
7.6 System File Management.....	202
7.6.1 Manage System Files.....	202
7.6.2 Create Backup Files.....	202
<i>About Backup Files.....</i>	203
7.6.3 Restore Backup Files.....	203
7.6.4 Import and Export the Tool Table.....	204
<i>Import a .csv File.....</i>	204
<i>Export the Tool Table as a .csv File.....</i>	204
BASIC OPERATIONS.....	205
8.1 Start the Machine.....	206
8.2 Reference the Machine.....	207
8.2.1 About Referencing.....	207

TABLE OF CONTENTS

8.3 Jog the Machine	208
8.3.1 About Jogging	208
<i>About Continuous Velocity Jogging</i>	208
<i>About Step Jogging</i>	208
8.3.2 Jog Controls Reference	209
<i>Jogging in PathPilot</i>	209
<i>Jogging with the Keyboard</i>	209
<i>Jogging with the Operator Console Pendant</i>	209
8.4 Manually Control the Spindle	210
8.4.1 About the Spindle	210
8.5 Load G-Code	211
8.6 Set Up Tooling	212
8.6.1 Install a Tool in a Set Screw Tool Holder	212
8.6.2 Install a Tool in an ER Collet Tool Holder	212
8.6.3 Install a Drill Chuck in a Jacobs Taper Arbor	212
8.7 Set Tool Length Offsets	213
8.7.1 About Tool Offsets	213
8.7.2 Touch Off the Tool Length Offsets	213
<i>Set a Known Reference Height</i>	213
<i>Measure Tools Using a Known Reference Height</i>	214
8.7.3 Use an Electronic Tool Setter (ETS) to Measure Tools	215
8.7.4 Use a Tool Height Setter to Measure Tools	215
<i>Set a Known Reference Height</i>	215
<i>Verify the Calibration of the Tool Height Setter</i>	216
8.8 Set Work Offsets	217
8.8.1 About Work Offsets	217
8.9 Operate the Coolant Pump	218
8.9.1 About Coolant	218
PROGRAMMING	219
9.1 Programming Overview	220
9.1.1 Before You Begin	220
9.1.2 About G-Code Programming Language	220
9.1.3 G-Code Formatting Reference	220
<i>Line Numbers</i>	221
<i>Words</i>	221
<i>Letters</i>	221
<i>Values</i>	221
<i>Order of Execution</i>	222
<i>Modal Groups</i>	223
<i>Comments</i>	224
9.1.4 Supported G-Codes Reference	224
9.2 Programming G-Code	226
9.2.1 About the Examples Used	226
9.2.2 Rapid Linear Motion (G00)	226

9.2.3 Linear Motion at Feed Rate (G01).....	226
9.2.4 Arc at Feed Rate (G02 and G03).....	227
<i>Radius Format Arc</i>	227
<i>Center Format Arc</i>	227
Arc in XY Plane.....	228
Arc in XZ Plane.....	228
Arc in YZ Plane.....	228
9.2.5 Dwell (G04).....	229
9.2.6 Set Offsets (G10).....	229
<i>Set Tool Table (G10 L1)</i>	229
<i>Set Coordinate System (G10 L2)</i>	229
<i>Set Tool Table (G10 L10)</i>	229
<i>Set Tool Table (G10 L11)</i>	230
<i>Set Coordinate System (G10 L20)</i>	230
9.2.7 Plane Selection (G17, G18, G19).....	230
9.2.8 Length Units (G20 and G21).....	230
9.2.9 Return to Predefined Position (G28 and G28.1).....	230
9.2.10 Return to Predefined Position (G30 and G30.1).....	231
9.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1).....	231
<i>Move to G37 Position Over ETS (G37.1)</i>	231
<i>Move and Measure Tool Length (G37)</i>	231
9.2.12 Straight Probe (G38.x).....	232
<i>Use the Straight Probe Command</i>	232
9.2.13 Cutter Compensation (G40, G41, G42).....	233
9.2.14 Dynamic Cutter Compensation (G41.1 and G42.1).....	233
9.2.15 Apply Tool Length Offset (G43).....	234
9.2.16 Engrave Sequential Serial Number (G47).....	234
9.2.17 Cancel Tool Length Compensation (G49).....	234
9.2.18 Absolute Coordinates (G53).....	234
9.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500).....	235
9.2.20 Set Exact Path Control Mode (G61).....	235
9.2.21 Set Blended Path Control Mode (G64).....	235
9.2.22 Distance Mode (G90 and G91).....	235
9.2.23 Arc Distance Mode (G90.1 and G91.1).....	235
9.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3).....	235
9.2.25 Feed Rate Mode (G93, G94, and G95).....	236
9.2.26 Spindle Control Mode (G96 and G97).....	236
9.3 Programming Canned Cycles	238
9.3.1 Canned Cycles Reference.....	238
<i>Supported Canned Cycles</i>	238
9.3.2 High Speed Peck Drill (G73).....	239
9.3.3 Cancel Canned Cycles (G80).....	239
9.3.4 Drilling Cycle (G81).....	239
9.3.5 Simple Drilling Cycle (G82).....	241
9.3.6 Peck Drilling Cycle (G83).....	241

TABLE OF CONTENTS

- 9.3.7 Tapping Cycle (G84).....241
- 9.3.8 Boring Cycle (G85).....241
- 9.3.9 Boring Cycle (G86).....242
- 9.3.10 Boring Cycle (G88).....242
- 9.3.11 Boring Cycle (G89).....242
- 9.4 Programming M-Code.....243**
 - 9.4.1 Supported M-Codes Reference.....243
 - 9.4.2 Program Stop and Program End (M00, M01, M02, and M30).....243
 - Display Information and Capture Images During an M00 or M01 Break.....244*
 - Display Information with Images.....244
 - Display Information with Text.....244
 - Capture Images with a USB Camera.....244
 - 9.4.3 Spindle Control (M03, M04, and M05).....244
 - 9.4.4 Tool Change (M06).....244
 - 9.4.5 Coolant Control (M07, M08, and M09).....245
 - 9.4.6 Override Control (M48 and M49).....245
 - 9.4.7 Feed Override Control (M50).....245
 - 9.4.8 Spindle Speed Override Control (M51).....245
 - 9.4.9 Set Current Tool Number (M61).....245
 - 9.4.10 Set Output State (M64 and M65).....245
 - 9.4.11 Wait on Input (M66).....246
 - 9.4.12 Chip Conveyor Control (M231 and M233).....246
 - 9.4.13 USB Camera Control (M301, M302, M303).....246
- 9.5 Programming Input Codes.....247**
 - 9.5.1 Feed Rate (F).....247
 - 9.5.2 Spindle Speed (S).....247
 - 9.5.3 Change Tool Number (T).....247
- 9.6 Advanced Programming.....248**
 - 9.6.1 Parameters.....248
 - Parameters Reference.....248*
 - Parameter Syntax.....248
 - Parameter Scope.....248
 - Behavior of Uninitialized Parameters.....248
 - Parameter Mode.....248
 - Persistence and Volatility.....248
 - Intended Use.....248
 - Numbered Parameters Reference.....249*
 - Read-Only Parameters.....249
 - Subroutine Parameters Reference.....249*
 - Named Parameters Reference.....249*
 - 9.6.2 Expressions.....250
 - Binary Operators Reference.....250*
 - Functions Reference.....250*
 - 9.6.3 Subroutines.....251
 - Subroutines Reference.....251*

<i>Conditional Subroutines Reference</i>	252
if/endif.....	252
if/elseif/else/endif.....	252
<i>Repeating Subroutines Reference</i>	252
<i>Looping Subroutines Reference</i>	252
do/while.....	253
while/endwhile.....	253
MACHINE MAINTENANCE	255
10.1 Maintenance Safety	256
10.1.1 All Maintenance Procedures.....	256
10.1.2 Swarf Maintenance Procedures.....	256
10.1.3 Coolant Maintenance Procedures.....	256
10.2 Maintenance Schedules	257
10.2.1 Daily.....	257
10.2.2 Weekly.....	257
10.2.3 Monthly.....	257
10.2.4 Semi-Annually.....	257
10.2.5 Annually.....	257
10.3 Regular Maintenance	258
10.3.1 Clean the Way Covers.....	258
10.3.2 Clean the Coolant System.....	258
<i>About Cutting Fluid</i>	258
<i>Cutting Fluid Reference</i>	258
10.3.3 Examine the Enclosure Windows.....	259
10.3.4 Lubricate the Machine.....	259
<i>About the Automatic Oiler</i>	259
About Actuation Time.....	259
<i>Lubrication System Reference</i>	260
10.3.5 Examine the Spindle Belt.....	260
10.3.6 Prevent Rust.....	260
<i>Remove Rust</i>	260
10.4 Accessories Maintenance	261
10.4.1 Chip Conveyor Maintenance Schedule.....	261
<i>Daily</i>	261
<i>Monthly</i>	261
<i>Semi-Annually</i>	261
TROUBLESHOOTING	263
11.1 Troubleshooting Safety	264
11.2 Getting Help	265
11.3 Required Tools	266
11.4 Frequently Found Problems	267
11.5 Electrical Service	268
11.5.1 LED Identification.....	268

TABLE OF CONTENTS

11.5.2 Overview.....	269
11.6 Power Distribution Subsystem.....	271
11.6.1 The Machine Won't Power On.....	271
11.6.2 The PathPilot Operator Console Won't Power On.....	271
11.7 Control Power Subsystem.....	273
11.7.1 The Machine Won't Power On.....	273
11.8 Servo Drive Subsystem.....	274
11.8.1 All Axes Won't Move When Commanded.....	274
11.8.2 One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move.....	275
11.8.3 Axis Movement is Noisy.....	276
11.8.4 Lost Motion on Axis Travel.....	277
11.9 Spindle Drive Subsystem.....	279
11.9.1 The Spindle Won't Turn.....	279
11.9.2 Machining Operations are Loud ("Chatter").....	281
11.9.3 Can't Load or Unload a Tool, or the Spindle's Drawbar Drags Against the Power Drawbar Cylinder's Piston.....	283
11.9.4 Spindle Rotates on Contact, or Spindle Isn't Rigidly Clamped.....	283
11.9.5 Spindle Doesn't Orient Correctly or Consistently.....	283
11.10 Servo IO Breakout Board Subsystem.....	284
11.10.1 Groups of Inputs and Outputs Aren't Functioning.....	284
<i>Servo Drive Inputs and Outputs.....</i>	<i>284</i>

DIAGRAMS AND PARTS LISTS.....	285
--------------------------------------	------------

12.1 Mill Diagrams and Parts Lists.....	286
12.1.1 Assembly Overview.....	287
12.1.2 BT30 Power Drawbar Cylinder.....	291
12.1.3 Electrical Cabinet.....	293
12.1.4 Enclosure.....	298
12.1.5 Flood Coolant Kit Assembly.....	303
<i>Coolant Tank Assembly.....</i>	<i>305</i>
<i>Flood Coolant Filter Assembly.....</i>	<i>307</i>
<i>Y-Axis Washdown Nozzle.....</i>	<i>309</i>
<i>Flood Coolant Manifold Assembly.....</i>	<i>311</i>
<i>Washdown Gun Kit.....</i>	<i>313</i>
12.1.6 Linear Actuator Assembly.....	315
12.1.7 Lubrication Assembly.....	317
12.1.8 Pneumatics Assembly.....	319
12.1.9 Spindle Head.....	321
12.1.10 Spindle Head Camera Assembly.....	323
12.1.11 Spindle Head Sheet Metal Cover Assembly.....	325
12.1.12 X-Axis Assembly.....	327
12.1.13 X-Axis Lubrication Assembly.....	329
12.1.14 X-Axis Sheet Metal Cover Assembly.....	331
12.1.15 Y-Axis Lubrication Assembly.....	333
12.1.16 Y-Axis Front Way Cover Assembly.....	335
12.1.17 Y-Axis Rear Way Cover Assembly.....	337

12.1.18 Z-Axis Lubrication Assembly	339
12.1.19 Z-Axis Way Cover Assembly	341
12.2 Accessory Diagrams and Parts Lists	343
12.2.1 Automatic Tool Changer	344
12.2.2 microARC 6	347
12.2.3 Mist Collector	350
12.2.4 MQL Solenoid Assembly, 24 Vdc	353
12.2.5 Oil Skimmer Kit	355
12.2.6 Washdown Kit Assembly	357
ELECTRICAL SCHEMATICS	359
13.1 Mill Schematics	360
13.1.1 230 Vac Power (Page 2)	361
13.1.2 24 Vdc Controls (Page 3)	362
13.1.3 Safety Systems (Page 4)	363
13.1.4 Spindle Drive (Page 5)	364
13.1.5 X-, Y-, and Z-Axis Drives (Page 6)	365
13.1.6 A- and B-Axis Drives (Page 7)	366
13.1.7 EtherCAT IO Board (Page 8)	367
13.1.8 Accessory / Auxiliary (Page 9)	368
13.1.9 Grounds (Page 10)	369
13.1.10 -X1 AC Terminal Strip (Pages 11-13)	370
13.1.11 -X2 Control Terminal Strip (Page 14)	373
13.1.12 -X3 Grounds Terminal Strip (Page 15)	374
13.1.13 Bill of Materials (Pages 16-17)	375
13.2 Accessory Schematics	377
13.2.1 Automatic Tool Changer (ATC) Electrical Schematic	378
<i>Bill of Materials</i>	379
13.2.2 Through-Spindle Coolant Electrical Schematic	380
13.2.3 Chip Conveyor Electrical Schematic	383



SAFETY

IN THIS SECTION, YOU'LL LEARN:

- About the standards and safety precautions associated with this machine.



Before operating the machine in any way, you must read and understand this section.

Safe operation of the machine depends on its proper use and the precautions you take. Only trained personnel — with a clear and thorough understanding of its operation and safety requirements — shall operate this machine.

CONTENTS

1.1 Intended Use	22
1.2 Machine Standards	23
1.3 Safety Overview	24
1.4 Machine Safety	27
1.5 Noise Exposure	30
1.6 Operating Modes Reference	31

1: SAFETY

1.1 Intended Use

1.1 INTENDED USE

This machine is intended for general-purpose, computer numerical control (CNC) machining in the following applications:

- Educational environments
- Hobby applications
- Light production
- Prototyping
- Research and development
- Secondary operations

The intended use includes:

- Appropriate workholding, toolholding, tooling, coolant systems, and machining parameters.
- Machining of conventional, non-abrasive materials such as ferrous and non-ferrous metals below 60 HRC, woods, and plastics.

The intended use **does not** include machining materials that:

- Are abrasive, carcinogenic, explosive, flammable, radioactive, or toxic
- Produce aerosols or fine particulates when machined

The intended use **does not** include the following materials (not a full list):

- Beryllium and its alloys
- Ceramics
- Fiberglass
- G10 fiberglass laminate
- Graphite
- Magnesium and its alloys

To safely operate products, you must obey all safety precautions and warnings that are on the machines and in the documentation.

1.2 MACHINE STANDARDS

When installed and operated as intended (see "Intended Use" (on the previous page)), this machine complies with the following standards. You must follow the requirements listed in the standards so that the machine remains compliant.

1.2.1 American National Safety Institute (ANSI)

- **ANSI B11.TR3-2000** *Risk Assessment and Risk Reduction — A Guideline to Estimate, Evaluate, and Reduce Risks Associated with Machine Tools*
- **ANSI B11.8-2001** *Safety Requirements for Manual Milling, Drilling, and Boring Machines with or without Automatic Control*
- **ANSI B11.19-2010** *Performance Requirements for Safeguarding*
- **ANSI B11.23-2002** *Safety Requirements for Machining Centers and Automatic Numerically Controlled Milling, Drilling, and Boring Machines*

1.2.2 Occupational Safety and Health Administration (OSHA)

- **OSHA 1910.212** *General Requirements for All Machines*
- **OSHA 3067** *Concepts and Techniques of Machine Safeguarding*

1: SAFETY

1.3 Safety Overview

1.3 SAFETY OVERVIEW

Any machine tool is potentially dangerous. A CNC machine's automation presents added risk not present in a manual machine.

Before operating the machine in any way, you must read and understand this section.

- Read and understand all safety messages used in this document.
- Locate and understand all safety decals on the machine.
- Locate and become familiar with all information decals on the machine.

1.3.1 Safety Messages

The following examples show the standard safety message types used to draw your attention to important information. The standards distinguish between personal injury safety messages and property damage warning messages.

Personal Injury

Personal injury safety messages have safety alert symbols and the following hazard level labels:

⚠ DANGER! Indicates a hazard with a high level of risk which, if not avoided, will result in death or serious injury.

⚠ WARNING! Indicates a hazard with a medium level of risk which, if not avoided, can result in death or serious injury.

⚠ CAUTION! Indicates a hazard with a low level of risk which, if not avoided, can result in minor or moderate injury.

Property Damage

NOTICE! Indicates a hazard which, if not avoided, can cause property damage.

1.3.2 Safety Decals

Before operating the machine in any way, you must read and understand all installed safety decals on the machine and equipment. Do not remove any safety decals. If any safety decals become worn or damaged, contact Tormach Technical Support for guidance on receiving replacement decals.

The following types of safety symbols are on the decals:

- **Warning** ⚠ This symbol indicates a hazard which, if not avoided, can result in personal injury or property damage.
- **Prohibition** ⛔ This symbol indicates an action that shall not be taken or that shall be stopped.
- **Mandatory Action** ⬢ This symbol indicates an action that you must take to avoid a hazard.

On the Electrical Cabinet Door

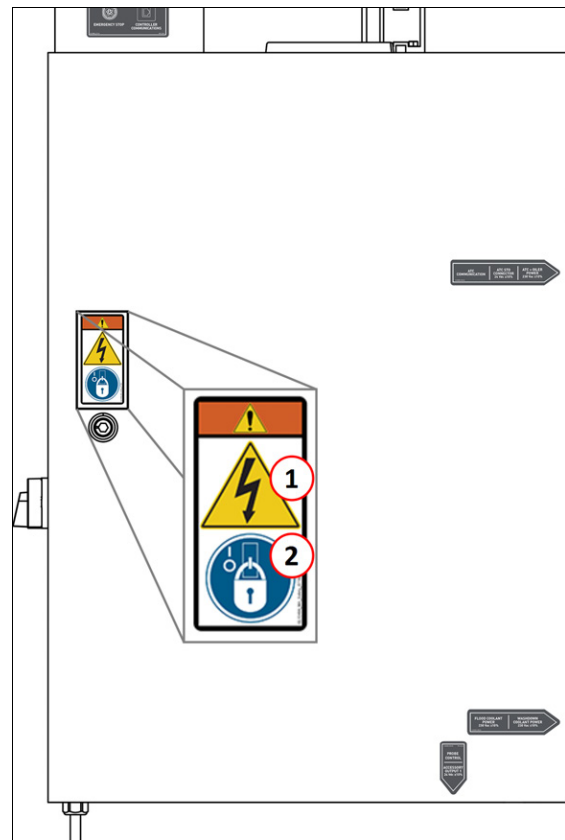


Figure 1-1: Example of a safety decal on the electrical cabinet door.

1. **WARNING! Electrocution Hazard.** Points in the electrical cabinet contain high voltages, which can electrocute or shock you, causing death or serious injury. Even after the machine is powered off, electronic devices in the

electrical cabinet can retain dangerous electrical voltages. Use caution when servicing the machine inside the electrical cabinet.

2. **Lockout/Tagout.** Before servicing the machine, you must power off the machine and use an approved lockout/tagout device to secure the Main Disconnect switch in the **OFF** position. Points in the electrical cabinet contain high voltages, which can electrocute or shock you, causing death or serious injury.

Next to the Main Disconnect

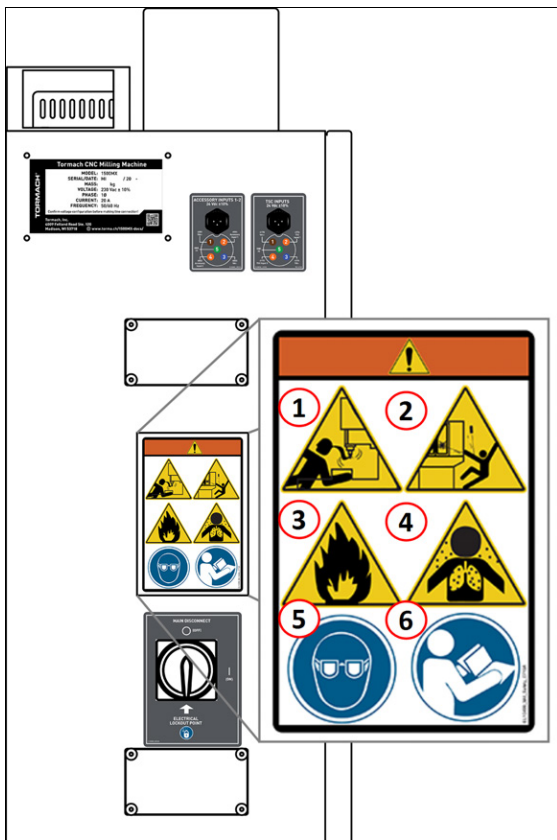


Figure 1-2: Example of a safety decal next to the Main Disconnect.

1. **WARNING! Entanglement / Entrapment Hazard.** The machine operates under automatic control — it can start at any time and crush, cut, entangle, or pinch body parts. Always keep clear of positions on the machine where unexpected or unintended machine motion could cause harm. Before operating this machine in any way, you must verify that all operators know the location of the machine's Emergency Stop button.
2. **WARNING! Ejection Hazard.** Fixtures, tooling, workpieces, or other loose items can become dangerous

projectiles and can cause death or serious injury. Before operating this machine in any way, you must verify that you have appropriately secured all components.

3. **WARNING! Fire Hazard.** The machine and its enclosure are not designed to contain fire or explosions. Only use materials and coolants that are intended for the specific machining operation. Never use flammable or explosive items. Before operating the machine in any way, you must read all Safety Data Sheets (SDSs) for any workpiece materials, coatings, coolants, lubricants, and other consumables used.
4. **WARNING! Inhalation Hazard.** The machine and its enclosure do not protect you from airborne particulates. Chips, dust, and vapors from certain materials can be toxic or otherwise harmful. Before operating the machine in any way, you must read all Safety Data Sheets (SDSs) for any workpiece materials, coatings, coolants, lubricants, and other consumables used.
5. **Personal Protective Equipment: Eyes.** Prevent injury by always wearing protective safety eyewear. Before operating this machine in any way, you must verify that your eyewear is impact-resistant and rated for ANSI Z87+.
6. **Operator Knowledge.** Before operating this machine in any way, you and all other operators must read and understand all instructions. If you don't, there's a risk of voided warranty, property damage, serious injury, or death.

1: SAFETY

1.3 Safety Overview

On the Spindle Nose

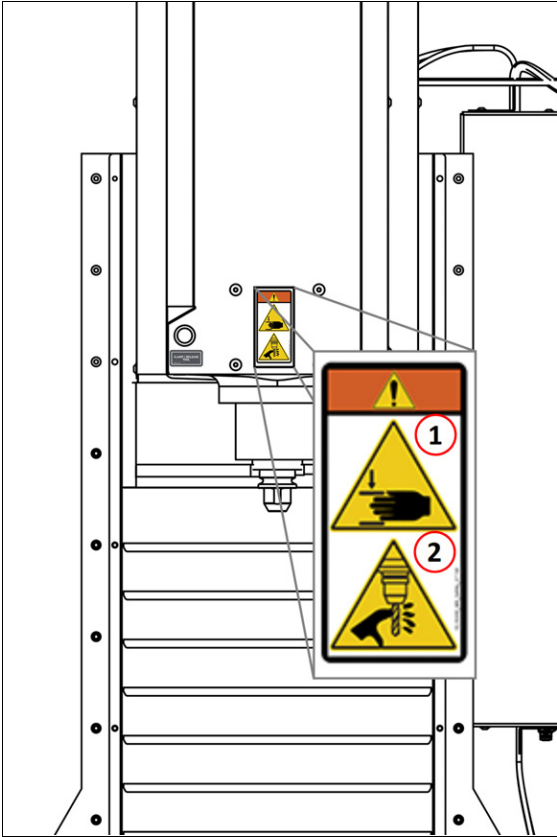


Figure 1-3: Example of a safety decal on the spindle nose.

1. **WARNING! Crush Hazard.** Moving parts can entangle, pinch, or cut you, causing death or serious injury. Before operating this machine in any way, you must verify that all body parts, long hair, and clothes are clear of the machine's extent of motion.
2. **WARNING! Cut Hazard.** Tools and swarf can cut you. Only hold tools by the tool holder. Before inserting or removing tools from the machine, you must verify that all motion is completely stopped.

1.3.3 Information Decals

Before operating the machine in any way, you must locate and become familiar with all installed information decals on the machine and equipment.

Serial Number Plate

The serial number plate is on the side of the electrical cabinet, near the Main Disconnect switch.

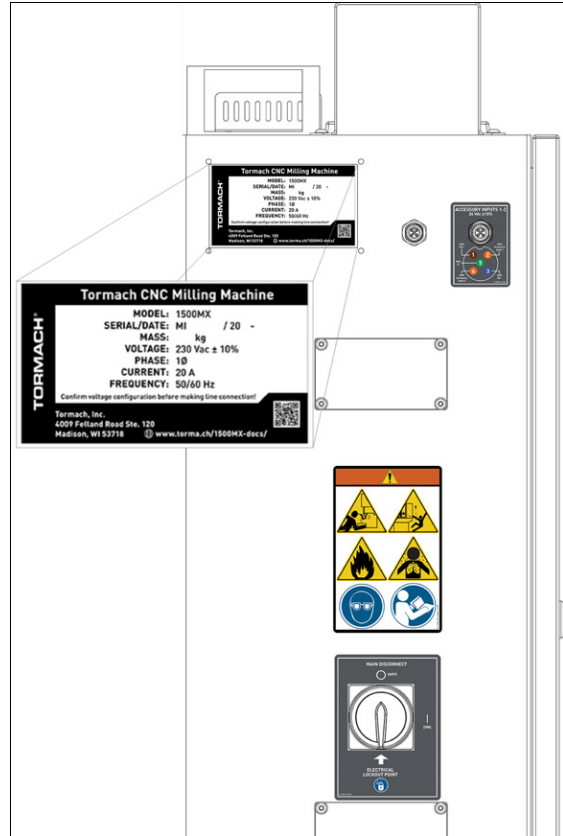


Figure 1-4: Example of the serial number plate on the side of the electrical cabinet.

1.4 MACHINE SAFETY



Before operating the machine in any way, you must read and understand this section.

Safe operation of the machine depends on its proper use and the precautions you take. Only trained personnel — with a clear and thorough understanding of its operation and safety requirements — shall operate this machine.

1.4.1 General Shop Safety	27
1.4.2 Operational Safety	27
1.4.3 Electrical Safety	28

1.4.1 General Shop Safety

- ✓ Verify that only qualified machinery maintenance professionals install, set up, or perform maintenance on this machine.
- ✓ Keep the work area well-lit. Use additional lighting if needed. The work area should be illuminated to a minimum of 500 lx.
- ✓ Keep the work area temperature- and humidity-controlled.
- ✓ Remove loose-fitting clothing, neckties, gloves, and jewelry.
- ✓ Tie up long hair and secure it under a hat.
- ✓ Wear safety eye protection rated for ANSI Z87+.
- ✓ Wear closed-toed safety shoes.
- ✓ Wear ear protection when you expect the machine or the machining processes to exceed safe exposure limits. For information, see "Noise Exposure" (page 30).
- ✓ Keep the work area clean and free of clutter. Machine motion can occur if controls are accidentally activated.
- ✓ Immediately clean up spills after they occur.
- ✗ Never operate the machine after consuming alcohol or taking medication that could prevent you from safely operating the machine.
- ✗ Never operate the machine while tired or otherwise impaired.
- ✗ Never operate the machine in an explosive (ATEX) atmosphere. Such explosive atmospheres include explosive gases, vapors, mists, powders, and dusts.

1.4.2 Operational Safety

General

- ✓ Understand that the machine is automatically controlled and can start at any time.
- ✓ If anyone enters the machining envelope during operation, immediately push in the Emergency Stop button. In case of a power loss, turn the Door Switch Override to the Unlocked position and open the enclosure doors.
- ✓ Become familiar with all physical and software controls.
- ✓ Always use a chip scraper or brush when clearing away chips, oil, or coolant.
- ✓ Examine all tools, fixtures, workpieces, and guarding for signs of damage. Replace any damaged components as soon as you find them.
The enclosure and other guards may not stop all types of projectiles, like broken tools or loose workpieces.
- ✓ Stop the machine and verify that all machine motion has completely stopped before doing any of the following:
 - ✓ Adjusting a part, fixture, or coolant nozzle.
 - ✓ Changing belt or pulley positions.
 - ✓ Changing tools or parts.
 - ✓ Clearing away chips, oil, or coolant.
 - ✓ Reaching into any part of the machine's motion envelope.
 - ✓ Removing protective shields or safeguards.
 - ✓ Taking measurements.
 - ✓ Doing any other action inside the machine enclosure.
- ✓ Use flood or MQL (mist) coolant as required by the machining operation.
- ✓ Only use coolants designed for metal working applications such as soluble oils, semi-synthetic, or synthetic coolants.
- ✓ Read the Safety Data Sheet (SDS) for all workpiece materials, coatings, coolants (flood or MQL), lubricants, and other consumables. Chips, dust, and vapors from certain materials can be toxic or otherwise harmful.
- ✓ Understand that this product can expose you to chemicals which are known to the State of California to cause cancer and birth defects or other reproductive harm. For more information, go to www.P65Warnings.ca.gov.

1: SAFETY

1.4 Machine Safety

- ✓ Dispose of scrap and swarf according to local regulations and guidelines.
- ✓ Thoroughly read all safety precautions and instructions.
- ✓ When machining an unproven program, use feed, speed, and maximum velocity overrides, Distance-to-Go (DTG) displays, single block, feed hold, and other control features.
- ✓ Follow all appropriate "Machine Standards" (page 23).
- ✗ Never enter the machining envelope.
- ✗ Never reach around a guard.
- ✗ Never allow the machine to run unattended.
- ✗ Never obstruct the Emergency Stop button or any other controls.
- ✗ Never allow untrained operators to install, operate, or maintain the machine.
- ✗ Never modify, defeat, or bypass safety devices or interlocks.
- ✗ Never machine abrasive, carcinogenic, explosive, flammable, radioactive, or toxic materials. Such materials include, but are not limited to:
 - ✗ Beryllium and its alloys
 - ✗ Ceramic
 - ✗ Fiberglass
 - ✗ G10 fiberglass laminate
 - ✗ Graphite
 - ✗ Lead and its alloys
 - ✗ Magnesium and its alloys
- ✗ Never allow swarf to accumulate on or within the machine.
- ✗ Never use flammable liquids (like alcohol, diesel fuel, or kerosene) in the machine's coolant system.
- ✗ Never use water, coolants without rust inhibitors, or straight cutting oil in the machine's coolant system.

Tooling

- ✓ Use appropriate speeds, feeds, and cutting parameters for your machine, machine operation, material, and tooling.
- ✓ Use tools and tool holders that are suitable for the current operation.
- ✓ Examine tools for signs of damage. Replace any damaged tools as soon as you find them.

- ✓ The enclosure and other guards may not stop all types of projectiles, like broken tooling.
- ✗ Never use unbalanced tooling or spindle fixtures.
- ✗ Never use tools that are larger or longer than necessary.
- ✗ Never use tools at speeds above their operational limits.

Workholding

- ✓ Secure workpieces with appropriate workholding devices (like a milling vise or strap clamps).
- ✓ Verify that the workpiece is adequately secured.
- ✓ Position clamps and workholding devices clear of any tool paths.
- ✓ Remove cutoff workpieces and other large chips before starting the machine.
- ✗ Never leave tools, stock, or other loose items inside the machine.

1.4.3 Electrical Safety



WARNING! Electrical Shock Hazard: You must power off the machine before making any electrical connections. If you don't, there's a risk of electrocution or shock.

- ✓ Power off the machine before servicing.
- ✓ Use an approved lockout/tagout system to secure the machine's Main Disconnect in the **OFF** position before servicing the machine.
- ✓ Understand that certain electrical components can retain dangerous electrical voltages, even after the machine is powered off and all power is removed from the system.
- ✓ Understand that certain installation, maintenance, and troubleshooting procedures — for the machine and certain accessories — require access to or modification of wiring inside of the electrical cabinet. Only qualified electrical machinery technicians shall perform these procedures.
- ✓ Confirm that the mains voltage conforms to requirements before connecting the machine.
For more information, see "Electrical and Power Requirements" (page 41).
- ✓ Confirm that the machine installation meets all codes and regulations of your locality.

- ✓ Confirm that electrical connections are performed by a certified electrician.
- ✓ Lock the electrical cabinet door and remove the keys when the machine is not being serviced to prevent unqualified or unauthorized personnel from accessing the electrical cabinet.
- ✗ Never operate the machine with the electrical cabinet door open.
- ✗ Never reach into the electrical cabinet with the machine powered on.
- ✗ Never modify the machine's electronics.
- ✗ Never drill into the electrical cabinet.

1: SAFETY

1.5 Noise Exposure

1.5 NOISE EXPOSURE



CAUTION! Noise Exposure Hazard: If you expect the machine or the machining processes to exceed safe exposure limits, you must wear ear protection.

With the axes moving and the spindle rotating (but not cutting), the emission sound pressure level at the operator control station is 70 dB(A).

Emission sound pressure levels vary depending on the machining processes. Factors that influence the actual level of noise exposure may include:

- Characteristics of the work room
- Other sources of noise (like the number of machines, or other adjacent processes)

The permissible noise exposure level may vary between countries. You must evaluate of the hazard and risk based on your locality, and mitigate as necessary.

1.6 OPERATING MODES REFERENCE

This machine has two modes: run mode and setup mode. In both modes, you must close and lock the enclosure doors before starting a program. In setup mode, experienced operators can perform maintenance or set up jobs while the enclosure doors are open. To access setup mode, you must have a key.

For unrestricted machine motion to occur, you must do the following in the order listed:

1. Close the enclosure doors.
2. Command the machine to move or start a program. The enclosure doors automatically lock before any machine motion occurs.

1.6.1 Run Mode (Mode 1)

When the enclosure doors are open, and the machine is in run mode, no motion can occur. For example, you can't jog the axis or control the spindle.

1.6.2 Setup Mode (Mode 2)

It's the machine owner's responsibility to verify that only personnel who are trained in operation, maintenance, or both shall access setup mode. Setup mode is intended only for qualified machinery operators and maintenance professionals, and only to set up a program or do maintenance procedures. When you're not using setup mode, you must verify that the machine is in run mode.

- **Mode Identification** To identify which mode the machine is in, read the **Status** read-only field.



Figure 1-5: PathPilot indicates the controller's current mode.

- **Key Use** To access setup mode, you must have a key. Use the key on the top of the operator console to switch between modes: turn the key to **0** for run mode, and **I** for

setup mode.

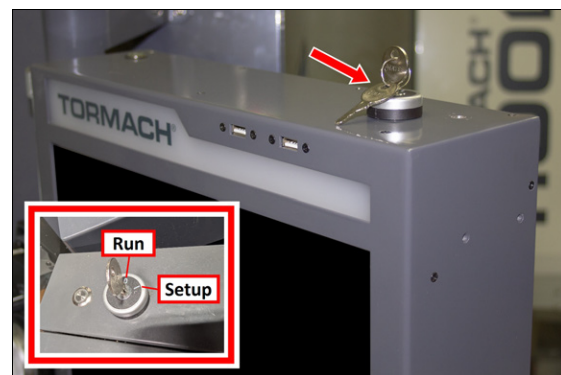


Figure 1-6: Setup mode key in the operator console.

Note: While in setup mode, you can't remove the key. Turn the key to run mode to remove the key from the operator console.

- **Hold-to-Run Device Use** For machine motion to occur in setup mode, you must use a hold-to-run device. Hold-to-run devices include:
 - The button on the side of the operator console's pendant.

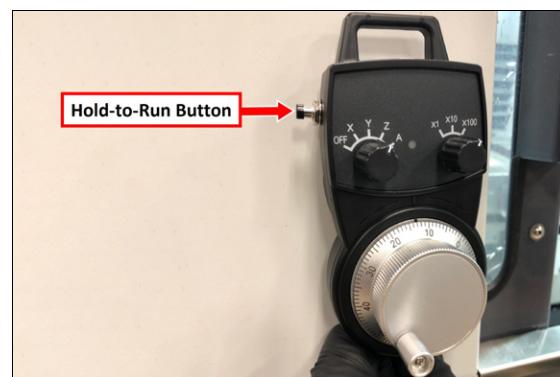


Figure 1-7: Hold-to-run button on the pendant.

1.6 Operating Modes Reference

- The jog shuttle wheel (the outer portion), which springs back to neutral when you release it.

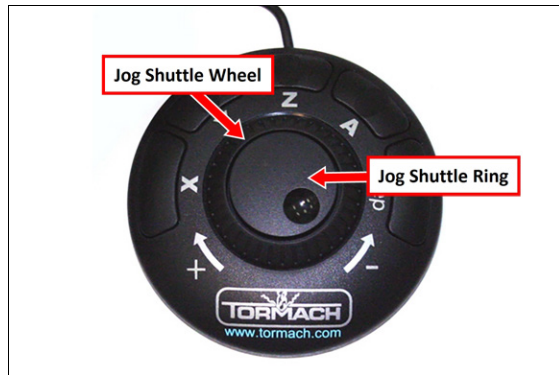


Figure 1-8: Jog shuttle components.

- **Machine Motion Restrictions** When the enclosure doors are open, and the machine is in setup mode, machine motion is restricted:
 - **Maximum Feed Rate** 2 m/min, on a maximum of one axis, with a hold-to-run device.
- 

Note: To jog an axis with the keyboard, also use a hold-to-run device.
- **Maximum Spindle Speed** 700 rpm with a hold-to-run device.



Note: To jog an axis with the keyboard, also use a hold-to-run device.

1.6.3 Mode Constraints

Both operating modes restrict some machine activities while the enclosure doors are open. To understand how to use the machine with the enclosure doors open, read the following table.



Note: This table assumes that the enclosure door is open and stays open during each activity.

To ... with the Enclosure Doors Open	In Run Mode	In Setup Mode
Move the (optional) Automatic Tool Changer (ATC) tray in or out		
Release a tool from the spindle		
Start a program		

To ... with the Enclosure Doors Open	In Run Mode	In Setup Mode
Use an ATC air blast		
Use coolant		
Use a hold-to-run device to move one axis		
Use a hold-to-run device to move more than one axis		
Use a hold-to-run device to rotate the spindle less than 700 rpm		
Use a hold-to-run device to rotate the spindle more than 700 rpm		

Key to the symbols used in the above table:

Symbol	Meaning of Symbol
	Allowed
	Not allowed

1.6.4 Automatic Tool Changer (ATC) Constraints

While the enclosure doors are open, the ATC tray won't rotate, move toward the spindle, or back to its retracted position.

To load tools into the tray, do one of the following:

- **Load One Tool**
 1. Open the enclosure doors and put a tool in the spindle. Then, close the enclosure doors.
 2. From the PathPilot interface, in the **Tool** DRO field, type the number of the tool that you put in the spindle in Step 1.
 3. Select **M6 G43**.
 4. On the **ATC** tab, select **Store Current Tool**.
 5. Repeat Steps 1 through 4 for each tool that you want to load.

- **Load an Entire Tool Tray**

1. Remove the tool from the spindle.
2. Close the enclosure doors.
3. From the PathPilot interface, on the **ATC** tab, select **Go To Tray Load Position**.
The ATC tray moves under the spindle, and the ATC door opens to the tool fork.
4. Open the enclosure doors.
5. Put the tool into the tool fork.
6. On the **ATC** tab, in the **Tool Number** DRO field, type the number of the tool that you put into the tool fork in Step 5.
7. Select **Insert**.
8. Select **Tray Fwd** or **Tray Rev** to rotate the tray to the next open tool fork.
9. Repeat Steps 5 through 8 for each tool that you want to load.
10. Close the enclosure doors.
11. On the **ATC** tab, select **Retract**.
The ATC tray moves away from the spindle.



ABOUT YOUR MACHINE

IN THIS SECTION, YOU'LL LEARN:

- About this machine's specifications.

CONTENTS

2.1 Machine Specifications.....	36
---------------------------------	----

2: ABOUT YOUR MACHINE

2.1 Machine Specifications

2.1 MACHINE SPECIFICATIONS

Travels	
X-Axis	19.7" (500 mm)
Y-Axis	13.8" (350 mm)
Z-Axis	14" (356 mm)
Spindle-to-Table Maximum Clearance	17.7" (450 mm)
Spindle-to-Table Minimum Clearance	3.7" (96 mm)
Spindle Centerline to Machine Column	14.7" (370 mm)
Spindle	
Spindle Power (Continuous)	4 hp (3 kW)
Spindle Power (4-Minute Overload)	6 hp (4.5 kW)
Spindle Maximum Speed	10,000 rpm
Transmission	5M Toothed Belt
Spindle Taper	BT30
Thread Machining	Rigid Tapping, Tension/Compression, Thread Mill
Maximum Feed Rate	
X- and Y-Axis	1200 IPM (30.5 m/min)
Z-Axis	600 IPM (15.2 m/min)
Axis Motor	Servo Driven
Power and Air	
Primary Power Required*	Single-Phase 230 Vac, 50/60 Hz
Recommended Circuit Amperage*	30 A breaker
Plug Type	NEMA L6-30P
Air Required	90-120 psi
Table	
Table Size	35" × 12.75" (890 mm × 325 mm)
T-Slot Size	5/8" (15.9 mm) (three slots)
T-Slot Spacing	3.9" (100 mm)
Maximum Weight on Table	300 lb (136 kg)
Overall Dimensions	
Machine Size [†]	86" × 104" (2.2 m × 2.6 m)
Overall System Height [†]	94" (2.4 m)

Typical System Weight†	2800 lb (1270 kg)
* Additional outlets may be required for optional accessories. † Installed size and weight depend on machine options and accessories. You may need additional space for service or maintenance access. Refer to "Site Requirements" (on page 1) for additional guidance.	



SITE REQUIREMENTS

IN THIS SECTION, YOU'LL LEARN:

- About the site requirements of this machine (including electrical and power requirements).



Before operating the machine in any way, you must read and understand this section.

CONTENTS

3.1 General Site and Space Requirements	40
3.2 Electrical and Power Requirements	41
3.3 Air Requirements	42
3.4 Space Planning Drawings	43
3.5 Electrical Site Plan Drawings	49

3: SITE REQUIREMENTS

3.1 General Site and Space Requirements

3.1 GENERAL SITE AND SPACE REQUIREMENTS

When choosing a location for your machine, you must verify that it meets all requirements outlined in this section.

3.1.1 Site Requirements

You must verify that the area:

- Allows for unrestricted access to machine controls.
- Conforms to the following:
 - **Primary Power Required** Single-Phase 230 Vac, 50/60 Hz
 - **Recommended Circuit Amperage** 30 A breaker



Note: For more information, see "Electrical and Power Requirements" (on the next page).

- Has clean, dry, compressed air.
- Has one continuous slab sufficient to support the weight of the machine, accessories, and any additional equipment.
- Is a dry, properly ventilated, and well-lit internal space that conforms to the following temperature and humidity requirements:
 - **Operating Temperature Range** 40°F-90°F (5°C-32°C)
 - **Storage Temperature Range** 30°F-100°F (-1°C-38°C)
 - **Humidity Range** 5%-95% (non-condensing)
- Provides for unobstructed machine motion and operation.

3.1.2 Space Requirements

The area must meet the following space requirements. Allow more space to access the rear of the machine for maintenance and repairs.



Note: For a detailed drawing of the space requirements, refer to the end of this chapter.

- **Machine Size** 86" × 104" (2.2 m × 2.6 m)
- **Machine Height** 94" (2.4 m)

3.1.3 Operator Workstation Reference

The typical operator workstation is the area in front of the enclosure doors and the PathPilot operator console, as shown in the following image.



Figure 3-1: Example of the typical operator workstation.

For information on the machine controls, go to "System Basics" (page 141).

3.2 ELECTRICAL AND POWER REQUIREMENTS

You must verify that the site conforms to the following electrical and power requirements.

3.2.1 Electrical Requirements

A certified electrician must make all electrical connections, and it's your responsibility to verify that the electrical installation of the machine meets all local regulations and electrical codes.

- **Primary Power Required** Single-Phase 230 Vac, 50/60 Hz
- **Recommended Circuit Amperage** 30 A breaker

3.2.2 Power Requirements

If the site conforms to the electrical requirements, verify that it meets the following power requirements:

- **No Electrical Noise** Primary power must be provided by a dedicated circuit, which must be isolated from electrically-noisy devices like welders or plasma torches. The machine should be isolated from inductive loads from items like vacuum cleaners or air compressors.
- **No Ground Fault Circuit Interrupter** Power for the machine must not be protected by a ground fault circuit interrupter (GFCI), as it interferes with the operation of the servo drives.
- **Proper Grounding** You must properly ground the power input to the machine. Examine the continuity between bare metal on the machine frame and true earth ground (a water pipe or similar) to verify that it's properly grounded.
- **Correct Plug Pattern** The machine is shipped with a NEMA L6-30P plug, designed for use with a NEMA L6-30R receptacle.

3: SITE REQUIREMENTS

3.3 Air Requirements

3.3 AIR REQUIREMENTS

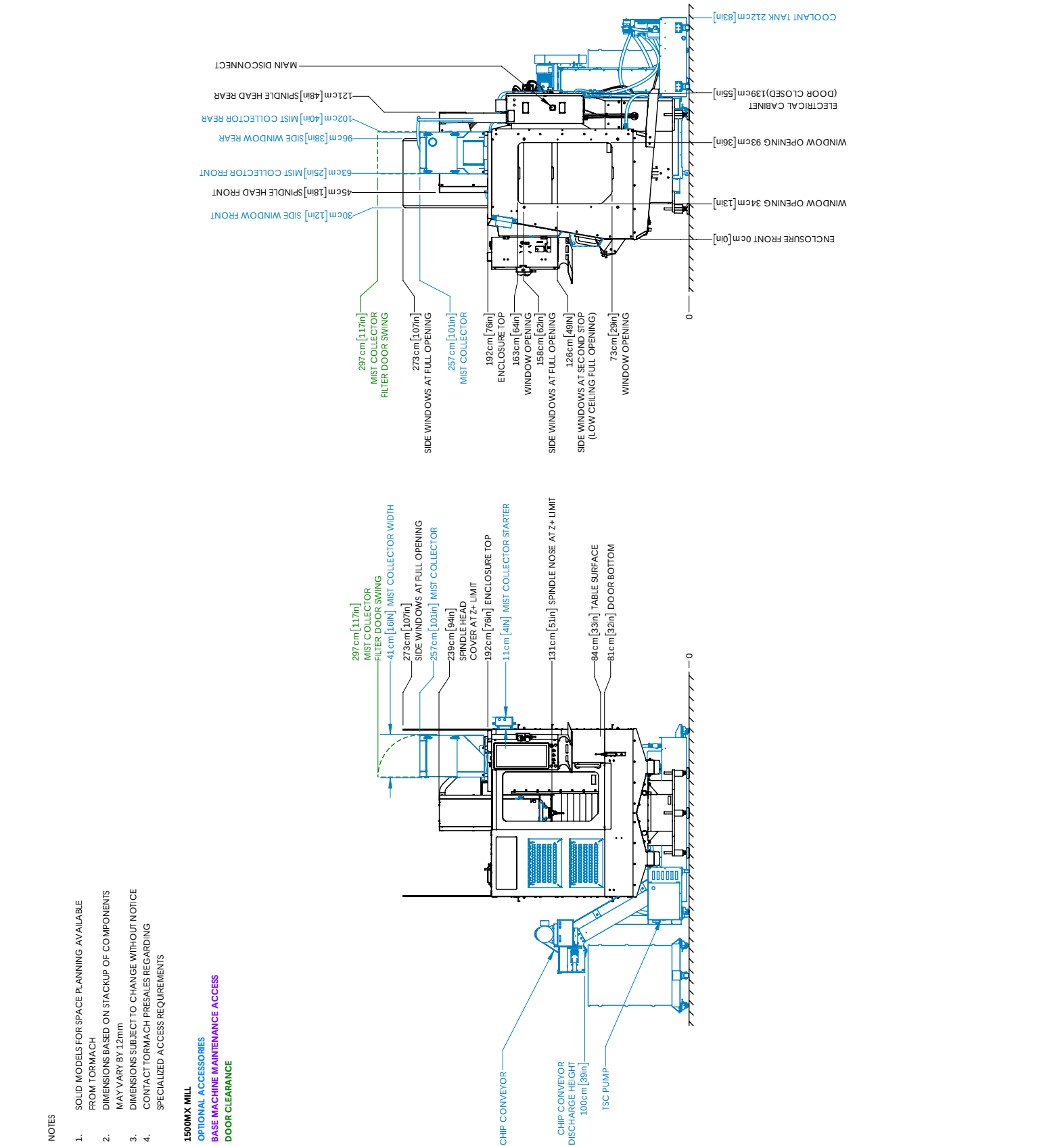
- **Air Pressure** 90-120 psi (620-825 kPa)
If the air supply is more than 120 psi (825 kPa), you must use a regulator.
- **Air Volume** For successive, back-to-back tool changes, at least 2 cfm at 90 psi is required.
Exact air volume depends on the frequency of tool changes.
- **Dry Air** We recommend using a compressed air dryer, desiccator, or filter between the air compressor and the machine.
- **Lubricated Air** You must lubricate the air with air tool oil.
Use the pre-installed FRL Filter-Regulator-Lubricator for this purpose.

3.4 SPACE PLANNING DRAWINGS

3.4.1 Space Planning	44
3.4.2 Minimum Transport Height	46
3.4.3 Table Clearance	47
3.4.4 Table Details	48

3: SITE REQUIREMENTS
3.4 Space Planning Drawings

3.4.1 Space Planning

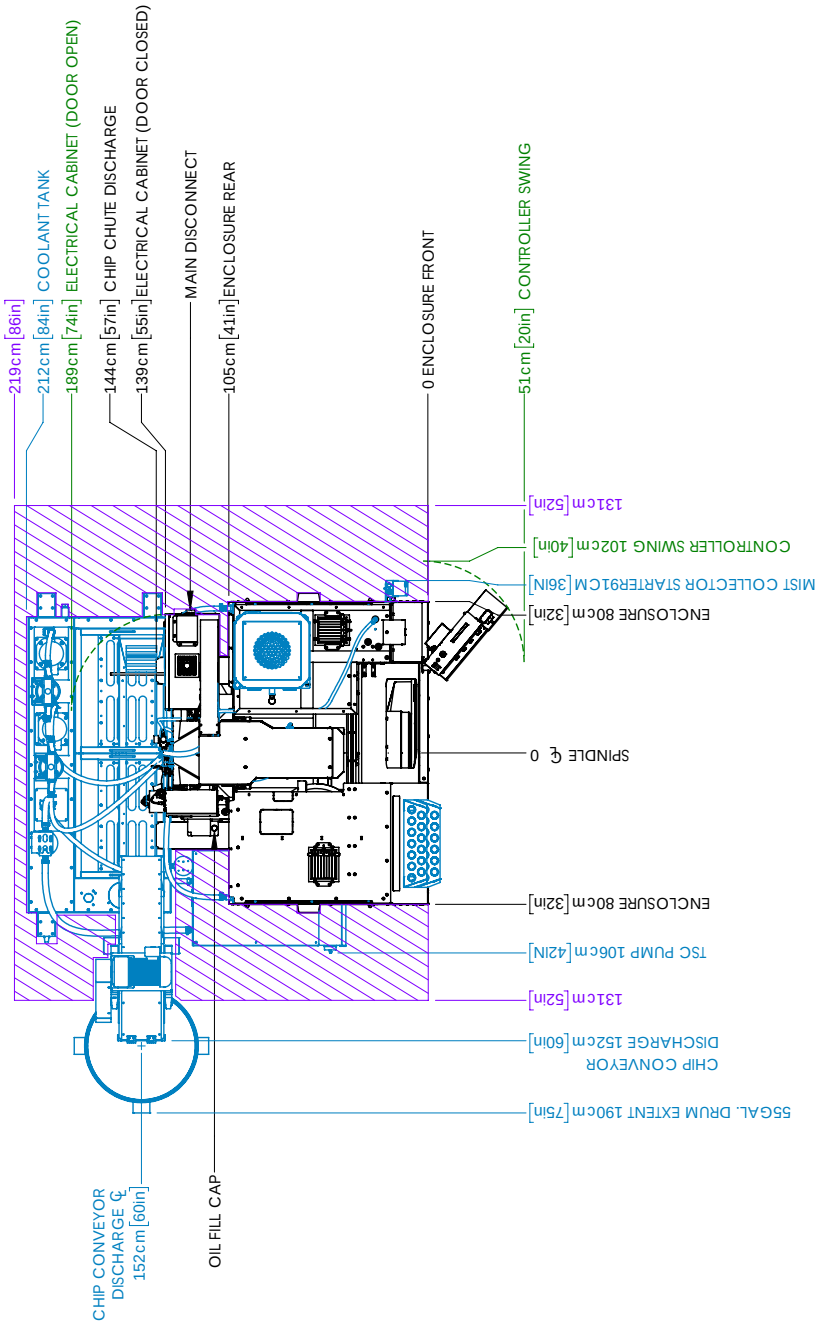


NOTES

- 1. SOLID MODELS FOR SPACE PLANNING AVAILABLE FROM TORMACH
- 2. DIMENSIONS BASED ON STACKUP OF COMPONENTS MAY VARY BY 12mm
- 3. DIMENSIONS SUBJECT TO CHANGE WITHOUT NOTICE
- 4. CONTACT TORMACH PRESALES REGARDING SPECIALIZED ACCESS REQUIREMENTS

1500MX MILL

OPTIONAL ACCESSORIES
BASE MACHINE MAINTENANCE ACCESS
DOOR CLEARANCE



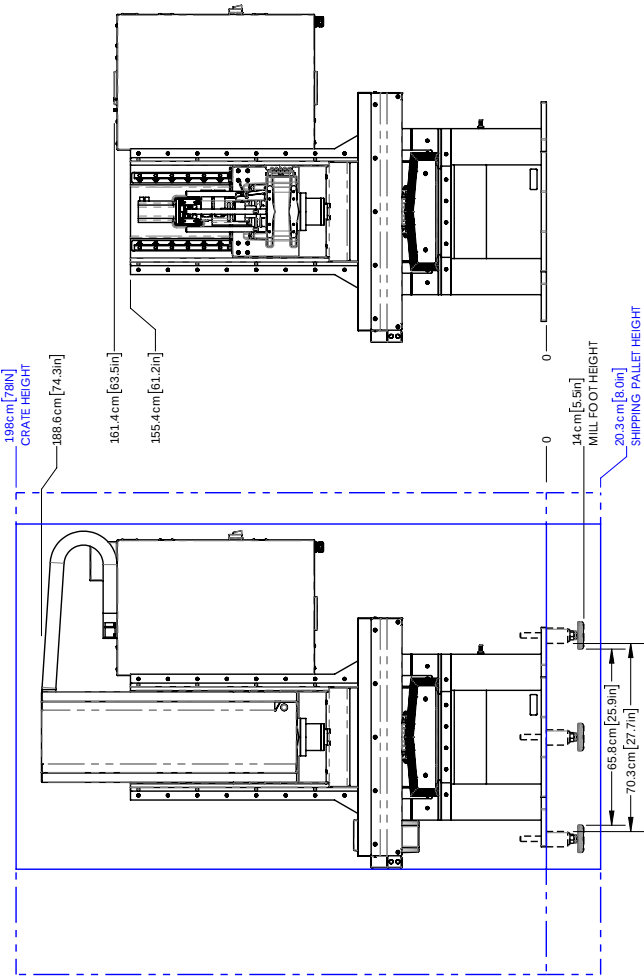
3: SITE REQUIREMENTS
3.4 Space Planning Drawings

3.4.2 Minimum Transport Height

NOTES

- 1. SOLID MODELS FOR SPACE PLANNING AVAILABLE FROM TORMACH
- 2. DIMENSIONS BASED ON STACKUP OF COMPONENTS MAY VARY BY 12mm
- 3. DIMENSIONS SUBJECT TO CHANGE WITHOUT NOTICE
- 4. CONTACT TORMACH PRESALES REGARDING SPECIALIZED ACCESS REQUIREMENTS
- 5. INDICATED HEIGHTS DO NOT INCLUDE HEIGHT REQUIRED FOR MACHINERY SKATES OR ROLLERS; VERIFY SKATE/ROLLER HEIGHT PRIOR TO MOVING MACHINE
- 6. MINIMUM HEIGHT CONFIGURATION REQUIRES PARTIAL DISASSEMBLY OF MACHINE

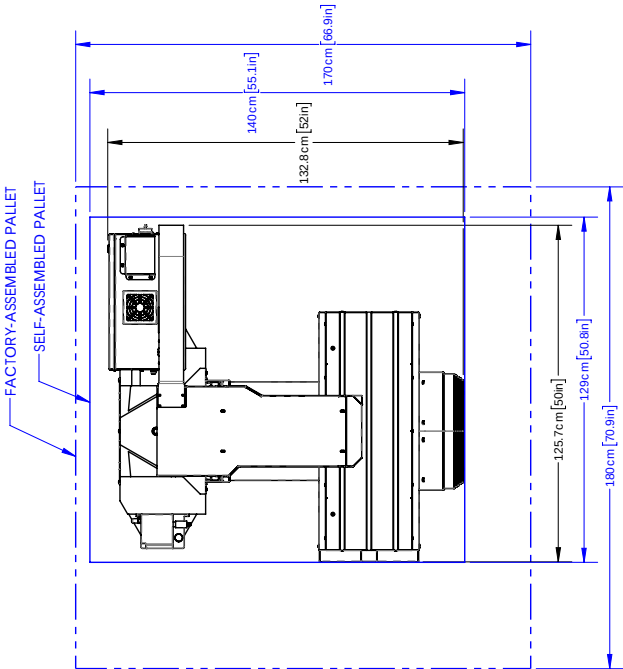
PACKAGING



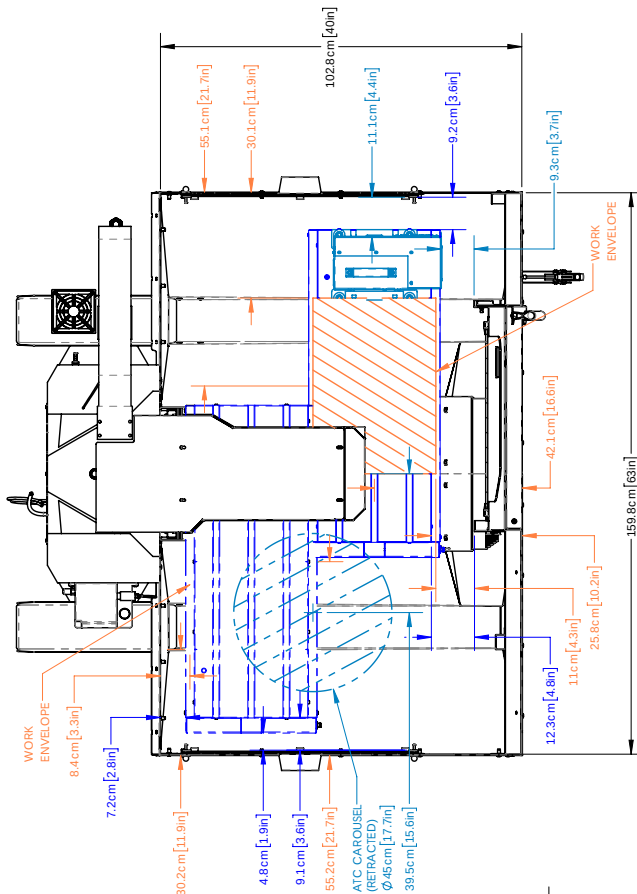
MINIMUM HEIGHT CONFIGURATION

SPINDLE HEAD COVER, POWER DRAWBAR CYLINDER, Z-AXIS DRAG CHAIN REMOVED

TYPICAL CONFIGURATION

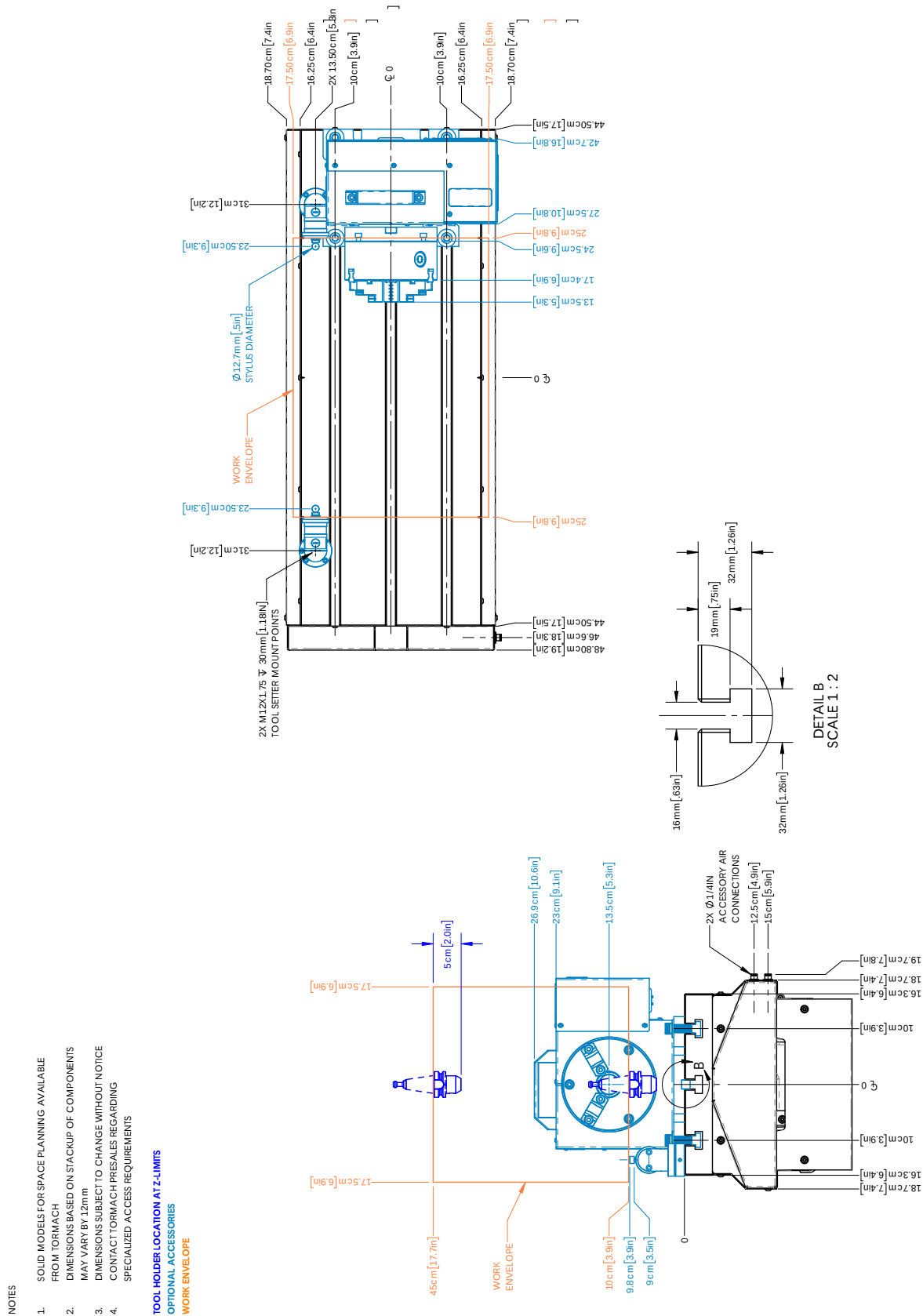


3.4.3 Table Clearance



3.4 Space Planning Drawings

3.4.4 Table Details



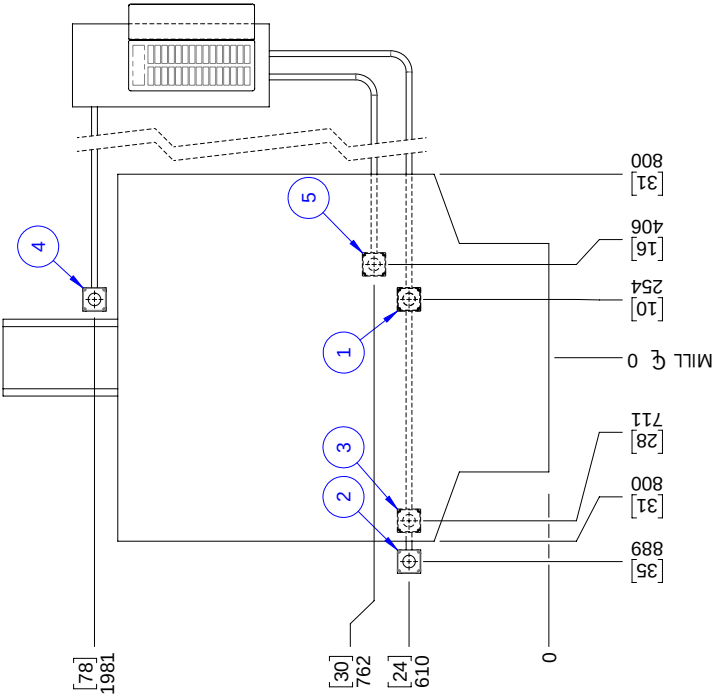
3.5 ELECTRICAL SITE PLAN DRAWINGS

3.5.1 Electrical Site Plan	50
---	-----------

3: SITE REQUIREMENTS
3.5 Electrical Site Plan Drawings

3.5.1 Electrical Site Plan

Table with 7 columns: ITEM NO., DEVICE, VOLTAGE, RUNNING WATTAGE, PEAK WATTAGE, BREAKER, CONNECTOR. It lists electrical components like Base Machine Mill, Flood Coolant, Mist Coolant, Washdown Coolant, Automatic Tool Changer, Spindle Coolant Pump, Chip Conveyor, Mist Collector, and Oil Skimmer with their respective ratings.



- NOTES
- 1. ELECTRICAL INSTALLATION MUST BE COMPLETED BY A QUALIFIED ELECTRICIAN IN ACCORDANCE WITH ALL APPLICABLE CODES AND REGULATIONS
 - 2. CONFIRM THAT THE MAINS VOLTAGE CONFORMS TO REQUIREMENTS BEFORE CONNECTING THE MACHINE OR ACCESSORIES
 - 3. NOMINAL VOLTAGE. VOLTAGES AS LOW AS 208V ARE PERMISSIBLE BUT WILL REDUCE SPINDLE PERFORMANCE.



INSTALLATION

IN THIS SECTION, YOU'LL LEARN:

- About the installation process required for this machine.



Before operating the machine in any way, you must read and understand this section.

CONTENTS

4.1 Pre-Installation Checklist	52
4.2 Installation Tools and Items	53
4.3 Move the Pallet	54
4.4 Unpack the Machine Crate	55
4.5 Self-Assembled Installation	58
4.6 Factory-Assembled Machine Setup	76
4.7 Verify the Installation	81
4.8 Install Accessory Components	84



TORMACH®

4: INSTALLATION

4.1 Pre-Installation Checklist

4.1 PRE-INSTALLATION CHECKLIST

Before beginning the installation of your machine, we recommend completing the following checklist.

Inspect Delivered Items

- ☐ Inspect the item(s):
 - Photograph any damage that may have occurred during shipping.
 - Note any damage on the delivery receipt before signing for the shipment. If there is extensive visible damage to the machine, refuse to accept the shipment.
 - Verify the received goods against the packing list.

If there is any damage or shortages, you must contact Tormach within 30 days of receipt. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

- ☐ If there are any items that have not yet been delivered, we recommend waiting until you've received all shipments to begin installing the machine. Depending on the product and options ordered, the system may arrive in one or more shipments of:
 - Accessories (if applicable)
 - Machine



Note: The machine system and large accessories are sent by freight carrier. Smaller accessories may be sent by parcel service.

Review Site Requirements

- ☐ Verify that your shop meets the necessary space, electrical, and air requirements (refer to "Site Requirements" (page 39)).
- ☐ Verify that the temperature and humidity levels are within the machine's operating requirements (40°F-90°F (5°C-32°C), 5%-95% humidity).
- ☐ Verify the availability of the appropriate power for the machine and any accessories you plan to install, and ensure a certified electrician is available if needed.

- ☐ Verify the availability of clean, dry air (90-120 psi (620-825 kPa)).

Prepare Your Shop Space

- ☐ Verify that the area where the machine will be installed is clean, dry, and free of clutter.
- ☐ Verify that the space has proper lighting and ventilation in accordance with the machine's operating requirements.
- ☐ Set up appropriate containers for packing materials, crates, and other waste generated during the unboxing and installation process to keep the work area clean and safe.

Gather Required Materials

- ☐ Have Citgo EP Compound 220 Oil (PN 52499) or similar available.
- ☐ Lay out all necessary tools, hardware, and materials in a convenient, accessible location near the installation site to prevent interruptions during the setup.
- ☐ Have safety equipment available, including protective eyewear, closed-toed shoes, and gloves, as required during installation and initial operation.

Review Installation Materials

- ☐ Before starting any installation tasks, read through the relevant procedures and safety precautions to better understand the steps and requirements.
- ☐ Identify your setup or installation procedure depending on which machine configuration you purchased.
 - **Self-Assembled Machine** Follow the installation procedures in "Self-Assembled Installation" (page 58), go to "Verify the Installation" (page 81), and then, if applicable, go to "Install Accessory Components" (page 84).
 - **Factory-Assembled Machine** Follow the setup procedures in "Factory-Assembled Machine Setup" (page 76), go to "Verify the Installation" (page 81) and then, if applicable, go to "Install Accessory Components" (page 84).

4.2 INSTALLATION TOOLS AND ITEMS

Before uncrating and beginning the initial setup of your machine, collect the following tools and items.

- Assistant to help you
- Cable ties
- Cordless drill with a Phillips bit
- Hammer
- Machinist level
- Metric hex wrench set
- Open end wrench, 27 mm and 30 mm
- Pallet jack
- Phillips screwdriver
- Pry bar
- Safety eyewear that meets ANSI Z87+
- Shears or knife
- Socket set
- Step ladder
- Snips
- Thread seal tape
- Work gloves

4: INSTALLATION

4.3 Move the Pallet

4.3 MOVE THE PALLET

Shipments arrive in crates loaded on pallets, which the freight carrier unloads onto the curb or loading dock.



WARNING! Transportation and Lift Hazard: Before moving the machine, you must confirm that all persons are clear of the area below the machine. Qualified professionals must transport, lift, and move the machine. Moving parts can entangle, pinch, or cut you, causing death or serious injury.

- Verify that the ground surface is smooth and clean of debris, and then use a pallet jack to move the pallet(s) to the desired installation location. Follow the instructions on the pallet to determine from which side to lift.



Note: If the ground is not smooth, you may need to use a forklift (or similar lifting equipment rated for uneven surfaces) to move the pallet(s).

4.4 UNPACK THE MACHINE CRATE

The machine's pallet has spaces that allow you to slide the pallet out from underneath the machine without using a lifting device. You'll need to partially disassemble the pallet and raise up the machine by its feet to remove the pallet, as described in the following procedure.

⚠ CAUTION! Sharp Objects Hazard: Before opening the shipping crate, you must put on work gloves and safety eyewear that meets ANSI Z87+. If you don't, the shipping crate and steel straps could cut you, causing serious injury.

1. Put on work gloves and eye protection.
2. Remove and discard the plastic wrapped around the shipping crate.
3. Disassemble the shipping crate, starting with the top and then the four sides. With an assistant, remove the bottom two screws on either side of the crate's top beam, and then remove it from the shipping crate.



Figure 4-1: Two screws on the top beam.

4. Remove the screws on each of the four sides of the shipping crate, starting at the bottom. With an assistant, lift the sides of the shipping crate off of the pallet.



Figure 4-2: Removing the sides of the machine crate.

5. Remove and discard the plastic wrapped around the machine and stapled to the pallet.
6. Remove and discard the shipping straps securing the accessory boxes (the machine owner's kit, a coolant filter, and, if not yet installed, the operator console kit).



Figure 4-3: Accessory boxes on the machine and the pallet.

7. Set aside the coolant filter box and the operator console box for later use, and open the machine owner's kit box.
8. Identify the three machine foot pads and the three machine foot spacers in the machine owner's kit.

4: INSTALLATION

4.4 Unpack the Machine Crate

- Remove the screws on the 2 × 4 on the left side of the pallet with an impact driver. Remove and discard the board.



Figure 4-4: Removing the 2 × 4 from the left side of the pallet.

- Identify the three threaded rods that attach the machine to the pallet. To prevent galling or seizing, we recommend using a high-quality anti-seize compound on the threads of the machine legs.



Figure 4-5: Two of the three threaded rods.

- Starting with one of the threaded rods, loosen the nuts from the top and bottom with an adjustable wrench.
- Put the machine's foot pad (from the machine owner's kit) under the threaded rod, and tighten the threaded rod into the foot pad.



Figure 4-6: Installing the machine's foot pad onto the threaded rod.

- Repeat Steps 10 and 11 for the two remaining threaded rods.
- Raise the machine up by its three feet until there's a 1/8 in. gap between the pallet and the machine.
- Remove the screws securing the plywood boards under each foot plate. Remove the boards off of the pallet and discard them.
- Verify that the machine is stable and secure on its three feet.
- Slide the pallet out from underneath the machine, taking care to do this slowly and evenly to avoid damaging the machine or pallet.
- Remove the three machine foot spacers from the owner's kit, and remove and discard the plastic wrapped around them. You'll install the spacers on the threaded rods, under the foot plate.



WARNING! Crush Hazard: Make sure to lower the machine slowly and evenly to avoid sudden movements that could cause injury or damage the machine.

- Begin lowering the machine toward the ground. Work your way around the machine, turning the hex nut on each threaded rod four or five times before moving to the next foot.
- Continue lowering the machine until there's a 5 3/4 in. to 6 in. gap between the floor and the bottom of the machine's foot plates. Level all three foot plates to the same height.

21. Install a foot spacer below each of the machine's foot plates. Make sure that the large, flat side of the foot spacer is flush with the edge of the foot plate. Then, tighten the flat washer and nut against the bottom of the foot spacer.

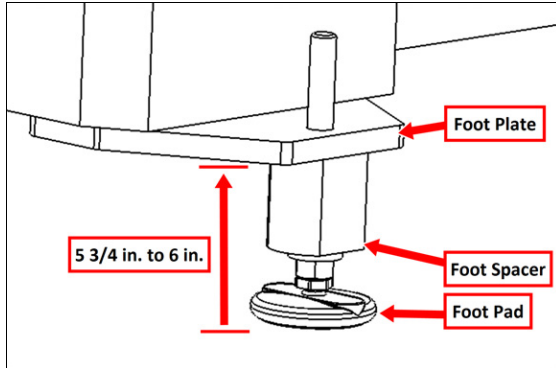


Figure 4-7: Foot spacer installation.

22. Once the machine is safely on the ground, verify that it is stable and secure.

4: INSTALLATION
4.5 Self-Assembled Installation

4.5 SELF-ASSEMBLED INSTALLATION

IMPORTANT! This section is for customers who are assembling the machine themselves. If you purchased the machine pre-assembled from the factory, you won't need to complete many of the procedures in this section. Go to "Factory-Assembled Machine Setup" (page 76) for information specific to factory-assembled machines.

Complete the following steps in the order listed:

4.5.1 Install the Enclosure 58
4.5.2 Set Up the PathPilot Controller 73
4.5.3 Set Up the Automatic Oiler 74

4.5.1 Install the Enclosure

Complete the following steps in the order listed:

Before You Begin Assembly 58
Required Tools and Items 59
Unpack the Shipping Crate 59
Prepare the Enclosure Panels 59
Assemble the Left Top Panel 59
Assemble the Right Top Panel 59
Assemble the Chip Tray Center Kick Plate 60
Assemble the Chip Trays 60
Prepare the Panels for Sealant 61
Set up the Operator Console 61
Install the Chip Trays 62
Install the Enclosure Panels 64
Secure Panel Screws 68
Clean Excess Sealant 68
Assemble the Door 68
Install the Door Latch 70
Install the Door Latch Push Button 70
Connect the Enclosure Lights 70
Mount the Operator Console 71
Install the Chip Tray Center Kick Plate 72
Install the Windows 73

Before You Begin Assembly

- 1. Inspect the item(s):
- Photograph any damage that may have occurred during shipping.
- Verify the received goods against the packing list.

If there is any damage or shortages, you must contact Tormach within 30 days of receipt. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

- 2. Read the packing list and locate all items:
- Arrange components so that they're easy to access during installation.
- Do not begin assembly until all parts are accounted for. Missing components can delay installation and may prevent proper alignment of the enclosure.
- During the installation, remove labels from the items as needed.
- 3. Plan your assembly time:
- The enclosure requires several hours to assemble. Do not begin applying sealant unless you can finish all applications without interruption. If the sealant cures before the enclosure is fully assembled and tightened, the panels may bond in place and prevent proper alignment.
- 4. Seal the enclosure correctly:

IMPORTANT! A well-sealed enclosure is essential for optimal machine functionality.

- We recommend using Sikaflex to seal the enclosure. Refer to the manufacturer's specifications for details on use and cure time.
- Refer to the images for an example of the amount of sealant to use on each component.
- Take the time to seal the enclosure correctly from the start — it significantly impacts the machine's performance. Don't rush through this step.
- After the sealant is completely cured, test the enclosure for leaks and identify any areas requiring extra sealant.
- 5. Install panels loosely for alignment:
- Keep all screws one quarter-turn loose while installing the enclosure panels. This makes it easier to align the panels.
- Once you're done installing the enclosure, fully tighten all screws.

Required Tools and Items

- Caulk gun
- Isopropyl alcohol for excess sealant cleanup
- Metric hex wrench set
- Painter's tape, 1/2 in. wide
- Phillips screwdriver
- Rubber gloves for working with sealant
- Safety eyewear that meets ANSI Z87+
- Shears or knife
- Shop rags
- Torque wrench, 3 Nm to 10 Nm (2 ft lb to 7 ft lb)
- Work gloves

Unpack the Shipping Crate



CAUTION! Sharp Objects Hazard: Before opening the shipping crate, you must put on work gloves and safety eyewear that meets ANSI Z87+. If you don't, the shipping crate and steel straps could cut you, causing serious injury.

1. Put on work gloves and eye protection.
2. Cut and remove the steel straps on the shipping crate with snips.
3. Pry up the metal tabs that secure the top panel to the crate. Lift the panel off of the crate and set it aside.

Prepare the Enclosure Panels

Assemble the Left Top Panel

1. Identify the right top panel (PN 54885), four flood light retainers (PN 54882), and two flood light (PN 51591). Place one flood light on the opening on the right top panel, and place a retainer on each side of the flood light.

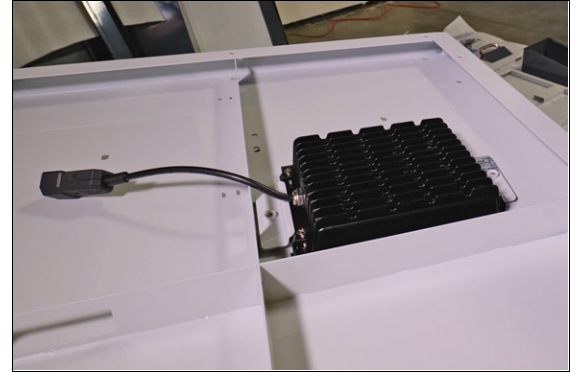


Figure 4-8: Flood light and retainers positioned on the top panel.

2. Insert two M6 × 1 - 12 screws (PN 38206) from the underside of the top panel and into the retainers. Using a torque wrench, tighten the retainer screws to 10 Nm.
3. Set the left top panel aside.

Assemble the Right Top Panel

1. Identify the right top panel (PN 54885). Place the remaining flood light on the opening on the right top panel, and place a retainer on each side of the flood light.
2. Insert two M6 × 1 - 12 screws from the underside of the top panel and into the retainers. Using a torque wrench, tighten the retainer screws to 10 Nm.
3. Identify two expandable locking grommets (PN 51519), and insert them from the underside of the top panel as shown in the following image.



Figure 4-9: Inserting the locking grommets into the right top panel.

4: INSTALLATION

4.5 Self-Assembled Installation

4. Identify the door switch lock (PN 51328). Place the door switch lock onto the notch on the top panel.



Figure 4-10: Door switch positioned on the top panel.

5. Insert four M4 × 1 - 8 screws (PN 51331) from the underside of the top panel and into the door switch lock. Loosely secure the screws with a 2.5 mm hex wrench. Do not fully tighten the screws — you may need to adjust the position later in this procedure.
6. Set the right top panel aside.

Assemble the Chip Tray Center Kick Plate

1. Identify the chip tray center kick plate (PN 54862) and the bulkhead union fitting (PN 52441). Remove one nut from the fitting and set it aside.
2. Insert the fitting into either of the lower tabs on the right side of the kick plate, and secure it with the nut.
3. Identify the pressure regulator (PN 39356), its pressure gauge, and two elbow fittings (PN 52544 and PN 31324).
4. Wrap thread seal tape onto the gauge threads, and install it onto the regulator.
5. With the gauge facing you, install the 8 mm elbow fitting into the regulator's left port and the 1/4 in. elbow fitting into the right port.
6. Remove the plastic nut on the bottom of the pressure regulator and set it aside. Then, insert the regulator into the hole closest to the bulkhead fitting, and secure it with the plastic nut.



Figure 4-11: Bulkhead fitting and pressure regulator installed.

7. Identify the two black air lines (PN 31457). Connect the shorter air line between the bulkhead fitting and the 8 mm elbow fitting on the pressure regulator.

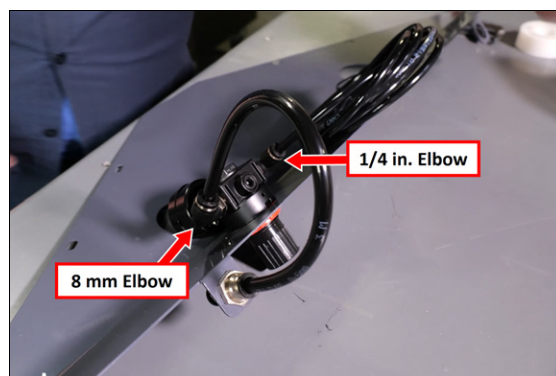


Figure 4-12: Air lines installed on the bulkhead fitting and pressure regulator.

8. Connect the longer air line to the 1/4 in. elbow fitting on the pressure regulator.
9. Set the kick plate aside.

Assemble the Chip Trays

1. Identify the right side chip tray (PN 54851) and the coolant chute (PN 55006). Apply painter's tape to the seams of the flange.



CAUTION! Chemical Exposure Hazard: Sealant and cleaning solvents may cause skin and eye irritation. Wear disposable gloves and safety eyewear. Use in a well-ventilated area and avoid contact with skin and eyes.

1. Put on disposable rubber gloves.
2. Puncture the inner seal of the Sikaflex tube, install the nozzle, and cut the tip to create an opening approximately 1/4 in. (6 mm).
3. Install the tube into a caulk gun.
4. Apply a bead of sealant around the screw holes on each side of the flange.

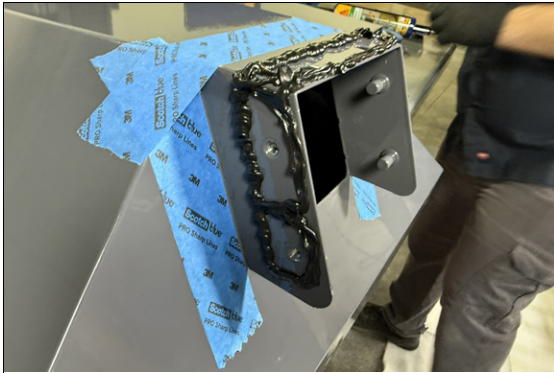


Figure 4-13: Sealant on the chip tray's flange.

5. Place the coolant chute onto the flange and secure it with six M6 × 1 - 12 screws. Using a torque wrench, tighten the chute screws to 10 Nm.
6. Remove the painter's tape from the chip tray.
7. Dampen a clean wipe with isopropyl alcohol and remove any residual sealant from the panel surfaces.



Tip! We recommend having a box of shop rags and isopropyl alcohol nearby as you work with sealant on the enclosure components. Isopropyl alcohol helps to clean excess sealant from the machine.

8. Set the right chip tray aside.
9. Repeat the steps in this section for the left side chip tray (PN 54861).

Prepare the Panels for Sealant

To reduce cleanup time, we recommend applying painter's tape to the edges of any enclosure panels that will be sealed. After you've applied the tape, set the panels aside.

1. Identify the right front panel (PN 54887). Apply painter's tape to the right and bottom edge, and up to the bend on the left edge of the panel.



Figure 4-14: Applying tape to the right front panel.

2. Identify the left front panel (PN 54889). Apply painter's tape to the left and bottom edge, and up to the bend on the right edge of the panel.
3. Identify the left side enclosure panel (PN 54890). Apply painter's tape to the left, right, and bottom edge of the panel.



Figure 4-15: Applying tape to the left side enclosure panel.

4. Identify the right side enclosure panel (PN 54868). Apply painter's tape to the left, right, and bottom edge of the panel.
5. Identify the center front panel (PN 54864). Apply painter's tape to the left, right, and bottom edge of the panel.

Set up the Operator Console

We recommend temporarily setting up the operator console on a work surface near the machine. It's easier to apply sealant to all areas of the machine if you can jog the machine table.

1. Open the PathPilot operator console box and remove the operator console.
2. Lay the control console down on the work surface to prevent tipping.

4: INSTALLATION

4.5 Self-Assembled Installation

3. Remove and set aside the three screws securing the operator console's front panel with a 2 mm hex wrench.

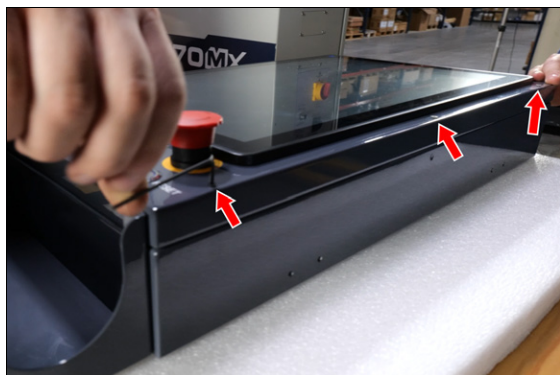


Figure 4-16: Opening the operator console's front panel.

4. Open the operator console's hinged front panel, and make the following connections on both the operator console and the machine:
 - Connect the power supply cable to the controller, and connect the loose end of the power cable to the **Console Power** outlet on the side of the electrical cabinet.
 - Connect the Ethernet cable to the LAN 1 port on the controller, and connect the loose end of the cable to the **Controller Communications** connector on the top of the electrical cabinet.
 - Connect the emergency stop cable to the back of the operator console, and connect the loose end of the cable to the **Emergency Stop** connector on the top of the electrical cabinet.
 - Connect the jog pendant cable to the back of the operator console.
5. Prop up the console to avoid pinching the cables.

Install the Chip Trays



IMPORTANT! Complete the sealant application in one continuous work session. Do not begin applying sealant unless you can finish all applications without interruption. If the sealant cures before the enclosure is fully assembled and tightened, the panels may bond in place and prevent proper alignment.

1. Identify the hardware required for this section:
 - a. M6 × 1.0 - 20 screws (PN 51418) with pre-applied thread locker, used to install the chip trays to the machine stand.
 - b. 3/4 in. washers with grommets (PN 55274), used to install the chip trays to the machine stand.
 - c. M6 × 1.0 - 12 screws (PN 38206), used to install the chip trays' support brackets.
2. Put on rubber gloves before working with sealant.
3. Remove the cover panels below the machine table on either side of the saddle. Set the panels aside.

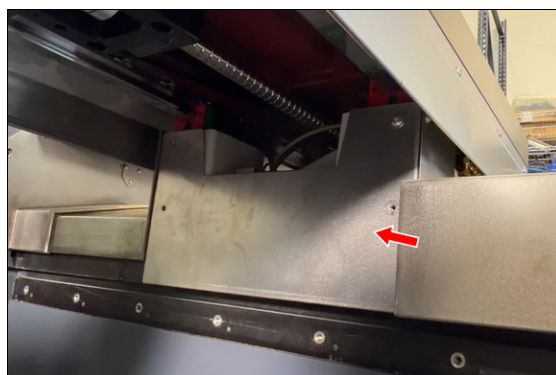


Figure 4-17: Cover panel below the machine table.

4. Apply a bead of sealant to both sides and the front of the machine's base as follows:
 - a. Apply a horizontal line above the channel on the machine's base.
 - b. Apply a horizontal line below the screw holes on the casting.
 - c. Apply a circle around each screw hole.
 - d. Apply a vertical line on each corner connecting the two horizontal lines, and apply additional sealant to the inside corners.

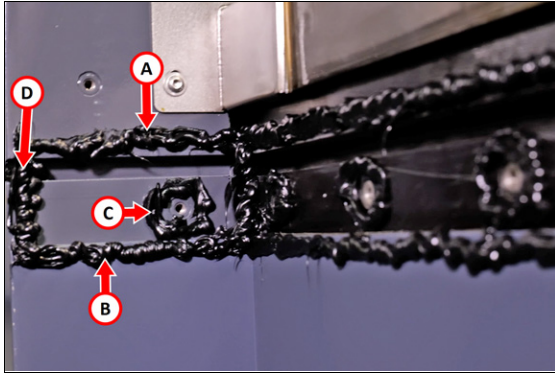


Figure 4-18: Example sealant application on the base of the machine.

5. Verify that all areas described in the previous step have a continuous bead of sealant with no visible gaps.



Figure 4-19: Example sealant application on the base of the machine.

6. Identify the chip tray support brackets (PN 54863). Loosely install one bracket to the left side of the machine stand using four M6 × 1.0 - 12 screws.



Figure 4-20: Installing a chip tray support bracket onto the machine stand.

7. Loosely install the left chip tray on the machine using nine M6 × 1.0 - 20 screws. Place one grommet washer onto each screw, and insert the screws through the chip tray and into the stand. Don't install a screw onto the machine column — you'll need to use that hole to install another enclosure panel later in this procedure.
8. Secure the left chip tray to the bracket installed on the machine stand with using two M6 × 1.0 - 12 screws.
9. Before you mount the right chip tray, you must apply a bead of sealant to the inner edge of the left chip tray and around the holes to seal the two halves of the chip tray to each other. Make sure to connect this bead of sealant to the other bead previously laid on the front of the base casting.

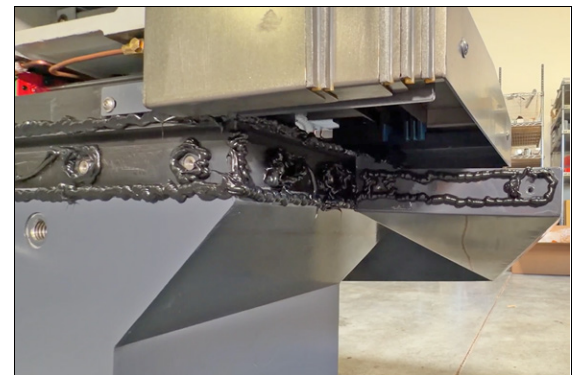


Figure 4-21: Sealant applied to the inner edge of the left chip tray.

10. Loosely install the remaining chip tray support bracket to the right side of the machine stand using four M6 × 1.0 - 12 screws.

4: INSTALLATION

4.5 Self-Assembled Installation

11. Loosely install the right chip tray on the machine stand using nine M6 × 1.0 - 20 screws. Place one grommet washer onto each screw, and insert the screws through the chip tray and into the stand. Don't install a screw onto the machine column — you'll need to use that hole to install another enclosure panel later in this procedure.
12. Secure the right chip tray to the bracket installed on the machine stand with using two M6 × 1.0 - 12 screws.
13. Apply painter's tape to the front edge of each chip tray.



Figure 4-22: Tape applied to the chip trays.

Install the Enclosure Panels

IMPORTANT! The enclosure's right and left side panels have a window panel that's installed later in this procedure. When fully raised, the window panel measures 9 ft (2.7 m) tall. If there isn't sufficient clearance above the machine for installing the window panels from above, install them before starting with the enclosure panels. First, go to "Install the Enclosure" (page 58), then come back to this section to finish the enclosure installation.



Note: We recommend mounting the automatic tool changer (ATC) and its electrical cabinet before installing the enclosure panels. Go to "Install the Automatic Tool Changer (ATC)" (page 115), and, once you've completed the section to install the electrical cabinet, come back to this section to finish the enclosure installation.

1. Before you install the rear enclosure panels, you must apply a bead of sealant to the following areas:

- Each side of the machine column casting



Figure 4-23: Example of sealant applied to the side of the machine column casting.

- Inside edge of the back side of each chip tray and around each screw hole

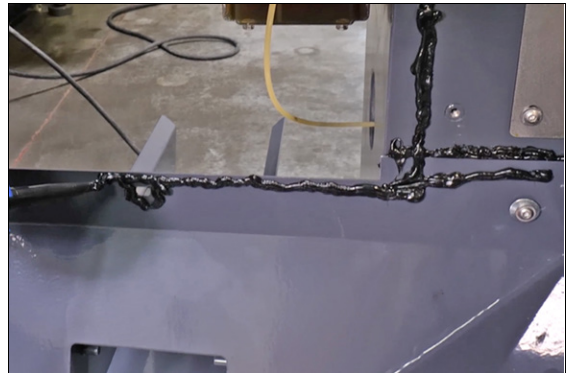


Figure 4-24: Example of sealant applied to the inside edge of the chip tray.

- Completely filling the channel in the base casting where the two beads meet



Figure 4-25: Example of sealant in the rear channel where the chip tray and machine casting meet.

2. Loosely install the right rear panel to the machine column and the inside of the right chip tray using 11 M6 $\times$ 1.0 - 12 screws.

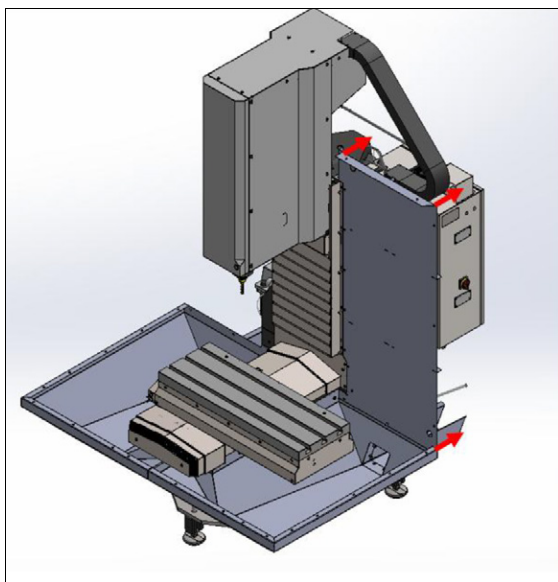


Figure 4-26: Installing the right rear panel.

3. Loosely install the left rear panel to the machine column and the inside of the left chip tray using eight M6 $\times$ 1.0 - 12 screws.

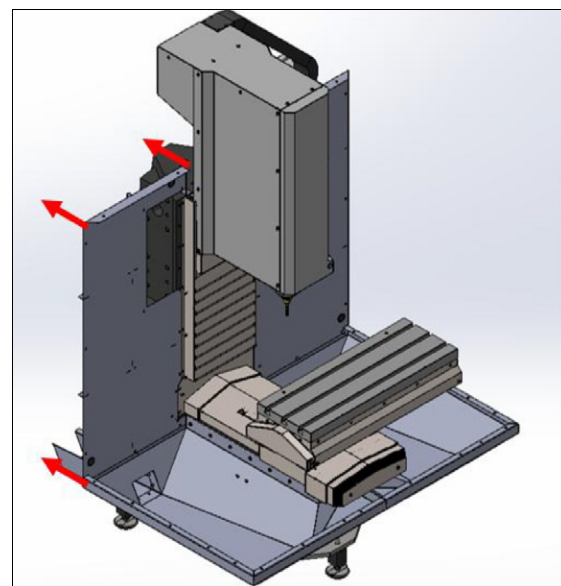


Figure 4-27: Installing the left rear panel.

4. Apply a bead of sealant to the corner edges and around the screw holes of each rear panel, and to the top edge and around each screw hole on the chip trays.
5. Loosely install the right side panel to the right rear panel and the right chip tray using seven M6 $\times$ 1.0 - 12 screws.

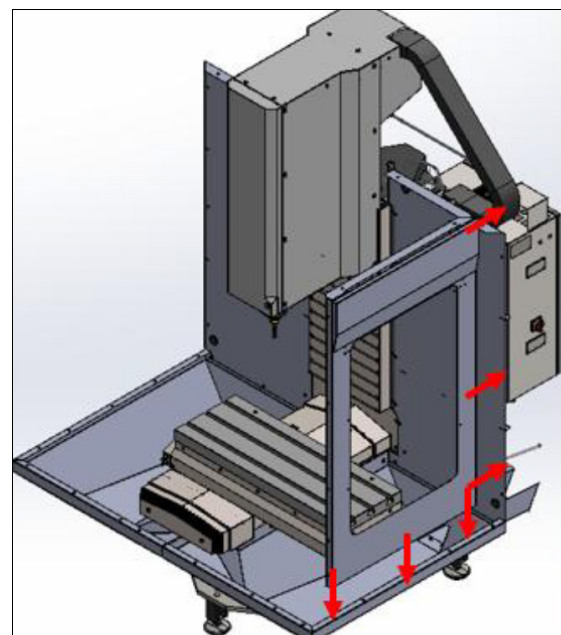


Figure 4-28: Installing the right side panel.

4: INSTALLATION

4.5 Self-Assembled Installation

- Loosely install the left side panel to the left rear panel and the left chip tray using seven M6 × 1.0 - 12 screws.

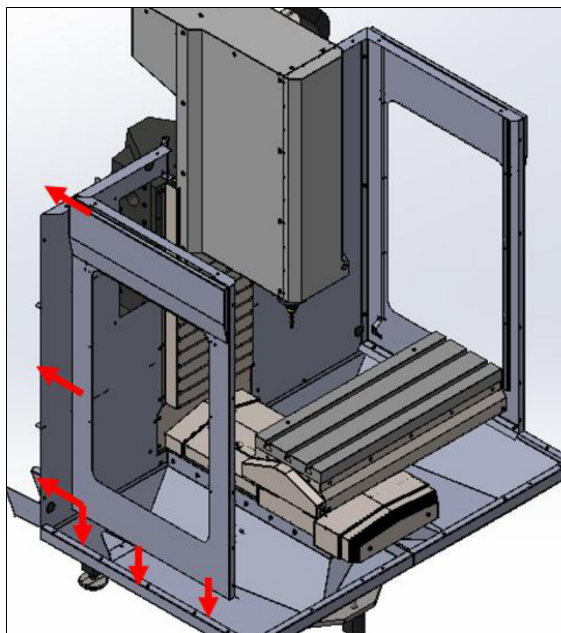


Figure 4-29: Installing the left side panel.

- Apply a bead of sealant to the edge of each side panel and around each screw hole, and to the top edge and around each screw hole of the chip trays.
- Loosely install the right front panel to the right side panel and the right chip tray using five M6 × 1.0 - 12 screws.

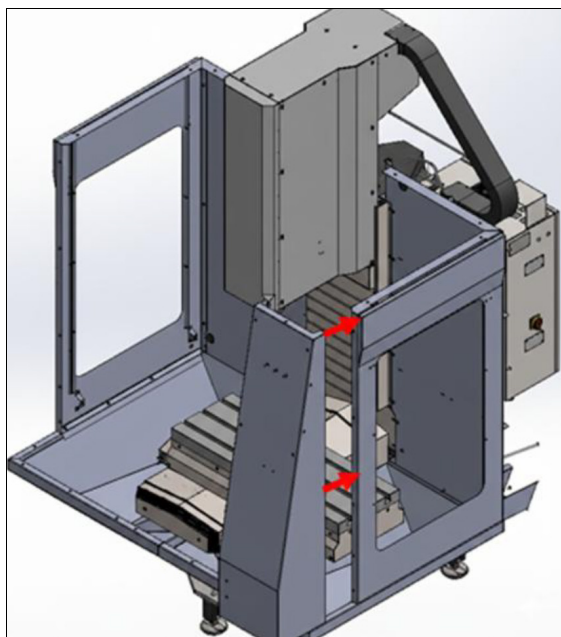


Figure 4-30: Installing the right front panel.

- Loosely install the left front panel to the left rear panel and the left chip pan using five M6 × 1.0 - 12 screws.

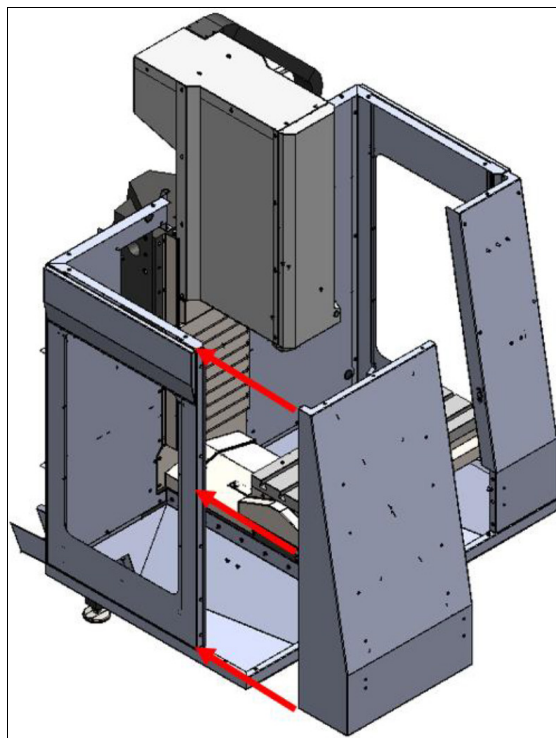


Figure 4-31: Installing the left front panel.

- Apply a bead of sealant to the lower edges of the two front panels and a bead across the two chip trays.

11. Loosely install the center front panel to the two front panels and the two chip trays with nine M6 × 1.0 - 12 screws.

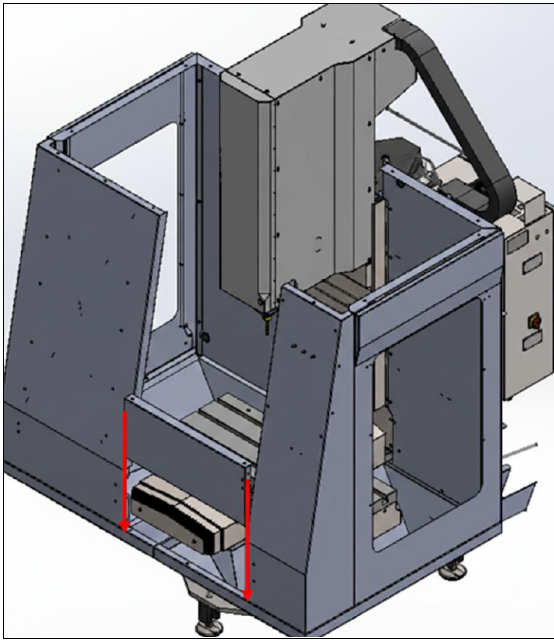


Figure 4-32: Installing the center front panel.

12. Loosely install the left top panel to the left rear panel, the left side panel, and the left front panel using seven M6 × 1.0 - 12 screws.

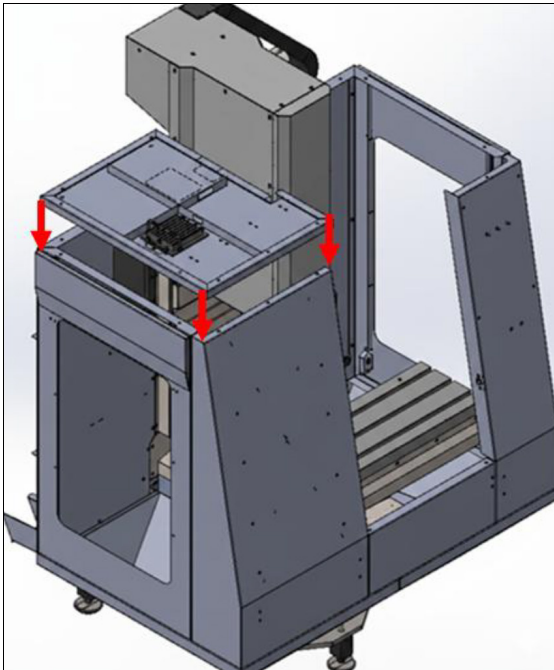


Figure 4-33: Installing the left top panel.

13. Loosely install the right top panel to the right rear panel, the right side panel, and the right front panel using five

M6 × 1.0 - 12 screws.

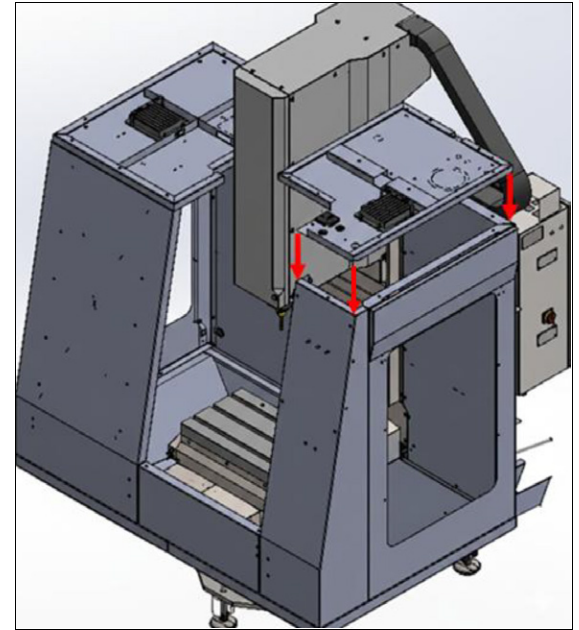


Figure 4-34: Installing the right top panel.

14. Identify the linear rail (PN 51816). Secure it to the left top panel and the right top panel using 10 M6 × 1.0 - 12 screws.

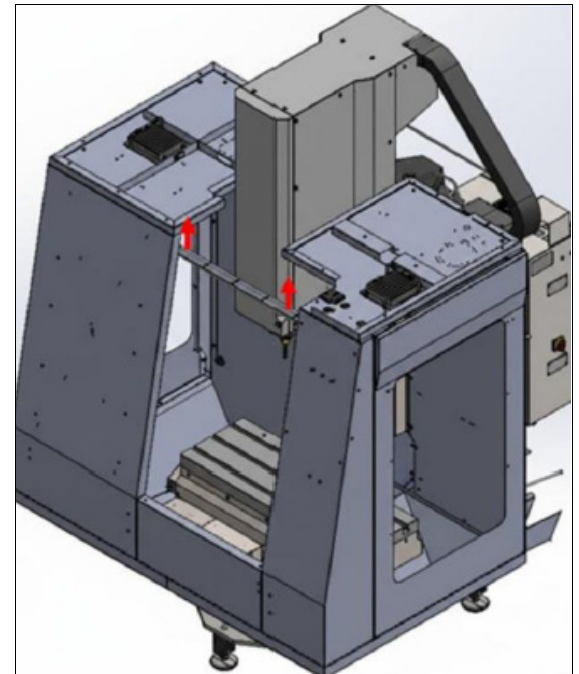


Figure 4-35: Top linear rail installed.

15. Replace the cover panels below the machine table on either side of the saddle.

4: INSTALLATION

4.5 Self-Assembled Installation

Secure Panel Screws

With all structural components installed, you can now fully tighten down each screw used to install the panels. We strongly recommend using a torque wrench to properly tighten each screw.

1. Use a torque wrench to tighten all screws to the following specifications:
 - Screws used to install the chip trays to the machine casting: 6 Nm

NOTICE! Use care when tightening screws into the machine casting. Over-tightening can cause damage.

- All other enclosure screws: 10 Nm
2. If a torque wrench is not available, tighten screws until snug and then tighten an additional quarter-turn. Do not force the screw. Refer to the image below to most closely match screws to the example, paying close attention to not overly compress the washer's grommet.

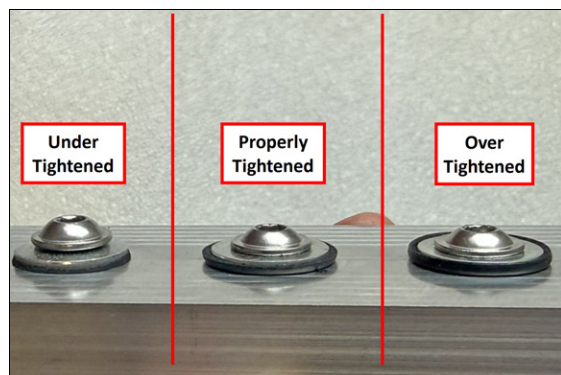


Figure 4-36: Torque examples.

Clean Excess Sealant

1. Using a clean, dry disposable wipe or paper towel, smooth each bead of sealant to press it into the joint.
2. Remove the painter's tape immediately after smoothing each section.
3. Dampen a clean wipe with isopropyl alcohol and remove any residual sealant from the panel surfaces.
4. Cover the nozzle tip of the sealant tube with painter's tape for future use.

Assemble the Door

Note: If you've already installed the window panels due to height restrictions, we recommend raising the windows as much as possible and temporarily securing them with the enclosure window pins. This helps to more easily install certain components.

1. Identify the enclosure scuff guard (PN 54929). Install it on the front panel using 2 M6 × 1.0 - 12 screws.

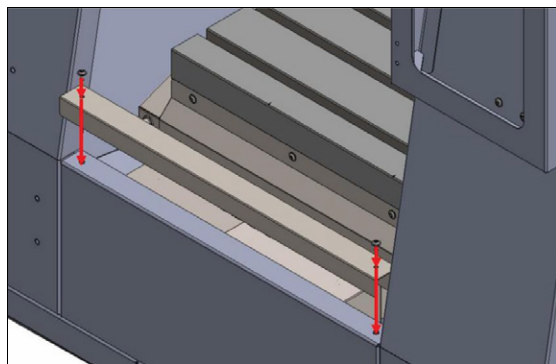


Figure 4-37: Installing the scuff guard.

2. Identify the four linear guide blocks (PN 37610 and PN 51817). One set of guide blocks is enclosed, and the other is open. Set aside the enclosed guide blocks.
3. Install two M5 × 0.8 - 10 screws into one side of each of the open linear guide blocks.



Figure 4-38: M5 screws installed in a linear guide block.

4. Slide both open linear guide blocks onto the top linear rail, spacing them roughly 16 in. (40 cm) apart. Make sure that the screws are facing down and nearest to the front of the enclosure, as shown in the following image.

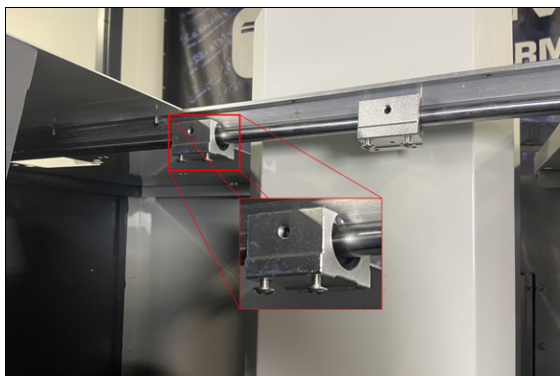


Figure 4-39: Linear guide blocks installed on the top linear rail.

5. Identify the linear rail (PN 54736), two support brackets (PN 37622), two bumpers (PN 54891), and the two enclosed guide blocks that you set aside earlier (PN 37610).
6. Assemble one linear rail:
 - a. Using a 4 mm hex wrench, remove the screws and washers from the each end of the rail and set them aside.
 - b. Slide both enclosed guide blocks onto the rail.
 - c. Slide one bumper onto each end of the rail, keeping it within approximately 0.5 in. (13 mm) from the end of the rail.
 - d. Slide one bracket up to the bumper. Loosely tighten its clamping screws using a 4 mm hex wrench.
 - e. Reinstall the screws and washers onto the each end of the rail.

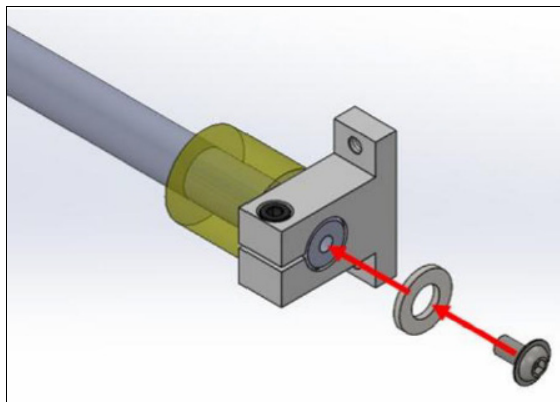
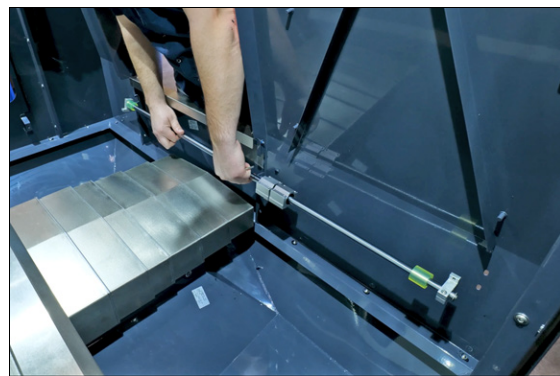


Figure 4-40: Assembling one end of the linear rail.

7. Position the linear rail assembly inside the enclosure below the door opening. Make sure that the clamping screws on the support brackets are pointing toward the top of the enclosure.



8. Loosely install the linear rail to the enclosure with four M6 × 1.0 - 12. Place one grommet washer (PN 55274) onto each screw, and then thread it from the outside of the enclosure into the support brackets. Don't completely tighten the enclosure screws yet — wait until after the door is installed.
9. Tighten the clamping screws on the support brackets.
10. Carefully move the door panel through the front of the enclosure. Tilt the bottom of the door toward the right side of the machine, and then slowly slide it onto the screws that you already installed onto the linear blocks.

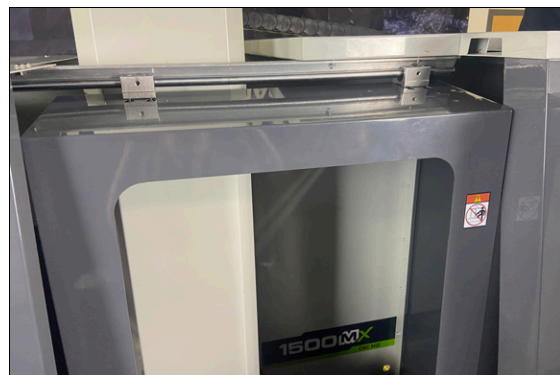


Figure 4-41: Door installed onto the linear guide blocks.

11. Install four M5 × 0.8 - 10 screws into the remaining open holes on the two linear guide blocks to secure the top of the door.
12. Align the holes of the two guide blocks on the bottom linear rail with the holes on the bottom of the door. Secure the door to the blocks with eight M5 × 0.8 - 10 screws.

4: INSTALLATION

4.5 Self-Assembled Installation

13. Identify the enclosure door linear bearing cover panel (PN 54875). Loosely install 2 M6 × 1.0 - 12 screws to the top of the door, and then slide the panel on. Tighten the screws.
14. Identify the door handle bracket (PN 51360).
15. Install the door handle bracket onto the enclosure door using 2 countersunk M6 × 1.0 - 12 screws (PN 51432).

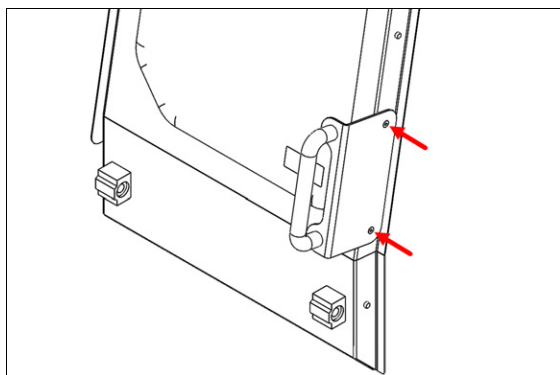


Figure 4-42: Installing the door handle bracket to the door panel.

Install the Door Latch

1. Identify the locking door switch plate bracket (PN 54877). Fasten the bracket to the top of the door panel using four M6 × 1.0 - 12 screws.
2. Align the door switch latch plate to the door switch by adjusting the mounting screws.
3. Close the enclosure door. The door switch latches closed. To open the enclosure door, remove the grommet on top right panel's **Manual Door Unlock** access hole, and use a screwdriver or other tool to unlatch the switch's release lever.

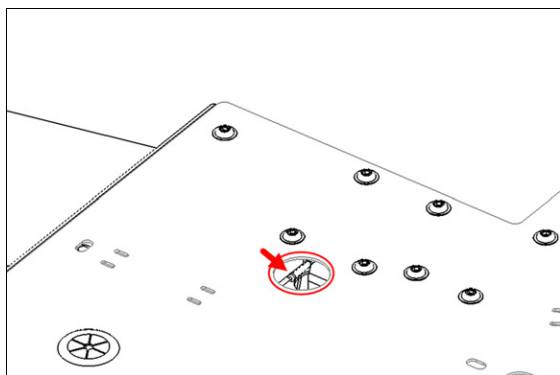


Figure 4-43: Door switch latch release lever.

Install the Door Latch Push Button

1. Identify the door push button (PN 51239). Remove the nut from the button.
2. Insert the button into the hole on the front edge of the right front panel, and secure it in place with the nut.
3. Identify the door switch wire harness. Thread the bulkhead connector end of the harness through the grommet that's installed below the door switch on the top right panel.
4. Route the harness along the top of the top right panel and into the electrical cabinet.

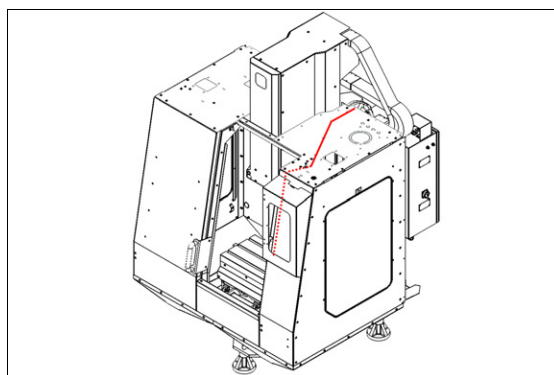


Figure 4-44: Routing the door switch push button's wire harness.

5. Inside the electrical cabinet, connect the bulkhead connector into the **Machine Door** outlet.
6. Connect the male and female connectors from the wire harness to the door switch itself (on the top right panel).
7. Connect the loose end of the harness to the button installed on the right front panel.
8. Identify the door button bracket. Install it inside of the right front panel with two M6 × 1.0 - 12 screws.
9. Secure the wire harness using zip ties on both the door button bracket and along the inside edge of the right front panel.

Connect the Enclosure Lights

1. Connect one enclosure light extension cable (PN 38389) to each light.

2. Route the flood lights' power cables across the enclosure's top panels.

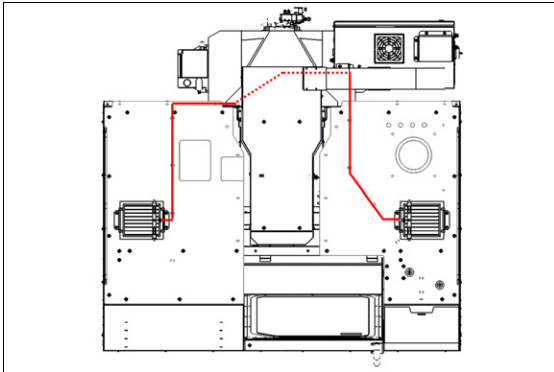


Figure 4-45: Routing the flood lights' power cables.

3. From the back of the machine, identify the **Enclosure Lights Power** outlet on the top of the machine's electrical cabinet. Remove the four screws securing the cover over the outlet with a 3 mm hex wrench, and set aside the cover and its screws.
4. Connect the power cables to the **Enclosure Lights Power** outlet. Then, reinstall the outlet cover.

Mount the Operator Console

Before installing the operator console onto the enclosure, we recommend powering off the machine and disconnecting the cables that you previously connected in order to properly route the cables between the console and the machine.

1. Disconnect the three cables (power, Ethernet, and emergency stop) from the console that you previously connected.
2. Install the two hinges onto the back of the operator console. The short side of each hinge attaches to the operator console.



Figure 4-46: Installing the hinges onto the operator console.

Note: The hinges are stiff — we recommend using an adjustable wrench to carefully bend each hinge to approximately 90 degrees before installing it on the machine.

3. With an assistant, lift the operator console and position it onto the console mount on the right side of the enclosure. One person should support the weight while the other aligns the hinges with the mounting holes. Secure the console to the mount.



Figure 4-47: Mounting the operator console onto the enclosure.

4. Route the loose end of the power, Ethernet, and emergency stop cables to the back of the enclosure. The cables route through the rectangular opening in the operator console mount and then up through the circular opening on the top of the mount. The operator console's power brick should rest on the inside ledge of the mount for support.



Figure 4-48: Routing the cables through the top operator console mount and to the top of the enclosure.

4: INSTALLATION

4.5 Self-Assembled Installation

5. Route the ATC USB cable from the back of the machine and through the openings on the operator console mount.
6. Bundle the cables inside the operator console mount together using zip ties.
7. Install the mouse panel onto the front of the operator console using two M4 screws. Place the keyboard and mouse onto the panels.
8. Install the jog shuttle panel onto the front of the operator console using two M4 screws. Place the magnetic jog pendant onto the panel.
9. Open the operator console's hinged front panel.
10. Route the loose ends of the USB cables from the keyboard, mouse, and (if equipped) ATC into the operator console. Connect them to the USB ports on the controller.



Tip! If you have a hardwired Ethernet connection for network access (not required for machine operation), connect it to the LAN 2 port inside the operator console now.

11. Close and secure the operator console's hinged front panel.
12. Route the Emergency Stop cable, the Ethernet cable, and the operator console's power cable along the top of the enclosure and to the electrical cabinet.
13. Connect the Emergency Stop cable to the **Emergency Stop** connector on the top of the electrical cabinet.
14. Connect the Ethernet cable to the **Controller Communications** connector on the top of the electrical cabinet.
15. Connect the operator console's power cord to the **Console Power** outlet on the side of the electrical cabinet.
16. Bundle all of the cables on the top of the enclosure together, using zip ties at regular intervals to secure them neatly. If you haven't already done so, now is a good time to secure the door switch cable that you routed earlier.
17. Identify the cable channel (PN 54883). Place it on top of the bundled cables, and secure it to the top right panel with three M6 × 1.0 - 12 screws.

Install the Chip Tray Center Kick Plate

1. Identify the Air Gun Kit (PN 51443).
2. Install the chip tray center kick plate to the chip trays using four M6 × 1.0 - 12 screws.
3. Identify the air gun holster assembly.

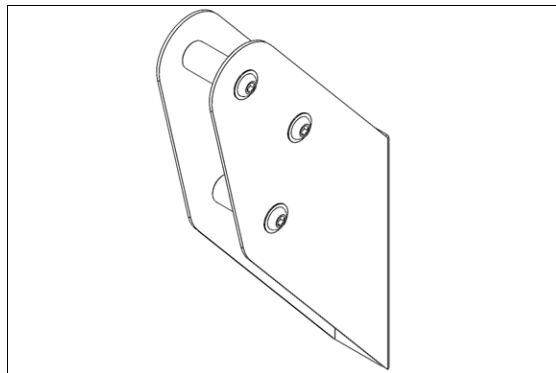


Figure 4-49: Air gun holster.

4. Install the air gun holster to the front right enclosure panel using two M6 × 1.0 - 12 screws using a T-handle hex wrench.

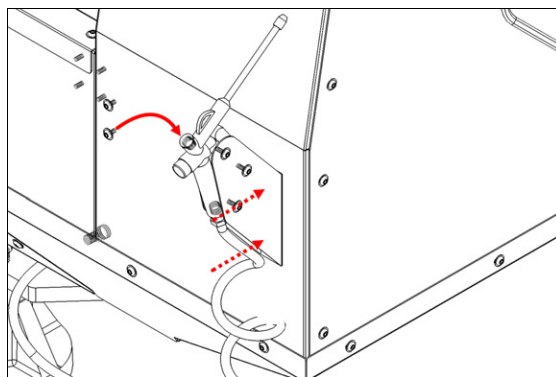


Figure 4-50: Installing the air gun holster on the front right enclosure panel.

5. Identify the coiled airline for the air gun hose. If the airline has a Euro fitting on the end, cut it off with snips.
6. Attach the coiled hose onto the air gun using a 13 mm wrench. Then, stow the air gun on the air gun holster.
7. Route the loose end of the coiled hose to the bulkhead fitting on the center kick plate.

- Route the air supply line underneath the chip trays to the machine's air manifold.

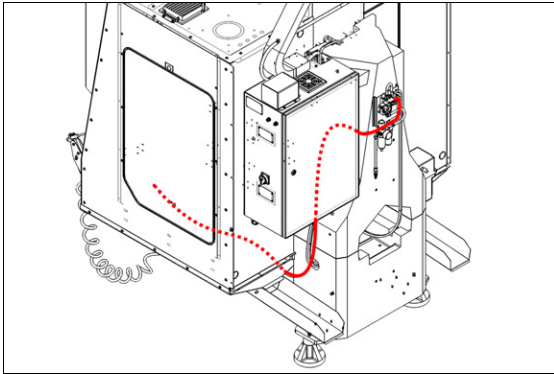


Figure 4-51: Routing the air supply line from the pressure regulator to the air gun.

Install the Windows

Note: We recommend installing the coolant washdown kit before installing the windows. Go to "Install the Automatic Chip Tray Washdown Kit" (page 92), and then come back to this section to finish the enclosure installation.

- Identify the enclosure windows (PN 54928) and the edge-mount finger pulls (PN 53864).
- Install the window through the slots in each top panel. Lightly press the window into the window frame's channel.

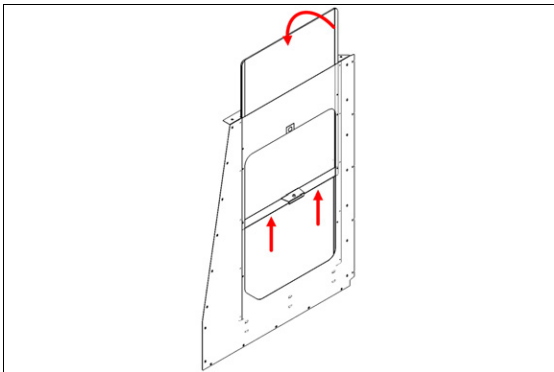


Figure 4-52: Installing the window into the slot of the top panel.

- Install the finger pull onto the bottom of each window.
- Identify the four enclosure window pins (PN 51534).
- Install one window pin on either side of the enclosure windows using the pin's magnet.

4.5.2 Set Up the PathPilot Controller

Before operating your machine, configure in PathPilot the date, time, keyboard language.

Specify the Date and Time

- If you haven't yet done so, turn the key on the top of the operator console into the setup mode position. You can identify which mode the controller is in by referencing the **Status** read-only field.



Figure 4-53: PathPilot indicates the controller's current mode.

- From the PathPilot interface, on the **Main** tab, in the **MDI Line DRO** field, type `ADMIN DATE`. Then select the **Enter** key.

The **Time and Date Settings** dialog box displays.

Note: Before using any **ADMIN** commands, you must release the Emergency Stop. Rotate the Emergency Stop button one quarter turn to release it.

- Complete the fields in the **Time and Date Settings** dialog box, and then select **Close**.

Specify the Keyboard Language

By default, the keyboard language is set to English.

To specify a different keyboard language:

- From the PathPilot interface, on the **Main** tab, in the **MDI Line DRO** field, type `ADMIN KEYBOARD`. Then select the **Enter** key. The **Keyboard Preferences** dialog box displays.
- Select the **Layouts** tab and select the desired language. If the language you want is not listed, select **Add** to specify the language. Then, select **Close**.

Update PathPilot

We're constantly updating PathPilot to bring you more features. Before operating your machine, update to the latest version.

- Confirm that the PathPilot controller is powered on and out of **Reset** mode.

4: INSTALLATION

4.5 Self-Assembled Installation

2. Downloading and installing an update file requires an Internet connection. From the **Status** tab, confirm that the **Internet** button LED light is on. (To configure the network, select the LED light.) Then, select **Update**.



Figure 4-54: Update button on the Status tab.

3. From the **Software Update** dialog box, select **Check Online**.

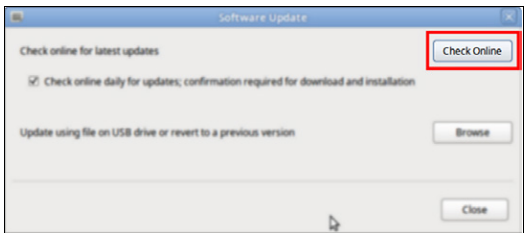


Figure 4-55: Software Update dialog box.

4. Select **Install**.



Figure 4-56: Install button on the Software Update dialog box.

The update file is downloaded, and a notification dialog box displays.

5. From the dialog box, select **OK**.
The update file is installed on the PathPilot controller.
6. Follow the on-screen instructions to restart the PathPilot controller.

4.5.3 Set Up the Automatic Oiler

Complete the following steps in the order listed:

Specify the Interval Time.....	74
Specify the Actuation Time.....	75
About the Automatic Oiler.....	75

Specify the Interval Time

The oiler distributes oil at the following times:

- When the machine is powered on
- After a specified interval

The interval time is the amount of time, in minutes, that the oiler waits between oil applications.

Note: If your machine will be unused for a long period of time (like overnight), we recommend powering off the machine to avoid over-lubricating the system.

1. Refer to "About the Automatic Oiler" (page 259) for recommended interval and actuation times.
2. On the oiler's control panel, push and hold either of the **Minutes Adjustment** buttons. It doesn't matter which button you push.

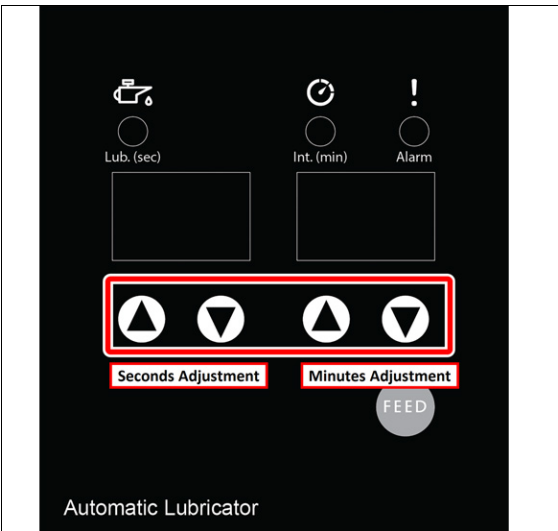


Figure 4-57: Automatic oiler control panel.

The oiler beeps.

3. While looking at the **Minutes** display, do one of the following:
- To increase the interval time, push the **Up Arrow**.
 - To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the interval time to less than five minutes.

Specify the Actuation Time

The actuation time is the amount of time, in seconds, that the oiler distributes oil during an oil application.

1. Refer to "About the Automatic Oiler" (page 259) for recommended interval and actuation times.
2. On the oiler's control panel, push and hold either of the **Seconds Adjustment** buttons. It doesn't matter which button you push.
The oiler beeps.
3. While looking at the **Seconds** display, do one of the following:
 - To increase the interval time, push the **Up Arrow**.
 - To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the actuation time to more than three minutes.

About the Automatic Oiler

The automatic oiler is powered whenever the machine is powered on. To prevent the excess use of oil, we recommend powering off the machine at the end of day to prevent the automatic oiler from continuing to pump oil overnight.

The automatic oiler has the following settings:

- 100% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)



Note: Each time the machine is powered on, it pumps oil for the amount of time equal to the actuation time. For this reason, we recommend setting the lubrication interval to 480 minutes (8 hours). This ensures that the machine has enough oil for a full eight-hour shift each time the machine is powered on.

- Actuation time: 7 seconds
- 75% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)
 - Actuation time: 5 seconds

- 50% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)
 - Actuation time: 4 seconds

About Actuation Time

The lubrication interval and actuation time are set from the factory for a 100% duty cycle. These settings assume the machine is running at maximum velocity 24 hours per day, 7 days per week. As a result, this tends to deliver more oil than is needed for most applications. To prevent excess usage of oil, we recommend that you adjust the actuation time of the automatic oiler to match the duty cycle that best fits your application.

When you estimate the duty cycle that best fits your application, the best indicator is the actual spindle run time for the machine during a standard eight-hour shift. Consider what percentage of that eight-hour shift the machine is running and cutting material versus the time spent for changing parts, setting up fixtures, and idle down time.

4: INSTALLATION
4.6 Factory-Assembled Machine Setup

4.6 FACTORY-ASSEMBLED MACHINE SETUP

IMPORTANT! This section is for customers who purchased the machine pre-assembled from the factory. If you are assembling the machine yourself, many of the procedures that you'll need are not included in this section. Go to "Self-Assembled Installation" (page 58) for information specific to self-assembled machines.

Complete the following steps in the order listed:

4.6.1 Set Up the PathPilot Controller 76
4.6.2 Set Up the Automatic Oiler 77
4.6.3 Set Up the Flood Coolant Tank 78

4.6.1 Set Up the PathPilot Controller

Before operating your machine, configure in PathPilot the date, time, keyboard language.

Specify the Date and Time

- 1. If you haven't yet done so, turn the key on the top of the operator console into the setup mode position. You can identify which mode the controller is in by referencing the Status read-only field.



Figure 4-58: PathPilot indicates the controller's current mode.

- 2. From the PathPilot interface, on the Main tab, in the MDI Line DRO field, type ADMIN DATE. Then select the Enter key. The Time and Date Settings dialog box displays.

Note: Before using any ADMIN commands, you must release the Emergency Stop. Rotate the Emergency Stop button one quarter turn to release it.

- 3. Complete the fields in the Time and Date Settings dialog box, and then select Close.

Specify the Keyboard Language

By default, the keyboard language is set to English. To specify a different keyboard language:

- 1. From the PathPilot interface, on the Main tab, in the MDI Line DRO field, type ADMIN KEYBOARD. Then select the Enter key. The Keyboard Preferences dialog box displays.
- 2. Select the Layouts tab and select the desired language. If the language you want is not listed, select Add to specify the language. Then, select Close.

Update PathPilot

We're constantly updating PathPilot to bring you more features. Before operating your machine, update to the latest version.

- 1. Confirm that the PathPilot controller is powered on and out of Reset mode.
- 2. Downloading and installing an update file requires an Internet connection. From the Status tab, confirm that the Internet button LED light is on. (To configure the network, select the LED light.) Then, select Update.



Figure 4-59: Update button on the Status tab.

- 3. From the Software Update dialog box, select Check Online.

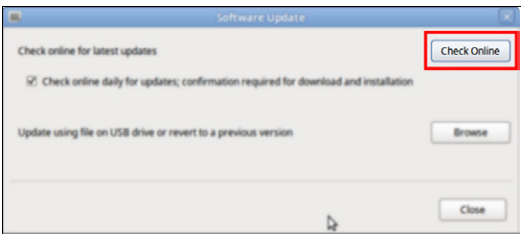


Figure 4-60: Software Update dialog box.

4. Select **Install**.



Figure 4-61: Install button on the Software Update dialog box.

The update file is downloaded, and a notification dialog box displays.

5. From the dialog box, select **OK**.

The update file is installed on the PathPilot controller.

6. Follow the on-screen instructions to restart the PathPilot controller.

4.6.2 Set Up the Automatic Oiler

Complete the following steps in the order listed:

Specify the Interval Time	77
Specify the Actuation Time	77
About the Automatic Oiler	78

Specify the Interval Time

The oiler distributes oil at the following times:

- When the machine is powered on
- After a specified interval

The interval time is the amount of time, in minutes, that the oiler waits between oil applications.

Note: If your machine will be unused for a long period of time (like overnight), we recommend powering off the machine to avoid over-lubricating the system.

1. Refer to "About the Automatic Oiler" (page 259) for recommended interval and actuation times.
2. On the oiler's control panel, push and hold either of the **Minutes Adjustment** buttons. It doesn't matter which button you push.

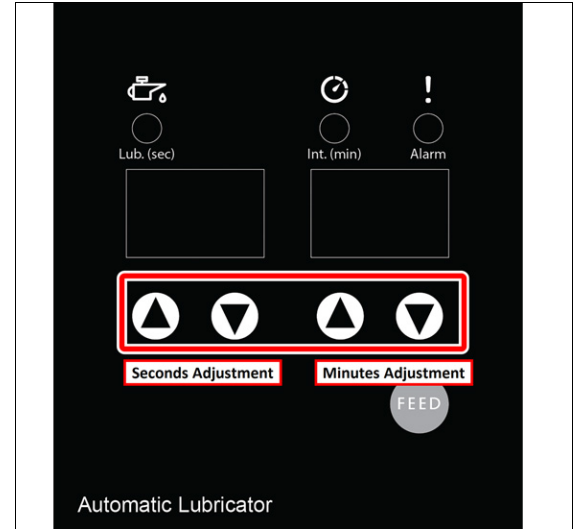


Figure 4-62: Automatic oiler control panel.

The oiler beeps.

3. While looking at the **Minutes** display, do one of the following:

- To increase the interval time, push the **Up Arrow**.
- To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the interval time to less than five minutes.

Specify the Actuation Time

The actuation time is the amount of time, in seconds, that the oiler distributes oil during an oil application.

1. Refer to "About the Automatic Oiler" (page 259) for recommended interval and actuation times.
2. On the oiler's control panel, push and hold either of the **Seconds Adjustment** buttons. It doesn't matter which button you push.
The oiler beeps.
3. While looking at the **Seconds** display, do one of the following:
 - To increase the interval time, push the **Up Arrow**.
 - To decrease the interval time, push the **Down Arrow**.

NOTICE! Pressure Hazard: To avoid potential equipment damage, don't set the actuation time to more than three minutes.

4: INSTALLATION

4.6 Factory-Assembled Machine Setup

About the Automatic Oiler

The automatic oiler is powered whenever the machine is powered on. To prevent the excess use of oil, we recommend powering off the machine at the end of day to prevent the automatic oiler from continuing to pump oil overnight.

The automatic oiler has the following settings:

- 100% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)



Note: Each time the machine is powered on, it pumps oil for the amount of time equal to the actuation time. For this reason, we recommend setting the lubrication interval to 480 minutes (8 hours). This ensures that the machine has enough oil for a full eight-hour shift each time the machine is powered on.

- Actuation time: 7 seconds
- 75% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)
 - Actuation time: 5 seconds
- 50% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)
 - Actuation time: 4 seconds

About Actuation Time

The lubrication interval and actuation time are set from the factory for a 100% duty cycle. These settings assume the machine is running at maximum velocity 24 hours per day, 7 days per week. As a result, this tends to deliver more oil than is needed for most applications. To prevent excess usage of oil, we recommend that you adjust the actuation time of the automatic oiler to match the duty cycle that best fits your application.

When you estimate the duty cycle that best fits your application, the best indicator is the actual spindle run time for the machine during a standard eight-hour shift. Consider what percentage of that eight-hour shift the machine is running and cutting material versus the time spent for changing parts, setting up fixtures, and idle down time.

4.6.3 Set Up the Flood Coolant Tank

Complete the following steps in the order listed:

Required Tools.....	78
Unpack the Coolant Tank Crate.....	78
Install the Flood Coolant Pump.....	78
Install the Flood Coolant Filter.....	79
Make Coolant Connections.....	79

Required Tools

- Hammer
- Metric hex wrench set
- Phillips screwdriver
- Pliers
- Punch
- Thread seal tape

Unpack the Coolant Tank Crate

1. Remove the silver screws from the top and one end of the crate with a Phillips screwdriver (or an impact gun and a bit).
2. Remove the chip baskets and any cardboard boxes included in the crate. Set them all aside.
3. Remove the wooden clamps that secure one end of the coolant tank to the pallet with a Phillips screwdriver (or an impact gun and a bit).
4. Release the brake on each of the coolant tank's four casters. Slide the coolant tank out from under the wooden clamps that are still installed on the crate.
5. With an assistant, carefully lift the coolant tank from the pallet and lower it to the floor.
6. Put the chip baskets back into the coolant tank.

Install the Flood Coolant Pump

1. Identify the 1/4 hp flood coolant pump (PN 51384) and the elbow fitting included in this kit. Wrap the threads of the elbow fitting with thread seal tape, and hand tighten it onto the flood coolant pump.

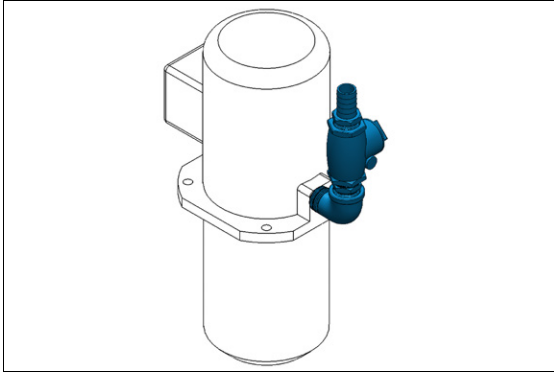


Figure 4-63: Coolant pump assembly.

2. On the coolant tank, identify the location for the flood coolant pump as shown in the following image. Remove the mounting plate, and knock out the center with a hammer and punch. Then, reinstall the mounting plate onto the coolant tank.

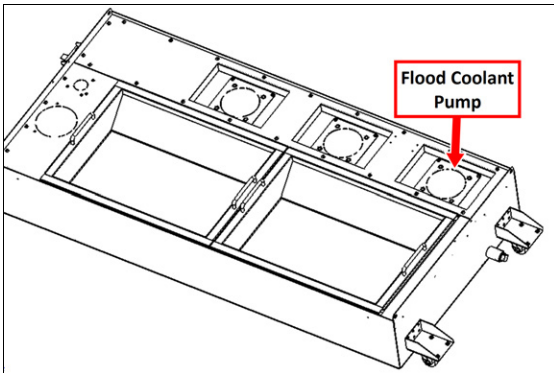


Figure 4-64: First mounting plate used for the flood coolant pump.

3. Put the coolant pump into its mounting plate. Orient the pump so that the elbow fitting is nearest to the end of the coolant tank. Secure the coolant pump to the mounting plate with four M10 × 1.5 - 20 socket head cap screws (PN 32625) and an 8 mm hex wrench.

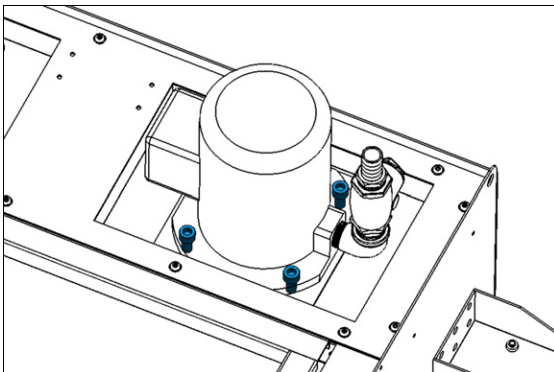


Figure 4-65: Flood coolant pump installed into the coolant tank.

Install the Flood Coolant Filter

1. Identify the flood coolant filter included with this kit. Place it next to the flood coolant pump on the coolant tank, and secure it to the rear mounting holes with four M5 × 0.8 - 10 flanged button head cap screws (PN 38205) and a 3 mm hex wrench.

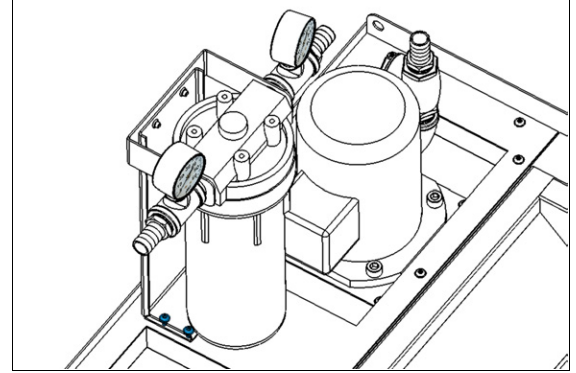


Figure 4-66: Filter installed next to the pump.

2. Identify the 1 ft long, 1 in. OD hose included with this kit. Install it between the barbed fittings on the outlet of the coolant pump and the inlet of the coolant filter with hose clamp springs (PN 51558) and a pair of pliers.

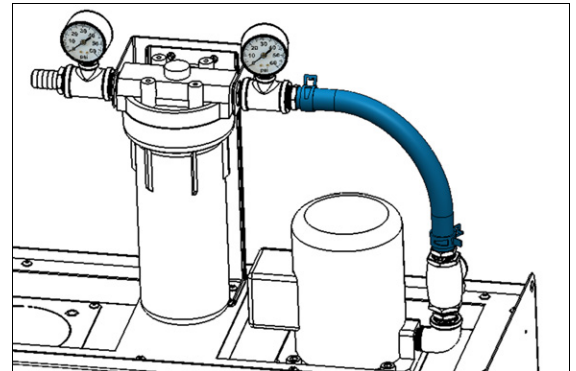


Figure 4-67: Hose installed between the filter and the pump.

3. Move the coolant tank off to the side of the machine. You'll move it to its final location behind the machine later in this procedure.

Make Coolant Connections

1. Roll the coolant tank behind the machine and push it up to the back of the machine against the base casting. Center the tank behind the machine, making sure that the chip chutes dump into the chip baskets.

4: INSTALLATION

4.6 Factory-Assembled Machine Setup

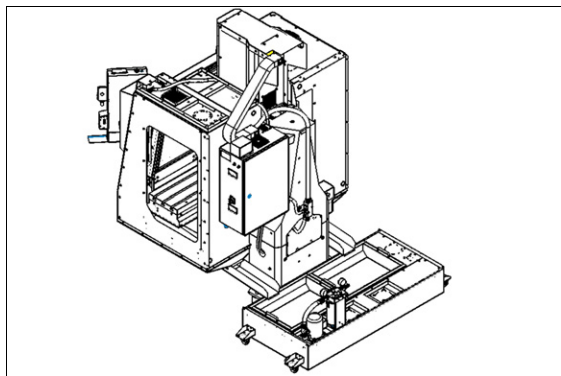


Figure 4-68: Coolant tank behind the machine.

2. Identify the 4 ft, 1 in. OD hose (PN 51608) included with this kit. Connect one end to the barbed fitting on the outlet of the coolant filter with a pair of pliers and one hose clamp (PN 51558).

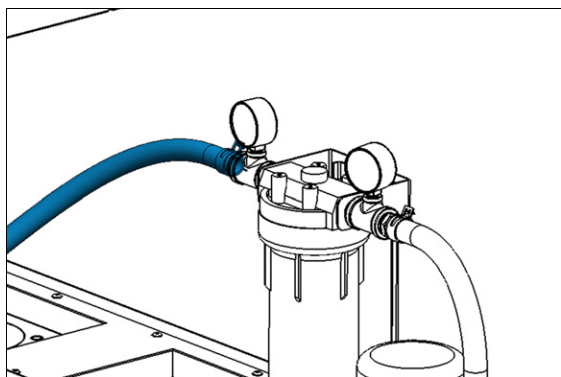


Figure 4-69: Hose connected to the coolant filter.

3. Connect the loose end of the hose to the barbed fitting on the bottom of the coolant manifold with a pair of pliers and one hose clamp (PN 51558).

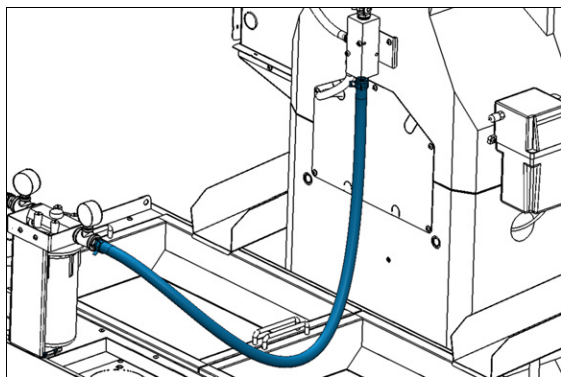


Figure 4-70: Hose connected to the coolant manifold.

4. Plug the flood coolant pump's power cable into the **Flood Coolant Power** outlet on the side of the electrical cabinet (on the side that's closest to the column).

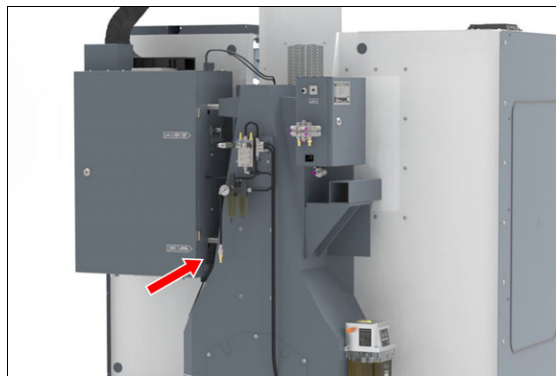


Figure 4-71: Flood coolant outlet on the side of the electrical cabinet.

5. After setting up the flood coolant kit, test the enclosure for coolant leaks. Identify and seal any areas requiring extra sealant.

Note: If you received a factory-assembled machine, the enclosure panels may have shifted during the shipping process. It's crucial to test the enclosure for leaks even if your machine was assembled at the factory.

4.7 VERIFY THE INSTALLATION

To properly validate the core installation of your machine, you must understand how to power on and off the machine and use the controls.

Complete the following steps in the order listed:

4.7.1 Power on the Machine	81
4.7.2 Verify Axes Function	82
4.7.3 Verify Spindle Function	82
4.7.4 Power off the Machine	83

4.7.1 Power on the Machine

1. Use a multimeter to verify that the electrical service in your location meets the following requirements. If your location does not meet these requirements, do not install the machine. Instead, you must consult with a local electrician about your options.
 - **Primary Power Required** Single-Phase 230 Vac, 50/60 Hz
 - **Recommended Circuit Amperage** 30 A breaker
2. Connect the machine's mains power cable to the verified electrical service.
3. Find the Main Disconnect switch, and then remove the hang tag.

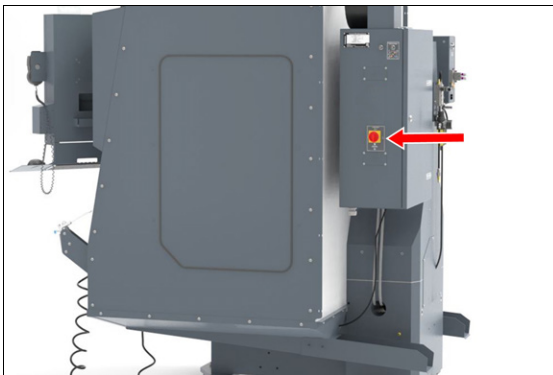


Figure 4-72: The Main Disconnect switch on the side of the machine's electrical cabinet.

4. Turn the Main Disconnect switch to **ON**.

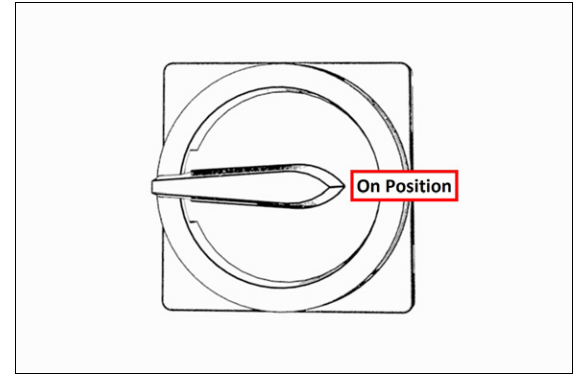


Figure 4-73: Example of the Main Disconnect switch in the On position.

Mains power is now connected to the machine.

5. Push the Power button on the PathPilot operator console, if it's not already powered on.



Figure 4-74: Power button on the top of the operator console (to the left of the key).

6. Rotate the Emergency Stop button one-quarter turn clockwise to release it.



Figure 4-75: Emergency Stop button.

4: INSTALLATION

4.7 Verify the Installation

- Push the blue Reset button to enable the machine.



Figure 4-76: Reset button.

The axis drives are now powered on.

- Verify that the blue Reset LED comes on. From the PathPilot interface, on the **Status** tab, verify that the **Machine OK** light changes from yellow to green.

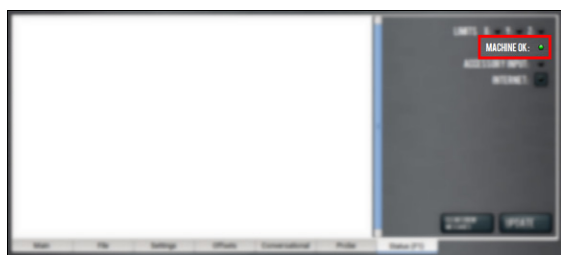


Figure 4-77: Machine OK light on the Status tab.

- Select **Reset**.

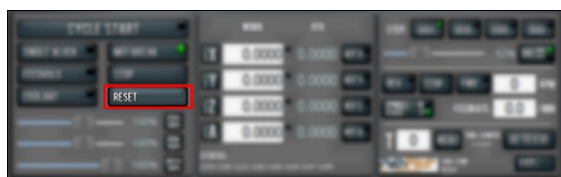


Figure 4-78: Reset button.

This initializes the connection between the machine and controller.

4.7.2 Verify Axes Function

You must confirm that the axes correctly operate.

- Close the enclosure door.
- Select Z on the manual pulse generator (MPG) and rotate the hand wheel clockwise to move the spindle head up (Z+).
- Remove and discard the M6 fasteners securing the shipping bracket to the column and the machine table with a 4 mm hex wrench. Jog the machine table towards the operator a few inches.

- Remove and discard the shipping block from the machine table.
- Use the MPG to verify axis motion:
 - Select X on the MPG. Rotating the hand wheel moves the table left (X+) and right (X-).
 - Select Y on the MPG. Rotating the hand wheel moves the table towards you (Y+) and away from you (Y-).
 - Select Z on the MPG. Rotating the hand wheel moves the spindle head up (Z+) and down (Z-).

4.7.3 Verify Spindle Function

You must confirm that the spindle correctly operates.

- Close and latch the spindle door.
- From the PathPilot interface, in the **RPM** DRO field, type 500. Then select the **Enter** key.

Note: If you have an operator console, confirm that the **RPM** knob isn't set to 0%. If it is, turn the **RPM** knob.

- Select **FWD**.



Figure 4-79: Spindle controls.

The spindle rotates clockwise (viewed from above) at 500 rpm.

- Select **STOP**.
The spindle stops rotating.
- Select **REV**.
The spindle rotates counterclockwise (viewed from above) at 500 rpm.
- Select **STOP**.
The spindle stops rotating.
- In the **RPM** DRO field, type 1000. Then select the **Enter** key.
- Select **FWD**.
The spindle rotates clockwise (viewed from above) at 1000 rpm.
- Repeat the procedure at 1000 rpm.

4.7.4 Power off the Machine

1. Push the Emergency Stop button to lock it into the disabled position.



Figure 4-80: Emergency Stop button.

With the Emergency Stop button in the disabled position all motion and spindle function stops, the Reset button is disabled, and the blue Reset LED goes off. From the PathPilot interface, on the **Status** tab, the **Machine OK** light illuminates yellow.

2. From the PathPilot interface, select **Exit**.
3. When prompted, select **OK**.
4. Once the PathPilot interface indicates that it's safe to power off the machine, turn the Main Disconnect switch to **OFF**.

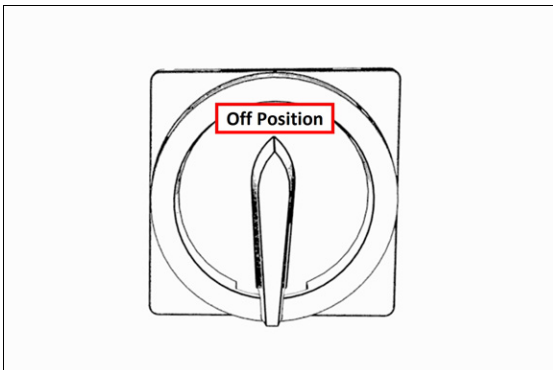


Figure 4-81: Example of the Main Disconnect switch in the Off position.

Mains power is disconnected from the machine.

4: INSTALLATION

4.8 Install Accessory Components

4.8 INSTALL ACCESSORY COMPONENTS

Install accessory components in the order specified, skipping any components that you don't have or that were installed at the factory for you.

4.8.1 Install the Flood Coolant Kit	84
4.8.2 Install the Automatic Chip Tray Washdown Kit	92
4.8.3 Install the Through-Spindle Coolant (TSC) Kit	95
4.8.4 Install the Chip Conveyor Kit	101
4.8.5 Install the Oil Skimmer Kit	106
4.8.6 Install the Mist Collector Kit	108
4.8.7 Install the MQL Kit	111
4.8.8 Install the Automatic Tool Changer (ATC)	115
4.8.9 Install the microARC 6	127
4.8.10 Install the Probe and Tool Setter	132

4.8.1 Install the Flood Coolant Kit

Complete the following steps in the order listed:

Required Tools	84
Unpack the Coolant Tank Crate	84
Install the Flood Coolant Pump	84
Install the Flood Coolant Filter	85
Install the Coolant Manifold	85
Install the Y-Axis Washdown Nozzle	86
Install the Flood Coolant Ring	88
Install the Manual Sprayer	89
Make Coolant Connections	92

Required Tools

- 13 mm wrench
- 17 mm wrench
- 30 mm wrench
- 32 mm wrench
- Hammer
- Metric hex wrench set
- Painter's tape
- Phillips screwdriver
- Pliers
- Punch
- Thread seal tape

Unpack the Coolant Tank Crate

1. Remove the silver screws from the top and one end of the crate with a Phillips screwdriver (or an impact gun and a bit).

2. Remove the chip baskets and any cardboard boxes included in the crate. Set them all aside.
3. Remove the wooden clamps that secure one end of the coolant tank to the pallet with a Phillips screwdriver (or an impact gun and a bit).
4. Release the brake on each of the coolant tank's four casters. Slide the coolant tank out from under the wooden clamps that are still installed on the crate.
5. With an assistant, carefully lift the coolant tank from the pallet and lower it to the floor.
6. Put the chip baskets back into the coolant tank.

Install the Flood Coolant Pump

1. Identify the 1/4 hp flood coolant pump (PN 51384) and the elbow fitting included in this kit. Wrap the threads of the elbow fitting with thread seal tape, and hand tighten it onto the flood coolant pump.

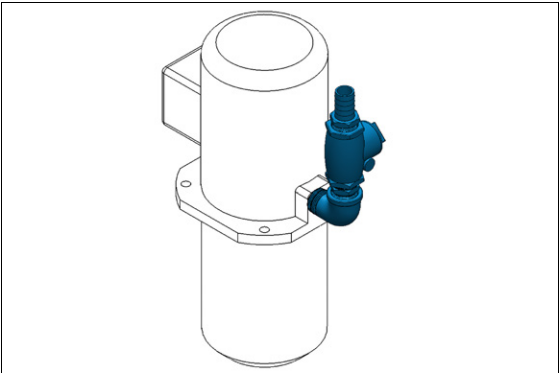


Figure 4-82: Coolant pump assembly.

2. On the coolant tank, identify the location for the flood coolant pump as shown in the following image. Remove the mounting plate, and knock out the center with a hammer and punch. Then, reinstall the mounting plate onto the coolant tank.

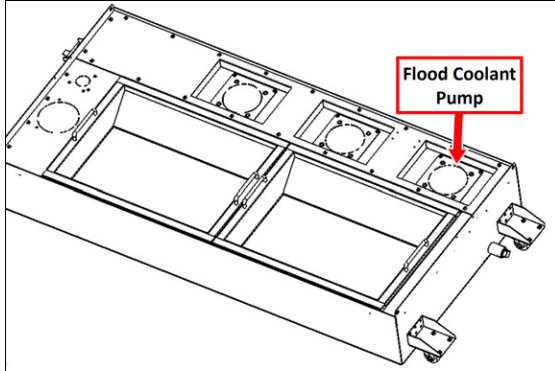


Figure 4-83: First mounting plate used for the flood coolant pump.

3. Put the coolant pump into its mounting plate. Orient the pump so that the elbow fitting is nearest to the end of the coolant tank. Secure the coolant pump to the mounting plate with four M10 × 1.5 - 20 socket head cap screws (PN 32625) and an 8 mm hex wrench.

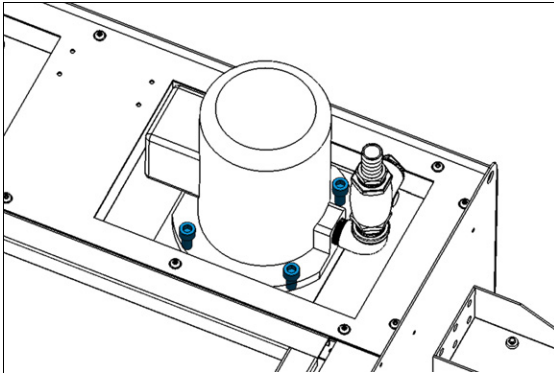


Figure 4-84: Flood coolant pump installed into the coolant tank.

Install the Flood Coolant Filter

1. Identify the flood coolant filter included with this kit. Place it next to the flood coolant pump on the coolant tank, and secure it to the rear mounting holes with four M5 × 0.8 - 10 flanged button head cap screws (PN 38205) and a 3 mm hex wrench.

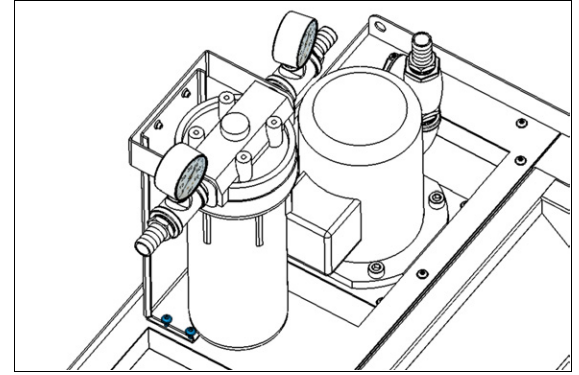


Figure 4-85: Filter installed next to the pump.

2. Identify the 1 ft long, 1 in. OD hose included with this kit. Install it between the barbed fittings on the outlet of the coolant pump and the inlet of the coolant filter with hose clamp springs (PN 51558) and a pair of pliers.

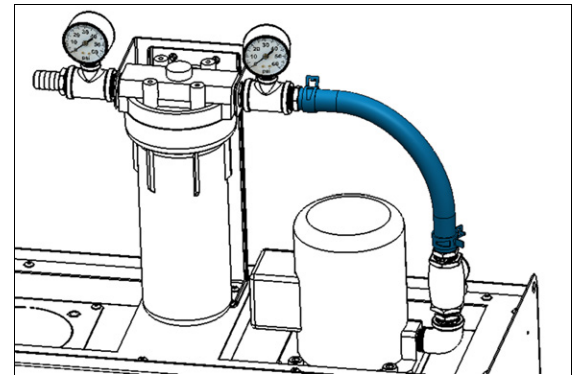


Figure 4-86: Hose installed between the filter and the pump.

3. Move the coolant tank off to the side of the machine. You'll move it to its final location behind the machine later in this procedure.

Install the Coolant Manifold

1. On the back of the machine column, identify the bottom set of M6 threaded inserts. Identify two standoffs (PN 51566) included with this kit. Then, install and tighten them into the back of the machine column with a 13 mm wrench.

4: INSTALLATION

4.8 Install Accessory Components

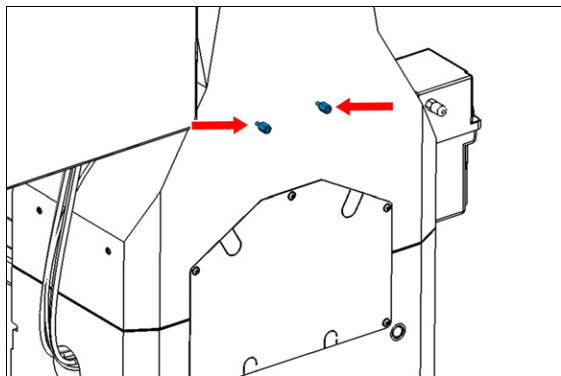


Figure 4-87: Two standoffs installed on the back of the machine column.

2. Identify the coolant manifold assembly (PN 51565) and two M6 × 1 - 10 flanged button head cap screws (PN 51616) included with this kit. Secure the manifold to the standoffs with a 4 mm hex wrench. Make sure that the manifold is oriented with the mounting screws toward the top of the machine.

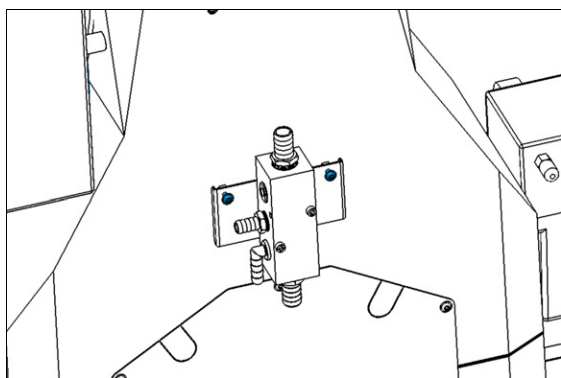


Figure 4-88: Coolant manifold assembly installed onto the standoffs.

Install the Y-Axis Washdown Nozzle

1. On the front of the machine, identify the Y-axis rear way cover. Remove and set aside the six M6 screws securing the Y-axis rear way cover to the column with a 4 mm hex wrench. Slide the cover toward the table to gain access to the back of the cover.

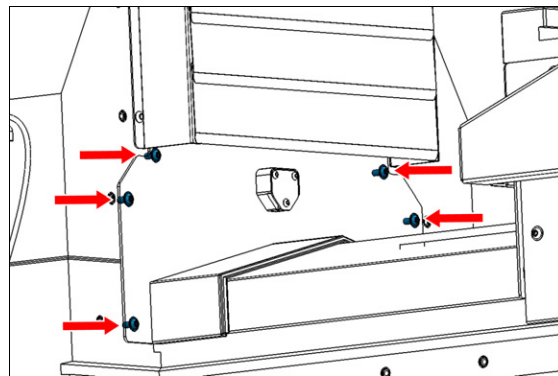


Figure 4-89: Screws securing the Y-axis rear way cover to the column.

2. Remove the three M4 screws that secure the cover plate onto the way cover with a 2.5 mm hex wrench. Discard the screws and the cover plate.

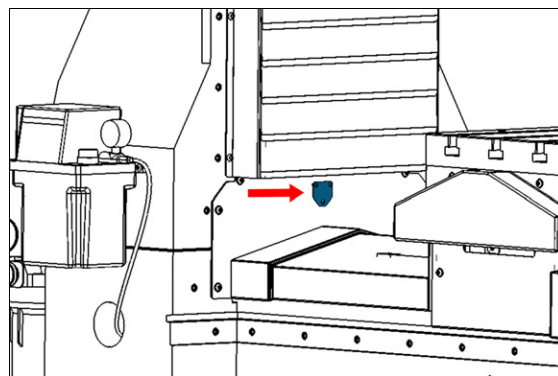


Figure 4-90: Y-axis washdown cover plate.

3. Identify the Y-axis washdown block that's included in this kit.

IMPORTANT! The Y-axis washdown block contains 3 very small O-rings. Pay attention and use care when handling to prevent dropping or losing the O-rings. We recommend taping the assembly together to prevent the cover plate from falling off while you're installing the block onto the machine.

4. Tape the washdown block assembly together. Then, remove the three hex nuts from the back of the washdown block with a 2.5 mm hex wrench and a 7 mm wrench. Do not remove the screws from the block because these help hold the O-rings in place. The nuts are for shipping purposes and can be discarded.



Figure 4-91: Y-axis washdown block assembly temporarily taped together.

5. Install the washdown block on the front of the Y-axis cover with its three pre-installed screws and a 2.5 mm hex wrench. Remove the painter's tape from the washdown block.

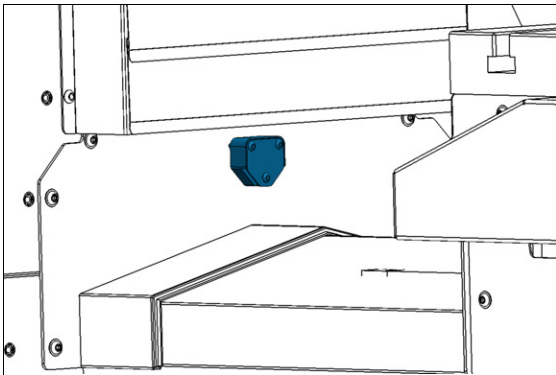


Figure 4-92: Washdown block installed on the front of the Y-axis cover.

6. Re-install the Y-axis rear way cover to the column of the machine with the six M6 screws that you set aside earlier.
7. On the back of the machine, identify the rear access panel. Remove the five M6 screws from the panel and set the screws aside.

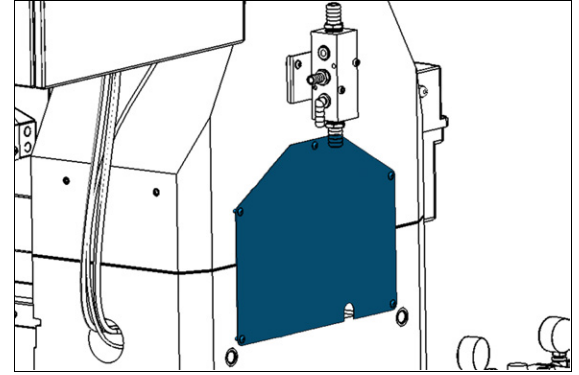


Figure 4-93: Rear access panel on the back of the machine.

8. Knock out the upper left knock-out on the access panel with a hammer and punch.
9. Identify the 20 in. long, 5/8 in. OD hose (PN 51516) included in this kit. From the back of the machine, install the hose to the 1/2 in. barbed hose fitting on the back of the washdown block with one hose clamp (PN 51679) and a pair of pliers.

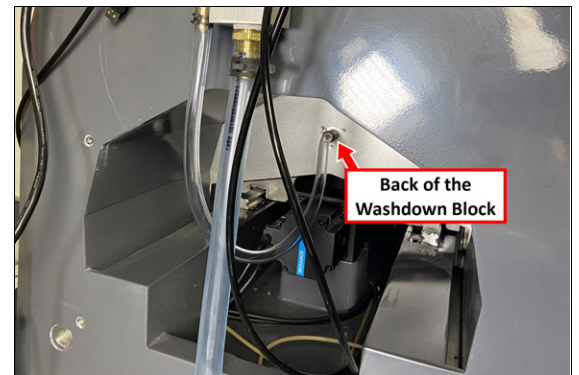


Figure 4-94: Hose installed on the washdown block.

10. Route the loose end of the hose through the knock-out in the access panel, and re-install the access panel onto the back of the machine with the five M6 screws that you set aside earlier.

4: INSTALLATION

4.8 Install Accessory Components

11. Install the loose end of the hose onto the 1/2 in. barbed elbow fitting on the coolant manifold with a hose clamp (PN 51679) and a pair of pliers.

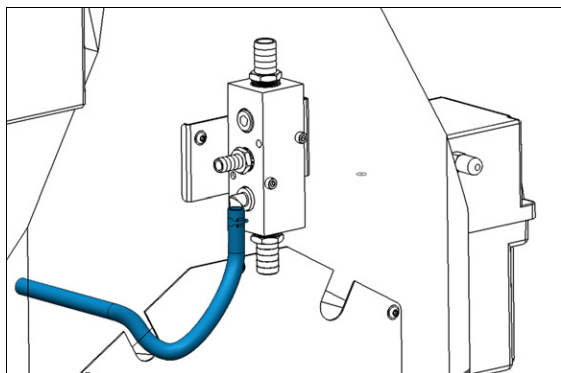


Figure 4-95: Hose installed onto the coolant manifold.

Install the Flood Coolant Ring

1. On the front of the machine, remove the nine M6 flanged button head cap screws on the side of the right side spindle cover with a 4 mm hex wrench. Set the screws aside. Then, loosen or remove the three screws on the bottom of the spindle head cover. Remove the cover, and set it aside.

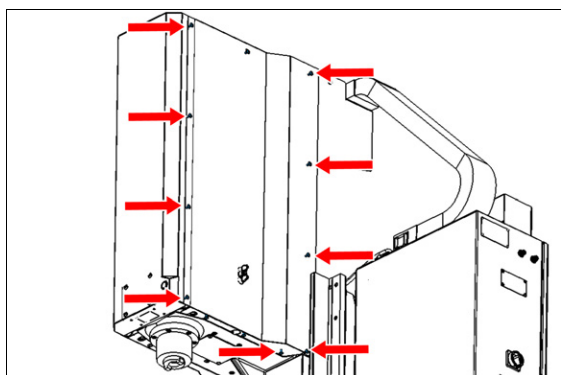


Figure 4-96: Screws securing the right side spindle cover.

2. Identify the four swiveling coolant nozzles (PN 38348) and the coolant ring that are included in the kit. Install each nozzle into the coolant ring with a 17 mm wrench. Tighten the nozzles until they're pointed toward the center of the ring.

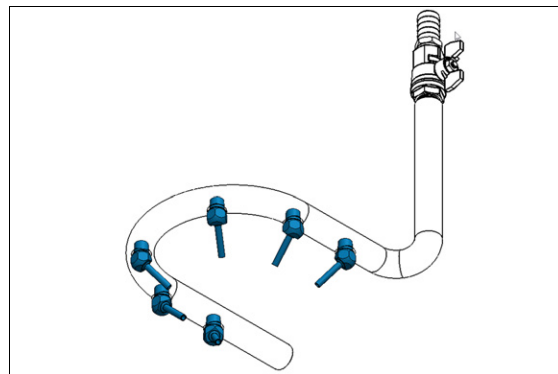


Figure 4-97: Coolant ring assembly.

3. Identify the two coolant ring mounts (PN 51249) included in this kit. Place one coolant ring mount on the right side of the coolant ring (the side opposite of the barbed fitting), and loosely install the coolant ring mount on the right side of the spindle with a 4 mm hex wrench.



Figure 4-98: Coolant ring mount.

4. Slide the remaining coolant ring mount under the left side of the coolant ring. Then, tighten both screws with a 4 mm hex wrench.

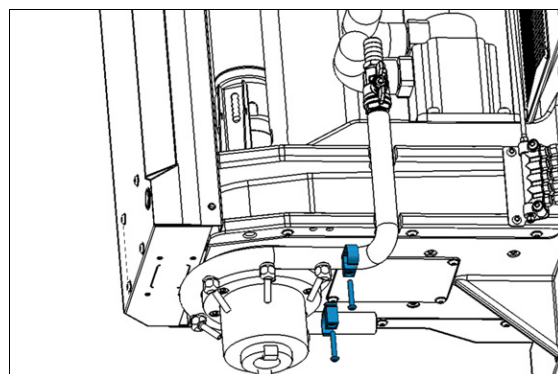


Figure 4-99: Coolant ring mounted to the bottom of the spindle head casting.

- Identify the 12 ft, 1 in. OD hose (PN 51608) and two hose clamps (PN 51558) included with this kit. Install one end of the hose to the barbed hose fitting on the top of the coolant manifold block with one hose clamp and a pair of pliers.

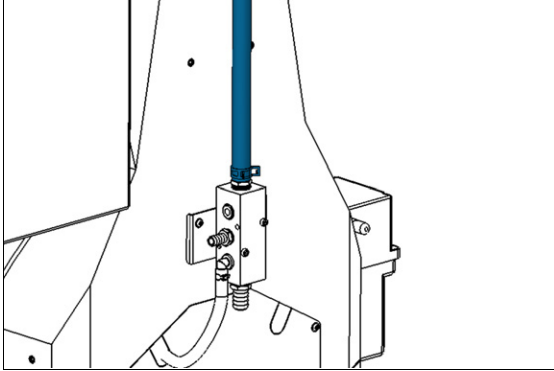


Figure 4-100: Hose installed onto the coolant manifold block.

- Route the loose end of the hose toward the top of the electrical cabinet. Starting at the electrical cabinet, feed the hose through the energy chain toward the back side of the spindle head cover.

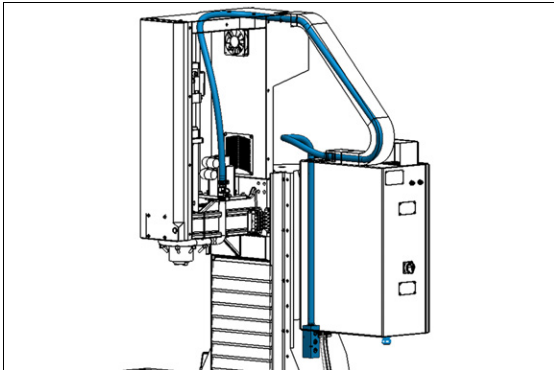


Figure 4-101: Hose routing to the electrical cabinet.

Tip! It may be helpful to have the Z-axis raised to its maximum height, and you may need to remove several of the energy chain covers with a flat-blade screwdriver (or similar) to help route the hose through the energy chain.

- Route the hose through the opening at the top left side of the spindle head cover.
- Connect the hose to the barbed fitting on the coolant ring using a pair of pliers and a hose clamp (PN 51558). Make sure the hose clamp is facing toward the front of the machine. If it's not, it may cause interference when

you reinstall the side panel.

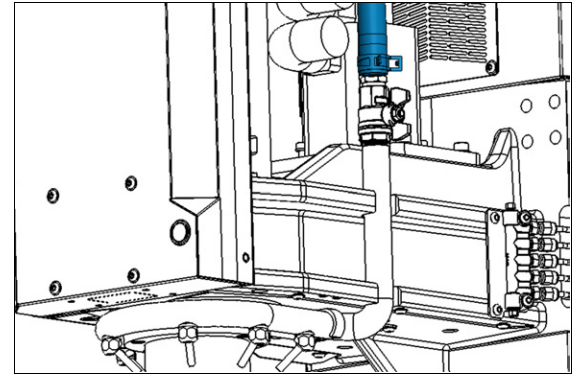


Figure 4-102: Hose connected to the coolant ring.

- On the side of the coolant ring, turn the handle for the valve to the vertical position. This allows the handle to slip through the hole in the right side spindle cover.
- Pull the slack from the coolant tube out at the back of the machine.
- On the right side spindle cover, remove the knock-out hole with a hammer and punch.



Figure 4-103: Knock-out hole on the right side spindle cover.

- Reinstall the right side spindle cover panel with a 4 mm hex wrench and the screws that you set aside earlier. It may help to loosen the three bottom screws even further when you're reinstalling the panel.

Install the Manual Sprayer

- On the top right panel of the enclosure, identify the hole for the washdown bulkhead fitting. Remove the plastic grommet.

4: INSTALLATION

4.8 Install Accessory Components

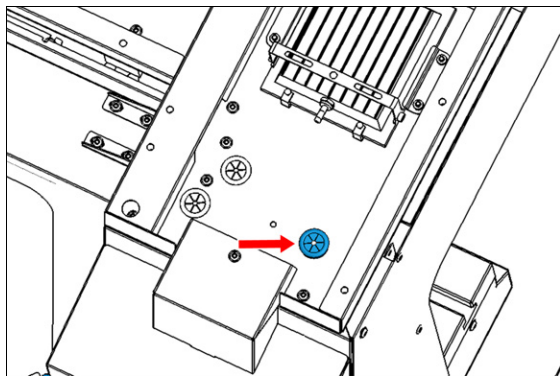


Figure 4-104: Grommet over the washdown bulkhead fitting hole.

2. Identify the hose nozzle bracket (PN 51621) and one M6 × 1 - 12 flanged button head cap screw (PN 38206) included in this kit. Mount the bracket to the underside of the top right enclosure panel with a 4 mm hex wrench. Make sure to align the large hole in the bracket with the hole in the top right enclosure panel.

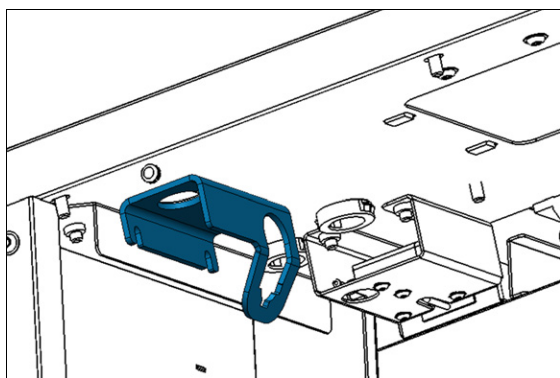


Figure 4-105: Hose nozzle bracket mounted to the top right enclosure panel.

3. Identify the bulkhead fitting included in this kit. Remove the locking nut from the bulkhead fitting, and install the fitting into the hole in the top of the enclosure panel with the elbow fitting on top of the enclosure. Turn the elbow fitting so that it's pointing at a 45 degree angle toward the spindle and the back of the machine. Then, re-install and tighten the locking nut onto the bulkhead fitting with a 30 mm wrench.

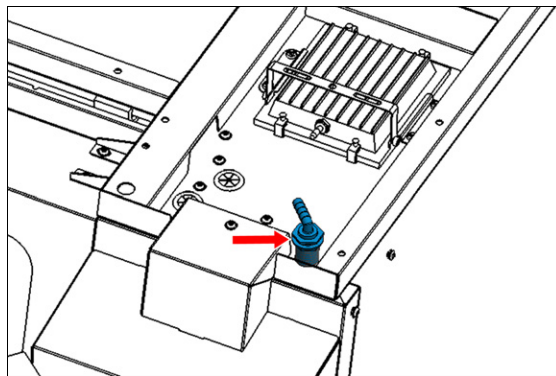


Figure 4-106: Fitting installed into the hole on the top of the enclosure panel.



Note: You can use a 1-1/8 in. socket wrench as a replacement for a 30 mm wrench.

4. Identify the hose bibb fitting included in this kit. Apply thread sealant tape to its threads. Then, tighten the hose bibb into the bulkhead fitting with a 32 mm wrench on top of the enclosure and an 8 mm hex wrench inserted into the end of the hose bibb. Tighten until the outlet of the hose bibb is pointing toward the front of the enclosure.

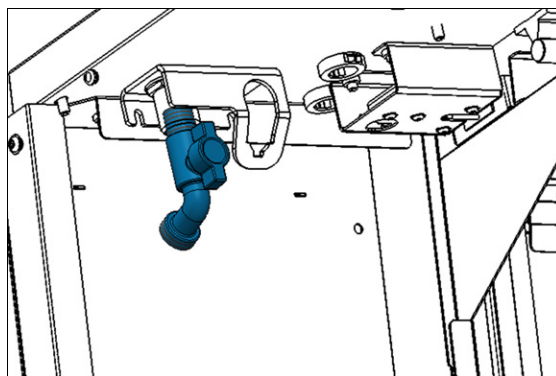


Figure 4-107: Bibb fitting installed into the bulkhead fitting.

5. Identify the hose and manual sprayer assembly that's included in this kit. Verify that the rubber seal is installed in the fitting on the loose end of the hose.

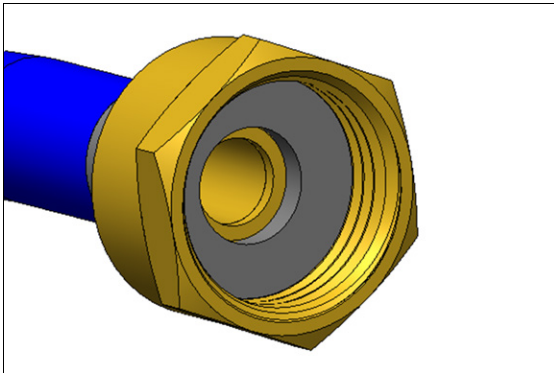


Figure 4-108: Rubber seal in the hose.

6. Connect the hose to the outlet of the hose bibb, and hang the manual sprayer in the loop of the bracket.

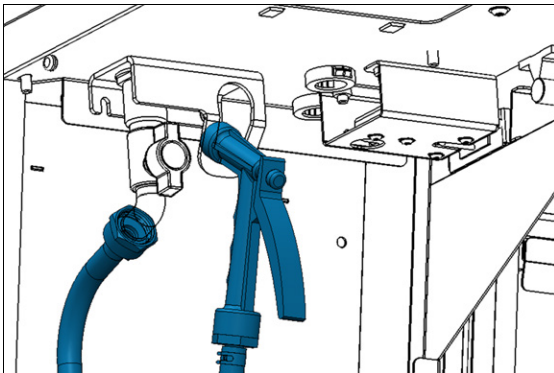


Figure 4-109: Hose connected to the bibb fitting.

7. Identify the 7 ft, 5/8 in. OD hose (PN 51516) included in this kit. Connect one end to the straight 1/2 in. barbed hose fitting on the side of the coolant manifold at the back of the machine with a pair of pliers and a hose clamp.

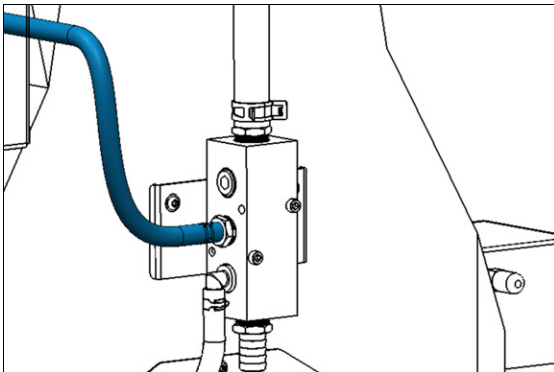


Figure 4-110: Hose connected to the coolant manifold.

8. Route the loose end of the hose as follows:
 - a. From the coolant manifold, route hose in between the electrical cabinet and the column casting and then back toward the enclosure.

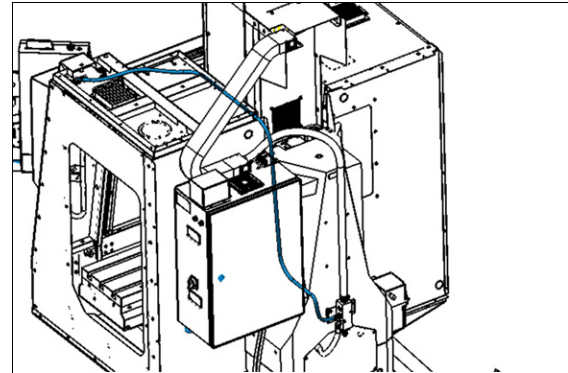


Figure 4-111: Hose routing to the front of the electrical cabinet.

- b. Then, route it up toward the top of the enclosure, and through the hole near the spindle head (on the back of the top right enclosure panel).

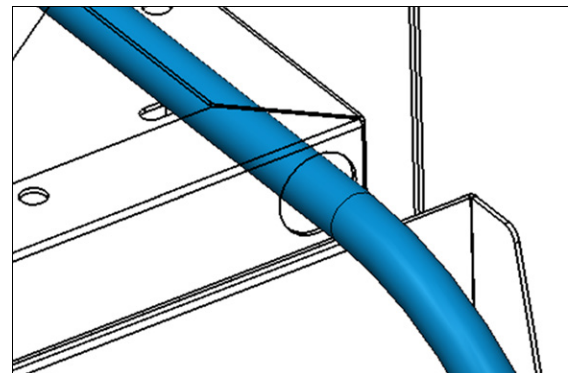


Figure 4-112: Hose routing detail.

- c. Finally, route the hose through the gap along the edge of the panel.

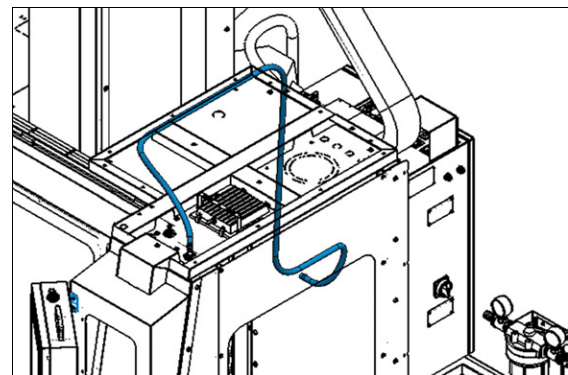


Figure 4-113: Hose routing detail.

4: INSTALLATION

4.8 Install Accessory Components

9. Connect the loose end of the hose to the elbow fitting using a pair of pliers and a hose clamp.

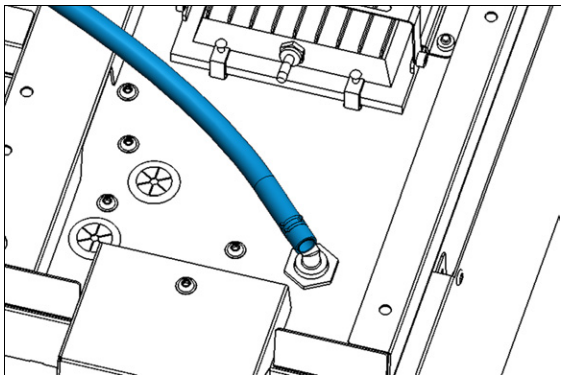


Figure 4-114: Hose connected to the elbow fitting.

Make Coolant Connections

1. Roll the coolant tank behind the machine and push it up to the back of the machine against the base casting. Center the tank behind the machine, making sure that the chip chutes dump into the chip baskets.

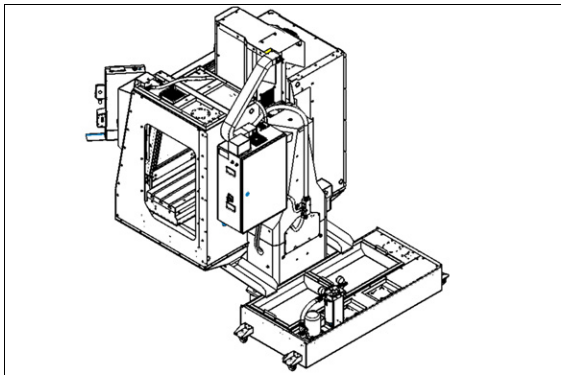


Figure 4-115: Coolant tank behind the machine.

2. Identify the 4 ft, 1 in. OD hose (PN 51608) included with this kit. Connect one end to the barbed fitting on the outlet of the coolant filter with a pair of pliers and one hose clamp (PN 51558).

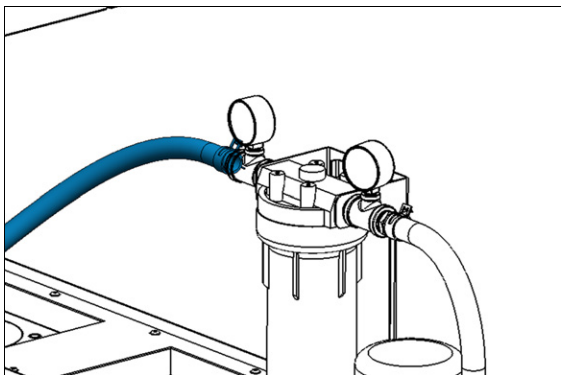


Figure 4-116: Hose connected to the coolant filter.

3. Connect the loose end of the hose to the barbed fitting on the bottom of the coolant manifold with a pair of pliers and one hose clamp (PN 51558).

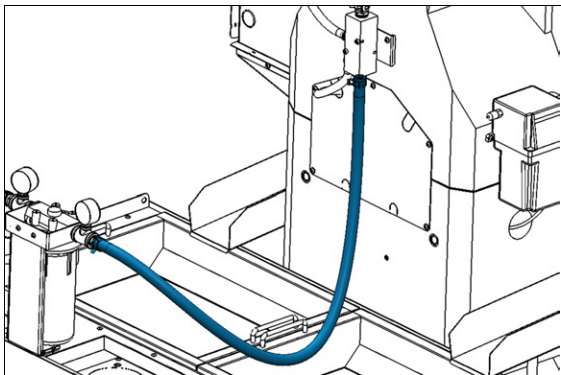


Figure 4-117: Hose connected to the coolant manifold.

4. Plug the flood coolant pump's power cable into the **Flood Coolant Power** outlet on the side of the electrical cabinet (on the side that's closest to the column).

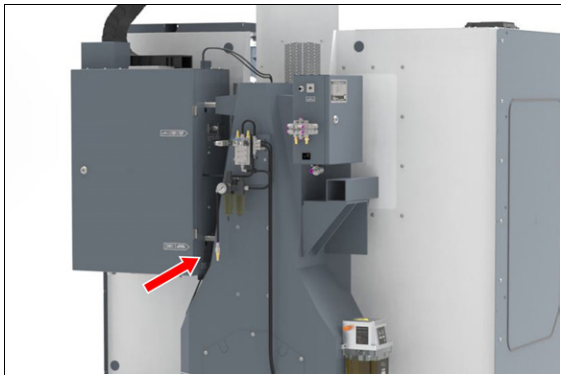


Figure 4-118: Flood coolant outlet on the side of the electrical cabinet.

5. After setting up the flood coolant kit, test the enclosure for coolant leaks. Identify and seal any areas requiring extra sealant.

4.8.2 Install the Automatic Chip Tray Washdown Kit

Complete the following steps in the order listed:

Before You Begin	92
Required Tools.....	93
Install the Washdown Pump.....	93
Install the Washdown Coolant Filter.....	93
Install the Coolant Hoses and Fittings.....	93
Install the Washdown Bars.....	94
Make Connections.....	95

Before You Begin

Make sure that:

- The machine is in its final location, with sufficient space for access to the electrical cabinet and coolant tank.
- The machine has been rough leveled.
- The flood coolant kit is installed.
- The enclosure is installed, with either the windows open or the window panels removed.

Required Tools

- Metric hex wrench set
- Pliers
- 13 mm wrench

Install the Washdown Pump

1. On the coolant tank, identify the location for the washdown coolant pump as shown in the following image.

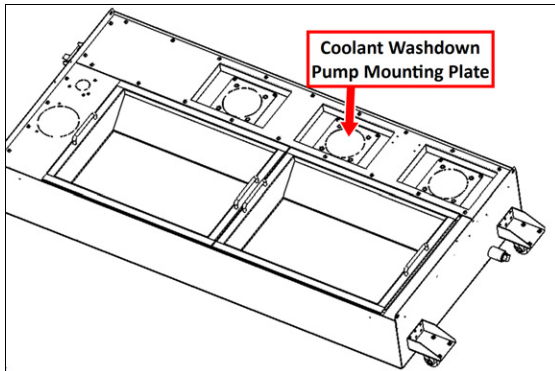


Figure 4-119: Middle mounting plate used for the washdown pump.

2. Identify the 1/2 hp washdown coolant pump (PN 51385) included with this kit. Put it into the tank with the pump's outlet pointing toward the third coolant pump mounting plate. Secure the pump onto the tank with four M8 × 1.25 - 20 socket head cap screws (PN 52436) and a 6 mm hex wrench.

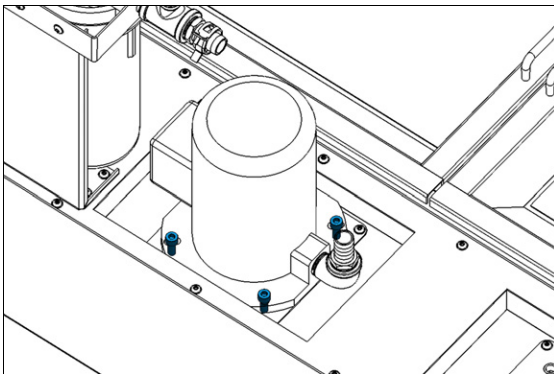


Figure 4-120: Washdown pump installed into the coolant tank.

Install the Washdown Coolant Filter

1. Identify the washdown coolant filter included with this kit. Place it next to the washdown coolant pump on the coolant tank, and secure it to the rear mounting holes with four M5 × 0.8 - 10 flanged button head cap screws (PN 38205) and a 3 mm hex wrench.
2. Identify the 1 ft long, 1 in. OD hose included with this kit. Install it between the barbed fittings on the outlet of the coolant pump and the inlet of the coolant filter with a pair of pliers and a hose clamp spring (PN 51558) on either side.

Install the Coolant Hoses and Fittings

1. Identify the two standoffs (PN 51556) included in this kit.
2. On the back of the machine, identify the two holes as shown in the following image. Install the standoffs into the two holes with a 13 mm wrench.

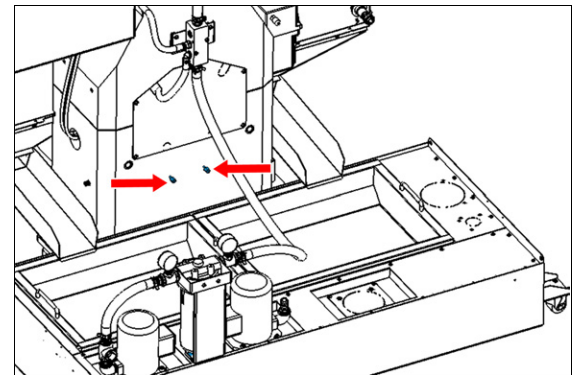


Figure 4-121: Standoffs installed onto the back of the machine.

4: INSTALLATION

4.8 Install Accessory Components

3. Identify the three hoses, one tee fitting (PN 52498), and three hose clamps (PN 51558) included in this kit. Install the hoses and the hose clamps onto the tee fitting with a pliers as shown in the following image.

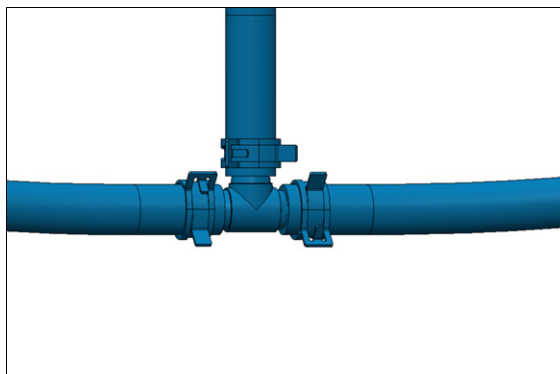


Figure 4-122: Hoses installed onto the tee fitting.

4. Identify the tee fitting bracket (PN 52500), two M6 × 1 - 10 flanged button head cap screws (PN 51616), and two loop clamps (PN 51379) included in this kit. Mount the bracket and hose assembly onto the previously installed standoffs with a 4 mm hex wrench.

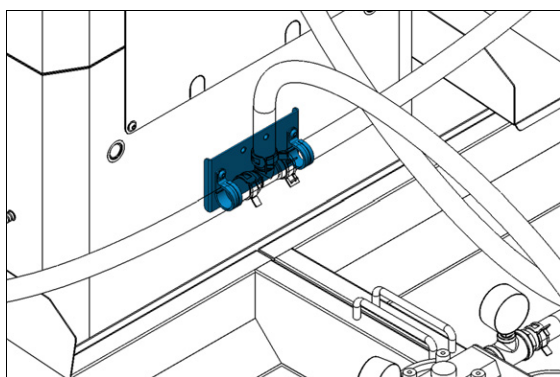


Figure 4-123: Tee fitting bracket and hose assembly installed onto the standoffs on the back of the machine.

Install the Washdown Bars

1. Open the windows on both sides of the enclosure.
2. Remove the two rubber plugs from both back panels of the enclosure.

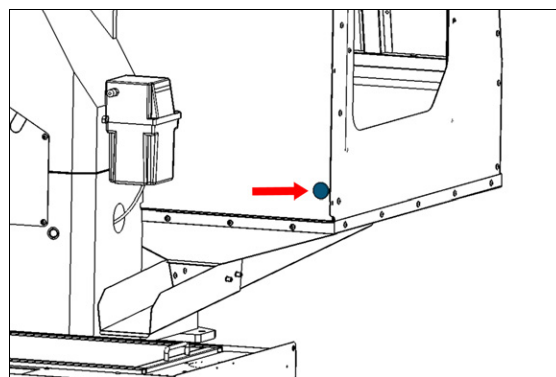


Figure 4-124: Rubber plug on the back panel of the enclosure.

3. Identify one washdown bar, three loop clamps, one pipe grommet, and three M6 screws included in this kit. Install the loop clamps onto the washdown bar as shown in the following image.

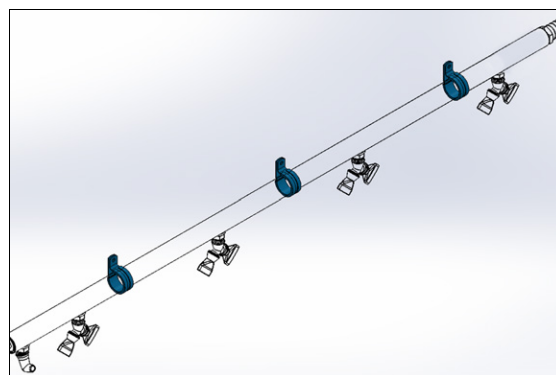


Figure 4-125: Washdown bar assembly.

4. Put one of the pipe grommets into the hole in the back panel (where you previously removed the rubber plug).
5. Slide the barbed fitting end of the washdown bar through the grommet in the back panel.

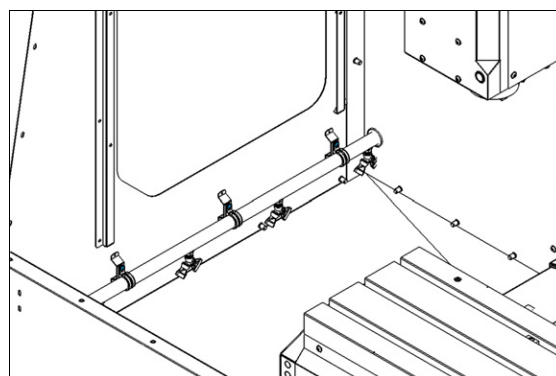


Figure 4-126: Washdown bar inside of the enclosure.

6. Loosely fasten each of the loop clamps to the side of the chip pan with three M6 screws and a 4 mm hex wrench. Turn the washdown bar so that the nozzles are pointing down toward the chip pan. Once the bar is correctly aligned, tighten all of the loop clamps.
7. Repeat Steps 3 through 6 for the washdown bar on the opposite side of the enclosure.

Make Connections

1. Connect the top hose from the tee fitting to the barbed fitting on the coolant pump with pliers and a hose clamp.

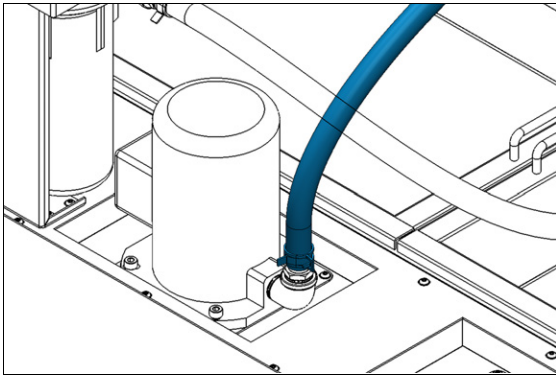


Figure 4-127: Top hose connected to the coolant pump.

2. Connect the loose end of each remaining hose on the tee fitting to the barbed fitting on either side of the enclosure with pliers and a hose clamp.

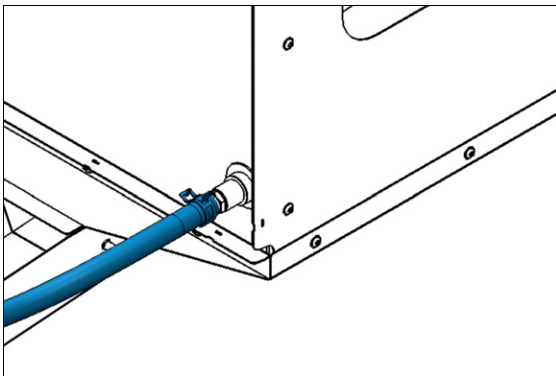


Figure 4-128: Coolant pump's hose connected to the barbed fitting on the outside of the enclosure.

3. Plug the flood coolant pump's power cable into the **Washdown Coolant Power** outlet on the side of the electrical cabinet (on the side that's closest to the column).

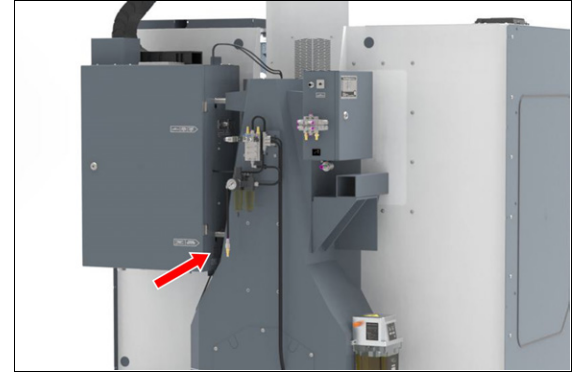


Figure 4-129: Washdown coolant power outlet on the side of the electrical cabinet.

4.8.3 Install the Through-Spindle Coolant (TSC) Kit

Complete the following steps in the order listed:

Before You Begin	95
Prerequisites	95
Required Tools	95
Unpack the Through-Spindle Coolant Kit	96
Prepare the Machine for Installation	96
Install the Coolant Pickup and Filter	96
Install the Rotary Union	97
Install the High-Pressure Hose	99
Install the Hose Bracket	100
Make Connections	100
Securely Tighten Hose Clamps	101

Before You Begin

Prerequisites

- The machine is in its final location and rough leveled.
- The following components must be installed:
 - Flood coolant kit
 - Enclosure
 - Operator console
- The ATC must **not yet** be installed.

Required Tools

- #2 Phillips screwdriver
- 5/16 in. wrench
- 13 mm open-ended wrench
- Adjustable wrench
- Engine hoist with two 500 lb (180 kg) straps, or a chain with a center hook
- Flat-blade screwdriver

4: INSTALLATION

4.8 Install Accessory Components

- Ladder
- Metric hex wrench set
- Wire snips

Unpack the Through-Spindle Coolant Kit

WARNING! Lifting Hazard: Only use suitable lifting equipment, ensuring that it's on a stable, level surface. Never lift over people. Heavy loads could tip, fall, or shift unexpectedly, causing death or serious injury.

1. The TSC pump is approximately 400 lb (180 kg). We strongly recommend lifting it from the shipping pallet with an engine hoist. Due to the uneven weight distribution (one side is heavier), have an assistant help to guide and stabilize the pump during the lift to prevent tipping or injury.



Figure 4-130: Removing the TSC pump from the pallet.

2. Remove the pallet, and slowly guide the pump to the ground.
3. Unpack the shipping box with the remaining components of the TSC kit.

Prepare the Machine for Installation

1. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the

Emergency Stop button).

- d. Bring the machine out of reset and reference it.
2. Position the table in the middle of the X- and Y- axis travels.
 3. Jog the spindle all the way down in the Z-axis.
 4. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
 5. Disconnect the machine from the shop air supply.

Install the Coolant Pickup and Filter

1. Standing behind the coolant tank, locate the coolant pump cover plate furthest to the right. Remove the four M5 screws securing the pump cover plate with a 3 mm hex wrench. Set the screws aside.

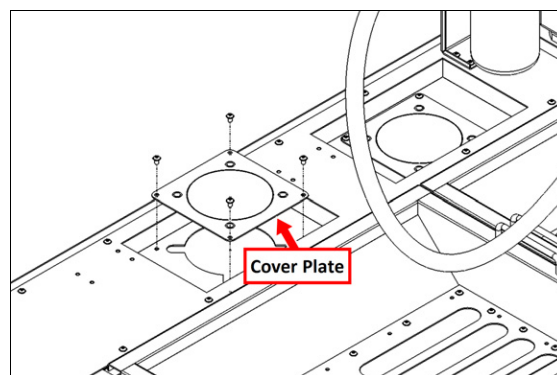


Figure 4-131: Cover plate for through-spindle coolant on the coolant tank.

2. Identify the coolant pickup assembly included in this kit. Remove the four bolts and screws that secure the assembly together with a 5/16 in. wrench. Put the basket into the coolant tank hole, then put the coolant filter on top so that the opening flap is nearest to the machine. Secure the assembly to the coolant tank with the M5 screws that you set aside and a 3 mm hex wrench.

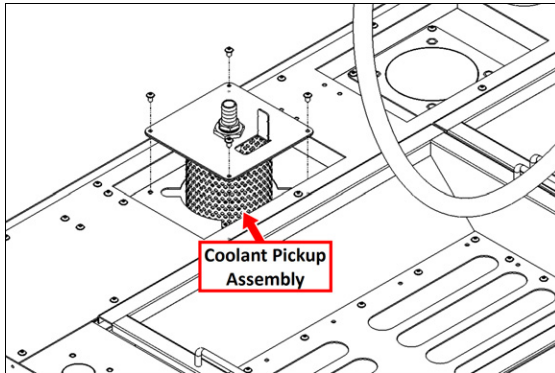


Figure 4-132: Installing the coolant pickup assembly into the coolant tank.

3. Identify the coolant filter assembly and four M5 screws included with this kit. Put it onto the coolant tank so that the inlet is facing the pickup assembly. Secure it to the coolant tank with four M5 screws and a 3 mm hex wrench.

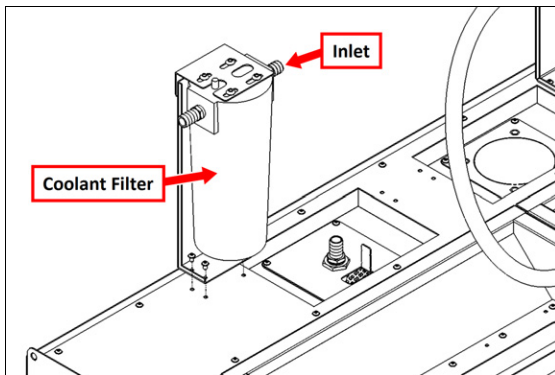


Figure 4-133: Installing the coolant filter assembly onto the coolant tank.

⚠ WARNING! High-Pressure Hazard: Ensure all hose connections are secure and properly tightened. High-pressure coolant can cause hoses to burst or become dislodged if not correctly installed, leading to serious injury or equipment damage.

4. Identify the shortest PVC hose included in this kit. Using two 1.25 in. hose clamps, connect the hose between the barbed fitting on the pickup assembly and the inlet of the filter assembly.

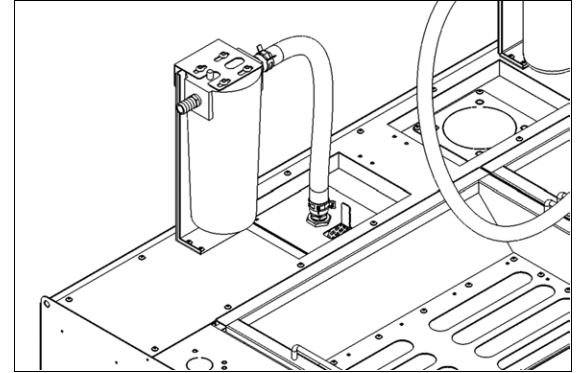


Figure 4-134: Hose connection between the coolant pickup assembly and the coolant filter.

5. Identify the longest piece of 3/4 in. ID PVC hose. Using two 1.25 in. hose clamps, connect the hose between the barbed fitting on the outlet of the filter assembly and the inlet of the TSC pump labeled **Coolant Inlet**.
6. Identify the 1/2 in. ID PVC hose. Connect one end of the hose to the barbed fitting on the TSC pump labeled **Pressure Relief** with a 1 in. hose clamp. Insert the loose end into the slot on the top of the coolant pickup assembly, and secure it to the vertical tab with two cable ties.

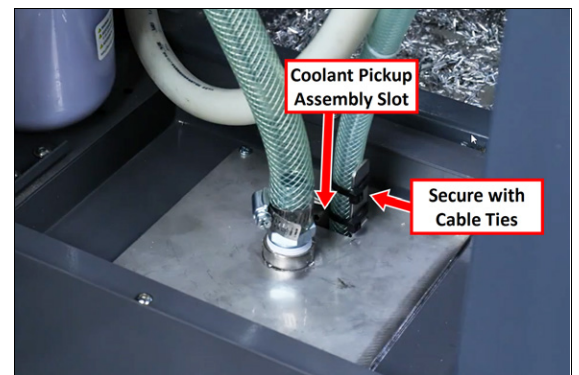


Figure 4-135: 1/2 in. ID hose installed in the coolant pickup assembly.

Install the Rotary Union

1. Remove the M6 screws that secure the right side panel of the spindle head cover using an M4 hex wrench. Loosen the two screws on the bottom (in slots). Remove the right panel and set it aside, along with all of the screws.

4: INSTALLATION

4.8 Install Accessory Components

2. From the left side panel, remove only the M6 screws securing the front edge to the front panel of the spindle head cover with an M4 hex wrench.
3. Remove the screws on the top of the front panel with an M4 hex wrench.
4. Before removing the remaining screws on the front panel, snip off the cable ties holding the power drawbar button cable along the inside edge of this panel.
5. Remove the screws along the bottom front edge of the panel and lower the panel slightly to access the cable along the top left. Snip the cable tie holding this cable in place.
6. Disconnect the power drawbar button cable from the front panel by pressing in the connector's latch and removing it from the drawbar button.



Figure 4-136: Power drawbar button cable on the front panel.

7. Remove the front panel and set it aside, along with all of the screws.
8. Remove the retaining cap from the drawbar solenoid. Let the solenoid dangle, but temporarily replace the cap to avoid losing it.

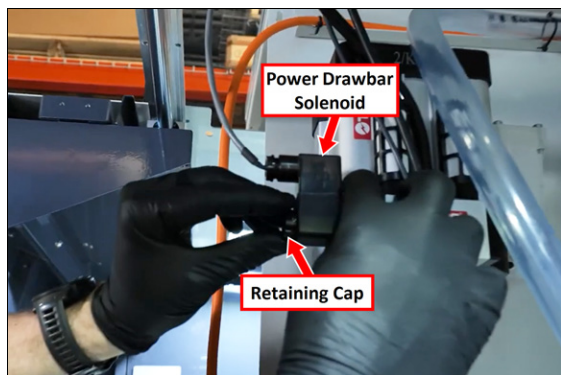


Figure 4-137: Removing the retaining cap from the drawbar solenoid.

9. Remove the four socket head cap screws that secure the power drawbar to its mounting plate using a 10 mm hex wrench. Set the screws aside.



Figure 4-138: Removing the screws securing the power drawbar to its mounting plate.

10. Press down on the push-to-connect fitting and disconnect the air line by pulling it out.

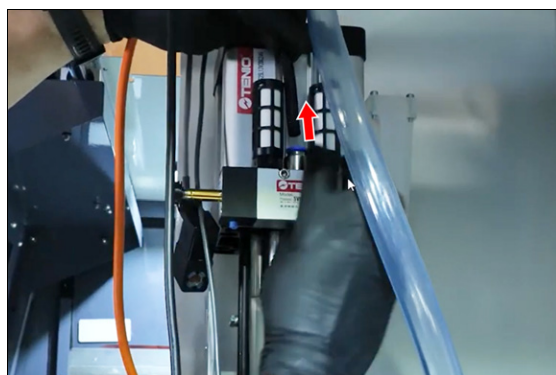


Figure 4-139: Removing the air line from the push-to-connect fitting.

11. Lift the power drawbar away from the mounting plate, being careful not to tug on the cables. Then set the power drawbar aside.
12. Identify the piece of 1/4 in. OD tubing and the rotary union included in this kit. Insert one end of the tube into the push-to-connect fitting on the rotary union.

13. Orient the rotary union so that the fittings are pointed toward the rear of the machine.

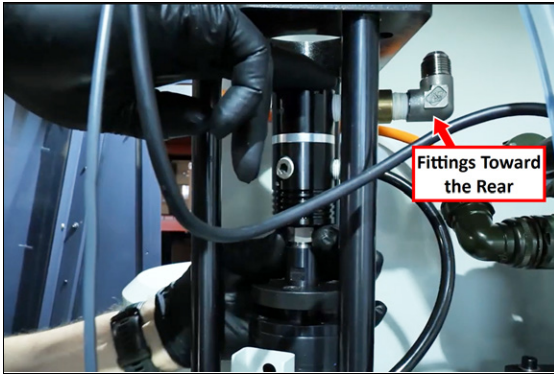


Figure 4-140: Orienting the rotary union.

14. Thread the rotary union into the top of the spindle and tighten with a 22 mm wrench.



IMPORTANT! The rotary union has a left-hand thread.

15. Re-install the power drawbar. Align the slot in the power drawbar extension with the fittings of the rotary union. Then secure it to the mounting plate with its original four screws that you set aside earlier.

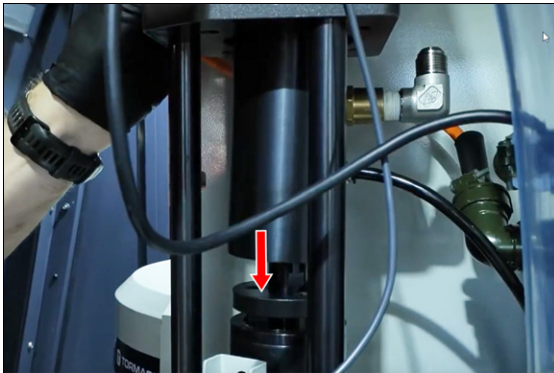


Figure 4-141: Aligning the power drawbar with the rotary union.

16. Reinstall the drawbar solenoid and secure it with its original retaining cap.
17. Reconnect the air line into the power drawbar's push-to-connect fitting.

Install the High-Pressure Hose

1. The high-pressure hose is routed through the energy chain. To avoid damaging other cables, we strongly recommend removing several of the retaining covers from the chain. Gently pry up each cover with a flat-

blade screwdriver and lift them off, continuing down the chain, including around the electrical connection cover. Set the covers aside.



Figure 4-142: Removing the covers from the energy chain.

2. Identify the high-pressure hose included with this kit. Route it through the energy chain channel, curving it to run towards the pump. Pull the loose end of the hose through the top section of the energy chain and pass it through the opening on the top right of the spindle, guiding it toward the rotary union.



Figure 4-143: Opening at the top of the spindle head cover.

4: INSTALLATION

4.8 Install Accessory Components

3. Attach the end of the hose to the rotary union and tighten the hose nut with an open-end wrench. You may need to use a second wrench to hold the rotary union's extension in place while tightening.

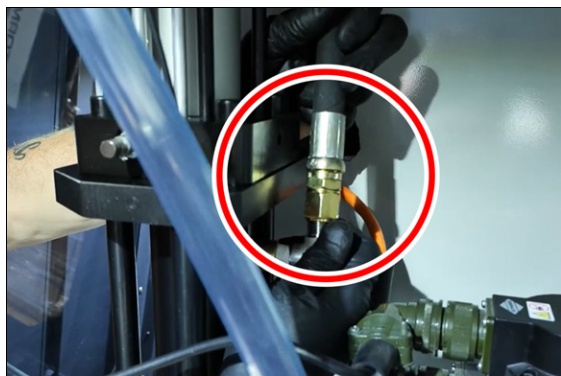


Figure 4-144: Attaching the high-pressure hose to the rotary union.

4. At the top of the spindle head cover, cut off the front cable tie securing the cables. Re-secure the cable and the high-pressure hose to the channel with a new cable tie.
5. At the rear of the machine, adjust the hose so that it's the same length as the other cables running through the energy chain, then secure them all together with two cable ties.



Figure 4-145: Securing the energy chain cables together.

6. Ensure that all cables are neatly arranged in the energy chain, and then replace the energy chain covers.
7. Reattach the drawbar button connector to the front cover. Align the front cover and resecure it with the screws that you set aside earlier. Then resecure the cables along both sides of the front cover using cable ties.

8. Route the loose end of the tubing down to the front of the spindle head cover.
9. Reinstall the right spindle cover with the screws that you set aside earlier.

Install the Hose Bracket

1. At the rear of the machine, locate the two threaded inserts.
2. Identify the two standoffs included with this kit, and install them into the two inserts with a 13 mm wrench.



Figure 4-146: Installing the standoffs into the machine.

3. Identify the hose bracket included with this kit, and align it onto the standoffs. Secure it with two cap head screws and a 5 mm hex wrench.
4. Put the high-pressure hose onto the bracket, and secure it with two cable ties.



Figure 4-147: High-pressure hose in the bracket.

Make Connections

1. Remove the cap from the TSC pump's outlet, and attach the loose end of the high-pressure hose. Securely tighten it with an adjustable wrench.



Figure 4-148: Connecting the high-pressure hose to the TSC pump.

2. Route the two electrical cables toward the electrical cabinet.
3. On the side of the electrical cabinet, connect the cable labeled **TSC Sensor** to the **TSC Inputs** outlet.



Figure 4-149: TSC Inputs connection.

4. On the bottom of the electrical cabinet, connect the cable labeled **TSC Control** to the **TSC Control** outlet.



Figure 4-150: TSC Control connection.

Securely Tighten Hose Clamps

WARNING! High-Pressure Hazard: Ensure all hose connections are secure and properly tightened. High-pressure coolant can cause hoses to burst or become dislodged if not correctly installed, leading to serious injury or equipment damage.

- Double-check all hose clamps to verify that they're securely tightened.

4.8.4 Install the Chip Conveyor Kit

Complete the following steps in the order listed:

Before You Begin	101
Prerequisites	101
Required Tools	101
Unpack and Assemble the Chip Conveyor Kit	102
Prepare the Coolant Tank	102
Lift and Install the Chip Conveyor	103
Make Connections	104
Verify the Installation	105

Before You Begin

Prerequisites

- The machine is in its final location and rough leveled.
- The following components must be installed:
 - Enclosure
 - Operator console
 - Flood coolant tank

Note: If you haven't yet done so, don't connect any of the coolant pumps to the machine.

- The site must have 240 Vac, single phase-power available (20 A).

Required Tools

- Engine hoist
- Flat-blade screwdriver
- Hammer
- Lifting strap rated for at least 1,000 lb (454 kg), 2
- Metric hex wrench set

4: INSTALLATION

4.8 Install Accessory Components

- Pry bar
- Wire snips

Unpack and Assemble the Chip Conveyor Kit

1. Cut the straps on the shipping crate with wire snips, and remove the top and sides of the crate with a hammer and pry bar.



Figure 4-151: Shipping crate.

2. Remove and discard the packaging protecting the chip conveyor on the pallet.
3. Identify the two casters and eight M6 × 1 - 12 button head cap screws included with this kit.
4. With the chip conveyor still on the pallet and laying on its side, install the two casters onto the end of the chip conveyor with a 5 mm hex wrench.



Figure 4-152: Installing the caster.

5. Lock the casters to prevent the wheels from spinning while lifting the chip conveyor from the pallet.



Figure 4-153: Locking the caster.

6. Remove and set aside the remaining boxes and additional packaging from the pallet.



WARNING! Tip Hazard: Use at least two people to lift the machine into an upright position. You must use proper lifting techniques and keep the machine stable throughout the process. Failure to do so could result in serious injury or equipment damage.

7. Slide the chip conveyor to the edge of the pallet. With the help of an assistant, slowly lift the chip conveyor upright, and lower it onto the ground.



Figure 4-154: Moving the chip conveyor off of the pallet.

8. Discard the pallet and any remaining packaging.

Prepare the Coolant Tank

1. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.

- c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
2. If you've already installed the flood coolant kit, the washdown coolant kit, or the through-spindle coolant kit, disconnect the hoses from the coolant pumps, and disconnect the pumps' power cords from the machine.
3. Remove the following items from the coolant tank, which aren't used with the chip conveyor:
 - a. Chip baskets.
 - b. Two cover panels on either side of the chip baskets, using a 3 mm hex wrench.
We recommend storing these items for future use.
4. Roll the coolant tank to the work area where you've unpacked the chip conveyor.

Lift and Install the Chip Conveyor

We recommend using an engine hoist and lifting straps rated for at least 1,000 lb (454 kg) to safely lift and position the chip conveyor into the coolant tank. You must have an assistant to guide the conveyor into position during this process. Follow the steps below carefully to avoid personal injury or damage to the equipment.

1. Position the engine hoist behind the front leg of the chip conveyor.
2. Secure a lifting strap to each eye bolt on either side of the front leg of the chip conveyor. Attach the front lifting straps to the lifting hook on the engine hoist.

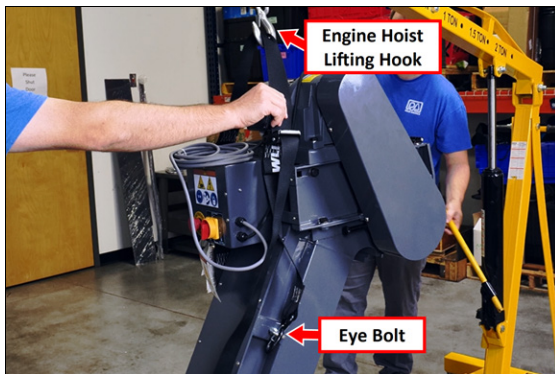


Figure 4-155: Attaching a lifting strap to the front leg of the chip conveyor and the lifting hook on an engine hoist.

3. Attach another set of lifting straps to the eye bolts on the rear section of the chip conveyor. These straps will be used to guide the conveyor into the coolant tank.

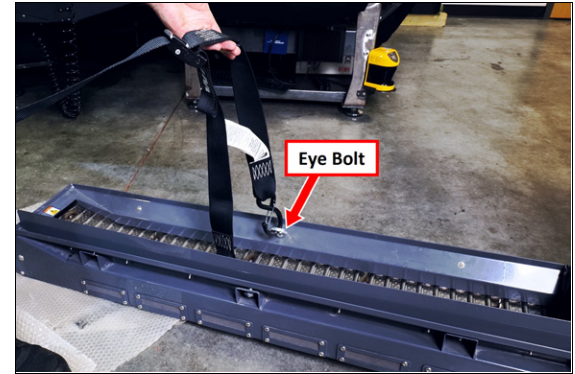


Figure 4-156: Lifting strap attached to the rear of the chip conveyor for guiding.



WARNING! Transportation and Lift Hazard:
Before moving the machine, you must confirm that all persons are clear of the area below the machine. Qualified professionals must transport, lift, and move the machine. Moving parts can entangle, pinch, or cut you, causing death or serious injury.

4. Verify that all lifting straps are secure and that the load is balanced. Slowly raise the engine hoist to lift the front leg of the chip conveyor off the ground.
5. While the front leg is lifted, have an assistant guide the rear of the conveyor using the lifting strap. Carefully lower the conveyor into the coolant tank, ensuring it aligns with the tank.



Figure 4-157: Guiding the chip conveyor into the coolant tank.

6. Gradually lower the engine hoist to set the rear of the conveyor inside the coolant tank.
7. Verify that the chip conveyor is fully seated and aligned within the tank, and that the front leg is stable on the floor. Remove the lifting straps.

4: INSTALLATION

4.8 Install Accessory Components

8. Identify the three cover panels and the 24 M5 × 0.8 - 10 button head cap screws included with this kit.
9. Loosely install the three cover panels onto the coolant tank with a 3 mm hex wrench:
 - a. Install the narrow panel along the side of the tank, making sure that the flange on the panel hooks into the inside of the chip conveyor.



Figure 4-158: Installing the narrow panel.

- b. Install the short panel at the end of the tank.



Figure 4-159: Installing the short panel.

- c. Install the wide panel between the conveyor and the pumps.



Figure 4-160: Installing the wide panel.



Note: The knock-outs on the wide panel are used to mount the oil skimmer. If you have an oil skimmer, remove the knock-outs before installing the panel.

- d. Tighten the screws on all three panels.
10. Unlock the casters on the conveyor, and roll the chip conveyor and coolant tank assembly to the back of the machine.

Make Connections

1. Connect the power cables and the coolant hoses for the flood coolant pump and, if installed, the washdown coolant pump and the through-spindle coolant pump.
2. Identify the control cable for the chip conveyor. Connect one end to the **Control** port on the chip conveyor's control box.



Figure 4-161: Connecting the control cable to the chip conveyor.

3. Route the loose end of the control cable to the bottom of the machine's electrical cabinet, and connect it to the **Accessory Output 1** port.



Figure 4-162: Connecting the loose end of the control cable to the mill.

4. Connect the chip conveyor's power cable to a 220 Vac wall outlet.
5. Secure the cables and hoses at the back of the machine with cable ties, making sure to position them so that they won't interfere with any moving parts.

Verify the Installation

1. With the machine still powered off, identify the Main Disconnect switch on the chip conveyor's control box. Turn it to the on position.

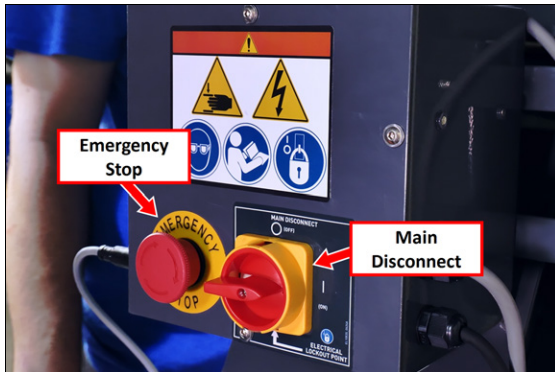


Figure 4-163: Chip conveyor's control box.

2. Twist out the Emergency Stop button on the chip conveyor.
3. Turn the Speed knob to the halfway position.
4. Test the forward and reverse controls:
 - a. Press and hold the Forward button on the chip conveyor control box. The chip conveyor runs forward (toward the control box), and the Run light illuminates.



Figure 4-164: Chip conveyor controls.

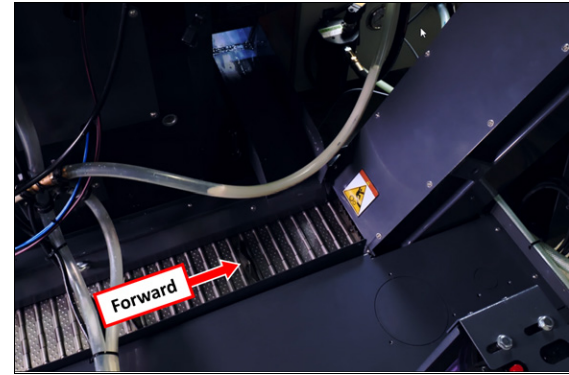


Figure 4-165: Chip conveyor's forward direction.

- b. While holding the Forward button, push in the Emergency Stop button on the chip conveyor. The chip conveyor stops running.
- c. Release the Forward button, and twist out the Emergency Stop button.
- d. Press and hold the Reverse button on the chip conveyor control box. The chip conveyor runs backwards (away from the control box), and the Run light illuminates.



Figure 4-166: Chip conveyor controls.

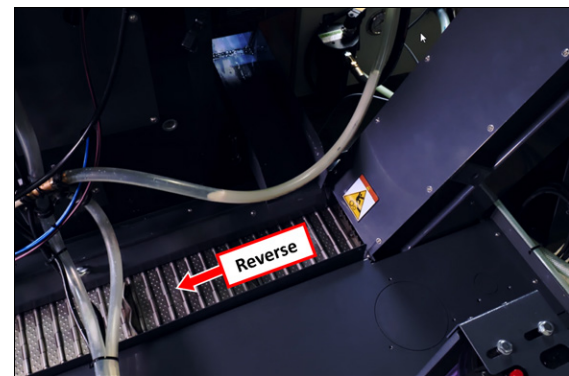


Figure 4-167: Chip conveyor's reverse direction.

4: INSTALLATION

4.8 Install Accessory Components

- e. While holding the Reverse button, push in the Emergency Stop button on the chip conveyor. The chip conveyor stops running.
- 5. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the Emergency Stop button).
- 6. Observe the chip conveyor, which should not be running in either direction at this time.
- 7. Test the M-code controls:
 - a. From the PathPilot controller, in the **MDI Line** DRO field, type each of the following commands, one at a time, while observing the chip conveyor.

M-Code	Expected Behavior
M231	Turns on the chip conveyor.
M233	Turns off the chip conveyor.
M231 P10 Q20	Begins an on/off duty cycle: Turns on the chip conveyor, runs for 10 seconds, and then turns off for 20 seconds. The P~ word specifies the run duration in seconds. The Q~ word specifies the off duration in seconds.

- b. From the PathPilot controller, in the **MDI Line** DRO field, type **M233**. Then select the **Enter** key. The chip conveyor turns off.
- c. Wait for two minutes, observing the chip conveyor to verify that it doesn't turn back on.



Note: For information on maintaining the chip conveyor, go to "Chip Conveyor Maintenance Schedule" (page 261).

4.8.5 Install the Oil Skimmer Kit

- 1. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.

2. Depending on your machine configuration, the installation location for the oil skimmer kit varies:
 - **If you have only the Flood Coolant Kit** Locate the skimmer plate cover on the coolant tank. Remove the four screws securing the plate to the coolant tank, and set the screws aside. Remove the skimmer plate from the coolant tank.

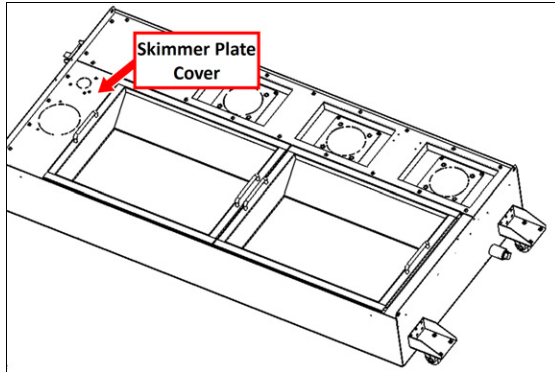


Figure 4-168: Skimmer plate cover on the coolant tank.

- **If you also have a Chip Conveyor Kit** Locate the skimmer plate cover on the chip conveyor. Remove the screws securing the plate to the chip conveyor, and set the screws aside. Remove the skimmer plate from the chip conveyor.

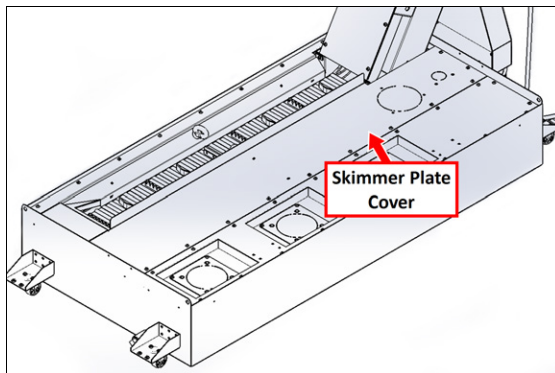


Figure 4-169: Skimmer plate cover on the chip conveyor.

3. Use a hammer and punch to knock out both circular knockouts — the larger one is for the oil container, the smaller one is for the skimmer.
4. Insert two M6 × 1 - 45 screws through the skimmer's mounting holes and into the matching holes in the spacer block.

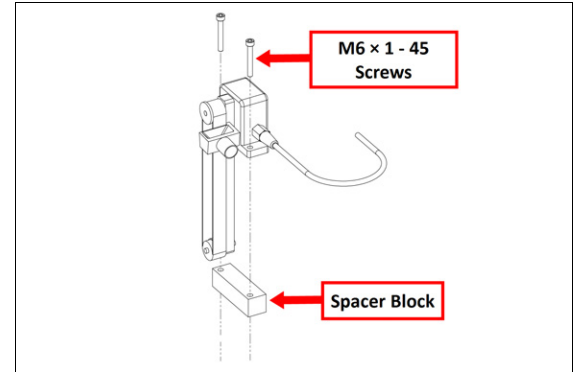


Figure 4-170: Securing the skimmer to the mounting block.

5. Insert the skimmer into the smaller hole of the skimmer plate, aligning its screws with the plate's mounting holes.
6. From the underside of the plate, secure each screw with an M6 lock washer and an M6 nut.

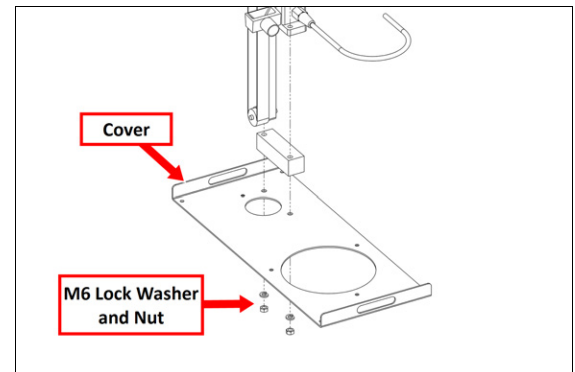


Figure 4-171: Securing the skimmer to the skimmer plate.

7. Tighten the fasteners with a 5 mm hex wrench and a 10 mm wrench.

4: INSTALLATION

4.8 Install Accessory Components

8. Identify the skimmer bucket adapter plate (PN 53696) and the two oil collection containers (PN 39128). Insert one container into the center of the adapter plate. Press down until the container's top lip contacts the plate.

 **Note:** The bracket should fit tightly around the container. You may need to flex the container slightly to insert it fully.

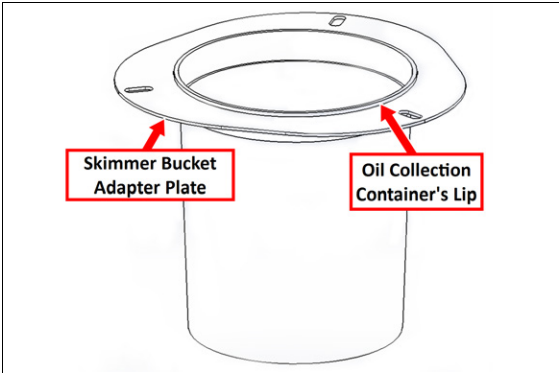


Figure 4-172: Adapter plate installed onto the container.

9. Nest the second container inside the first.
10. Secure the container assembly to the skimmer plate: insert one M5 screw through each slot in the adapter plate, then thread an M5 nut onto each screw from underneath. Tighten with a 3 mm hex wrench and an 8 mm wrench.

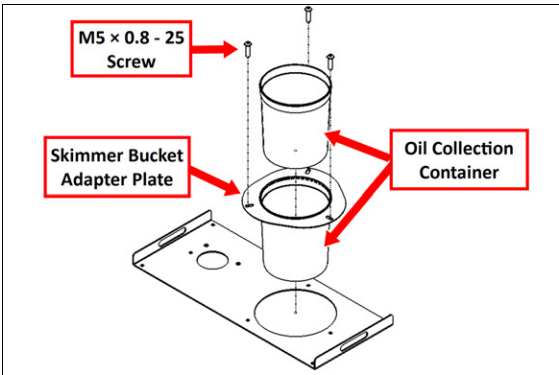


Figure 4-173: Securing the oil collection container to the skimmer plate.

11. Reattach the skimmer plate to the coolant tank using the four screws that you set aside earlier.
12. Attach the oil discharge hose to the skimmer's discharge outlet.

13. The hose may be longer than necessary for your setup. To determine the appropriate length, route the loose end to the oil container, and then cut the hose as necessary with a pair of cutters.
14. Slide the hose clamp onto the hose and tighten it around the outlet with a flat-blade screwdriver.
15. Route the skimmer's power cable toward the back of the coolant tank.
16. Plug the power cable into a 115 Vac outlet. You've completed the installation.

 **Note:** While the skimmer is plugged in, it runs continuously. To power off the skimmer, unplug it from the outlet. For information, see the Skimpy Skimmer documentation (provided).

4.8.6 Install the Mist Collector Kit

Complete the following steps in the order listed:

Before You Begin	108
Prerequisites.....	108
Required Tools.....	108
Mechanical Installation	109
Top of Enclosure Installation (Recommended Location).....	109
Floor Installation (Alternate Location).....	110
Electrical Installation	111

Before You Begin

Prerequisites

- The enclosure must be installed.
- The site must have 240 Vac, single phase-power available (20 A).

Required Tools

- #2 Phillips screwdriver
- Adjustable wrench
- Flat-blade screwdriver
- Lifting device suitable for lifting 198 lb (90 kg) to a height of 101 in.(257 cm). Use of a gantry crane or forklift is strongly recommended.
- Punch
- Ratchet strap

Mechanical Installation

The recommended location for the mist collector is mounted on top of the mill's enclosure. This mist collector location requires a minimum ceiling height of 9 ft, 9 in. (297 cm) to allow clearance for the opened filter door. The mist collector's filter housing weighs 92 lb (42 kg), and must be lifted with a suitable lifting device.

If your installation location does not have sufficient clearance, or does not have a suitable lifting device available, go to "Floor Installation (Alternate Location)" (on the next page).

Top of Enclosure Installation (Recommended Location)

1. To prepare the enclosure for the mist collector installation, remove the 150 mm and 34 mm knockouts from the enclosure's top right panel using a punch to break the tabs. Discard the knockouts.

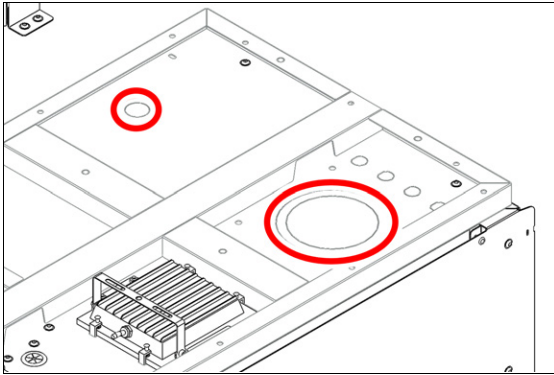


Figure 4-174: Knockout holes on the enclosure's top right panel.

2. Identify the eight provided vibration isolation mounts: four are flat (for floor installation), and four have threaded rods on both ends (for enclosure installation). Remove and discard the nuts from the bottom threaded rod of the mounts.
3. Install the four vibration isolation mounts onto the enclosure's top right panel. Remove and set aside the nuts and washers from the top threaded rod of the mounts.

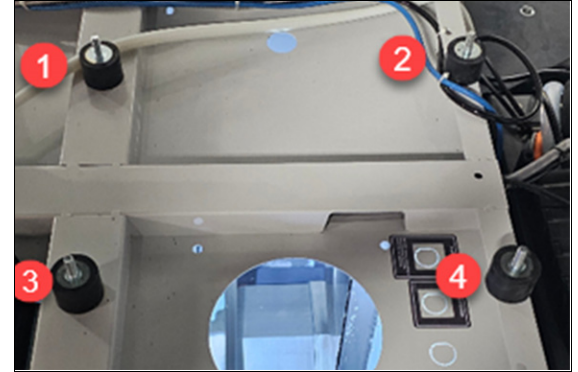


Figure 4-175: Vibration isolation mounts on the enclosure panel.

4. Securely install the lifting eye into the center hole on the top of the mist collector.
5. Verify that all four of the mist collector filter housing's latches are secured in the latched position.
6. Secure a lifting strap to the previously installed eyelet on the top of the mist collector.



WARNING! Lifting Hazard: Only use suitable lifting equipment, ensuring that it's on a stable, level surface. Never lift over people. Heavy loads could tip, fall, or shift unexpectedly, causing death or serious injury.

7. Using a gantry crane, forklift, or other suitable lifting device, place the mist collector filter housing on 4 x 4 blocks.
8. The mist collector's plenum inlet is installed facing the back of the mist collector for shipping. You must reorient it for installation on top of the enclosure. Remove the eight fasteners securing the cover with a #2 Phillips screwdriver. Set the cover and its screws aside.
9. Remove four fasteners securing the plenum inlet with a socket wrench. Reorient the plenum so that the circular opening is facing downwards, and reattach it using the four fasteners previously removed.
10. Reattach the cover to the mist collector using the eight fasteners previously removed.

4: INSTALLATION

4.8 Install Accessory Components

11. Attach the threaded-to-barbed adapter elbow to the mist collector's coolant return. Tighten using an adjustable wrench until the fitting is snug and the barbed section is pointing downwards.

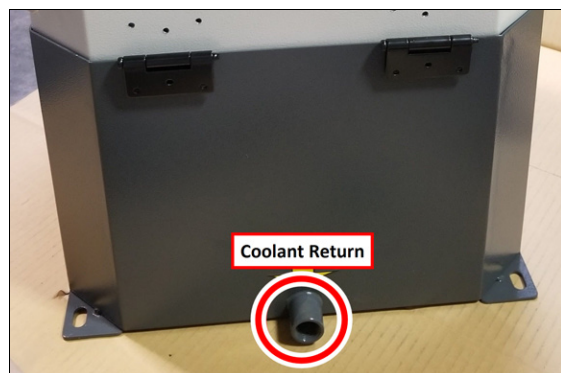


Figure 4-176: Mist collector's coolant return.

WARNING! Lifting Hazard: Only use suitable lifting equipment, ensuring that it's on a stable, level surface. Never lift over people. Heavy loads could tip, fall, or shift unexpectedly, causing death or serious injury.

12. Using a gantry crane, forklift, or other suitable lifting device, place the mist collector on the enclosure's top right panel. Align the slots in the mist collector's foot flanges with the previously installed vibration isolation mounts.
13. Secure the mist collector to the vibration isolation mounts using the M8 washers and nuts that you previously removed and set aside.
14. Remove the lifting strap from the mist collector.
15. Secure the coolant drain hose to the mist collector's drain using the provided hose clamp. Trim the excess coolant drain tubing inside the enclosure. The coolant drain tube should extend 1 in. (25 mm) into the enclosure.

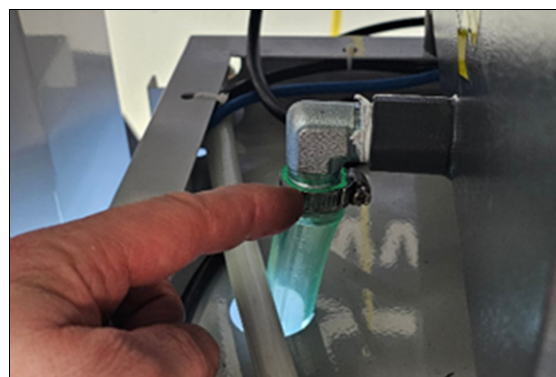


Figure 4-177: Coolant drain hose installed.

Floor Installation (Alternate Location)

1. Identify a suitable mounting location for the mist collector's filter housing using the following guidelines:
 - The mist collector filter housing should be located as close as possible to the machine to reduce the length of flexible ducting required.
 - If mounting to a worktable or wall bracket, the mounting location must be sufficiently sturdy to support it.

We recommend placing the mist collector housing on a suitable worktable or wall bracket with sufficient access to allow reclaimed coolant to be returned to the machine's coolant tank using a drain hose or collected in a container.

2. Identify a suitable mounting location for mist collector's intake flange. The mist collector's intake flange should be mounted as close as possible to the area where mist is produced, but not so close as to ingest excessive amounts of chips/swarf.
3. Cut the necessary intake flange mounting holes.
4. Secure the intake flange and provided flange gasket to the enclosure.
5. Connect the flange-to-hose adapter to the intake flange.
6. Securely install the lifting eye into the center hole on the top of the mist collector.
7. Verify that all four of the mist collector filter housing's latches are secured in the latched position.

8. Secure a lifting strap to the previously installed eyelet on the top of the mist collector.

 **WARNING!** Lifting Hazard: Only use suitable lifting equipment, ensuring that it's on a stable, level surface. Never lift over people. Heavy loads could tip, fall, or shift unexpectedly, causing death or serious injury.

9. Using a gantry crane, forklift, or other suitable lifting device, place the mist collector filter housing on in selected mounting location.
10. Mount the mist collector filter housing to the selected mounting location using the provided vibration-isolating mounts or feet.
11. Connect the mist collector hose to the flange-to-hose adapter. Secure using the provided spring clamp.
12. Route the mist collector hose from the flange-to-hose adapter to the mist collector filter housing. For best performance, the hose routing should be as direct as possible with as few bends as possible. Cut the hose to length, and secure it to the mist collector's inlet plenum with the provided spring clamp.
13. Attach the threaded-to-barbed adapter elbow to the mist collector's coolant return. Tighten using an adjustable wrench until the fitting is snug and the barbed section is pointing downwards.
14. Secure the coolant drain hose to the mist collector's drain using the provided hose clamp. Tighten using a flat-blade screwdriver.
15. Route the coolant drain tube to the machine's coolant tank or enclosure. Coolant flows by gravity down the drain tube. The return end of the coolant drain tube must be it's lowest point to effectively drain. Trim excess coolant drain tubing.

 **Note:** If a suitable coolant drain location is not available, a container can be placed below the coolant return elbow and emptied periodically.

Electrical Installation

1. Remove the two M6 panel fasteners and use them to secure the mist collector motor starter to the mill

enclosure's right side panel.

2. Route the motor starter's cables along the enclosure's top right panel towards the mist collector.
3. Connect the switched power cable connector to mist collector's power connector.
4. Connect the mains power cable to the wall outlet.
5. Test the mist collector installation:
 - a. Press the Mist Collector Start Button to turn on the mist collector.
 - b. Press the Mist Collector Stop Button to turn off the mist collector.

4.8.7 Install the MQL Kit

Complete the following steps in the order listed:

Required Tools	111
Remove the Tubing from the Pump	111
Route the Tubing	112
Mount the Pump	113

Required Tools

- 3/16 in. hex wrench
- 4 mm hex wrench
- Needle-nose pliers
- Razor blade
- Thread seal tape

Remove the Tubing from the Pump

We recommend mounting the MQL pump on the access panel on the back of the machine's column. If your unit was shipped with the tubing already connected to the pump, you'll need to disconnect it to route it from the spindle to the pump, then reconnect it at the back of the machine.

 **Note:** If your unit did not ship with the tubing already connected to the pump, you can skip this section. Go to "Route the Tubing" (on the next page).

1. Unscrew the 3/8 in. push-to-connect fitting from the pump block.

4: INSTALLATION

4.8 Install Accessory Components

2. Pull the outer 3/8 in. tube and push-to-connect fitting away from the pump block, exposing the 1/8 in. nylon capillary tube.



Figure 4-178: Push-to-connect fitting removed from the pump.

3. Grasp the 1/8 in. capillary tube with a pair of needle-nose pliers. Lever the pliers against the pump block to pull the capillary from the brass barbed fitting in the pump.

NOTICE! Don't use a razor blade to cut the capillary along its axis to remove it from the barb fitting. Doing so can damage the barbed fitting and result in system performance issues. Also, don't grab onto the barbed fitting itself with the pliers — make sure you're pulling on the tubing.

4. In the pump, verify that there's no remnants of the 1/8 in. capillary tube on the brass barbed fitting.

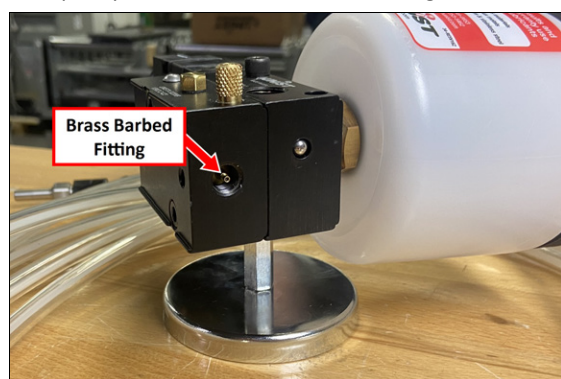


Figure 4-179: Brass barbed fitting in the pump.

5. Remove the push-in fitting from the 3/8 in. tube, and set it aside.
6. To reconnect the tubing to the pump (done later in this procedure), you'll need about 1 in. of the 1/8 in. capillary

tube exposed from the 3/8 in. tube. If you need to expose the capillary tube, complete the following steps. Otherwise, go to the next section.

- a. Carefully insert a hex wrench into the 3/8 in. tube, and lightly push back the 1/8 in. capillary tube.

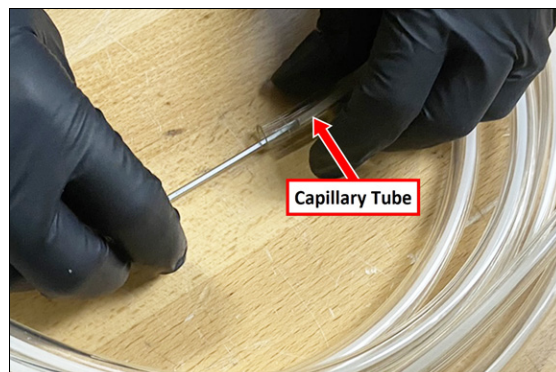


Figure 4-180: Push back the 1/8 in. capillary tube with a hex wrench, or similar tool.

- b. While holding the capillary tube back with the wrench, cut the 3/8 in. tube with a razor blade.



Figure 4-181: Cut the 3/8 in. tube away from the 1/8 in. capillary tube.

NOTICE! Don't cut the 3/8 in. tube where the blade could also cut the 1/8 in. capillary tube. If the capillary tube is accidentally cut, it could result in system performance issues.

Route the Tubing

1. Mount the nozzle behind the spindle head with the included hardware and a 3/16 in. hex wrench.

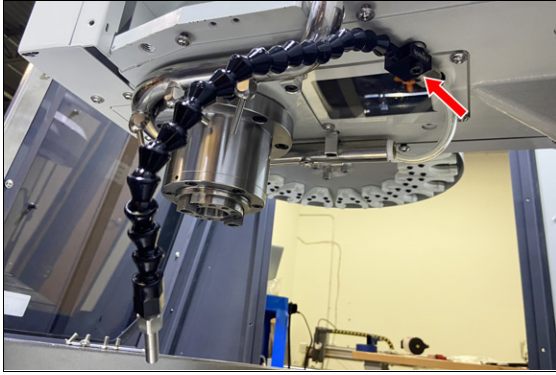


Figure 4-182: Nozzle mounted behind the spindle.

2. Remove the nine M6 flanged button head cap screws on the side of the right side spindle cover with a 4 mm hex wrench. Set the screws aside. Then, loosen or remove the three screws on the bottom of the spindle head cover. Remove the cover, and set it aside.

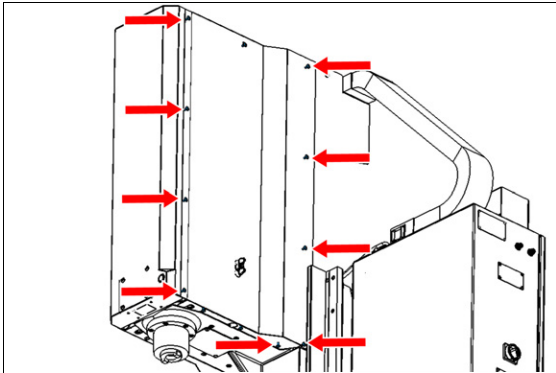


Figure 4-183: Screws securing the right side spindle cover.

3. Route the tubing from the nozzle up through the hole on the bottom left of the spindle head casting. Continue up to the top of the spindle housing, and out through the top left hole.

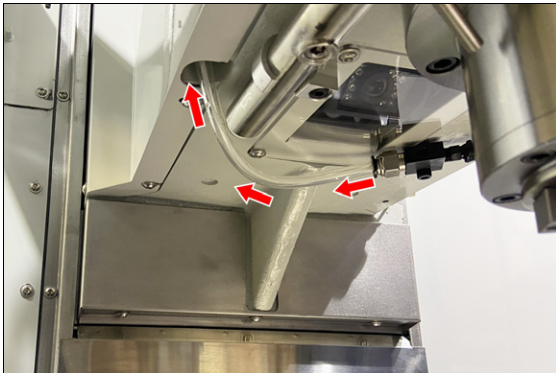


Figure 4-184: Tubing routing into the spindle housing.

4. From the back of the machine, route the tubing through

the energy chain, taking care to keep all the contents in the energy chain free from twists.



Tip! It may help to raise the Z-axis to its maximum height, and remove a few of the energy chain cover panels to more easily route the tubing through the energy chain.

5. Route the tubing between the machine casting and the electrical cabinet.

Mount the Pump

1. Identify the solenoid and pressure regulator assembly included with this kit. Wrap thread seal tape around the threads of the brass fitting on the solenoid.

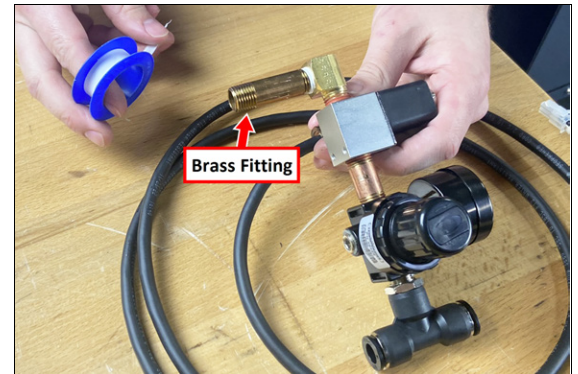


Figure 4-185: Brass fitting on which to use Teflon tape.

2. Thread the brass fitting on the solenoid onto the pump.



Figure 4-186: Solenoid mounted onto the coolant pump.

4: INSTALLATION

4.8 Install Accessory Components

3. Reinstall the push-to-connect fitting that you set aside earlier onto the 3/8 in. tube.

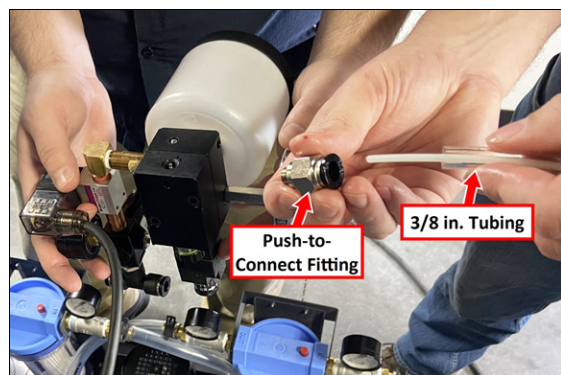


Figure 4-187: Reinstalling the push-to-connect fitting onto the tubing.

4. Carefully install the 1/8 in. capillary tube onto the barbed fitting on the pump with a pair of pliers.

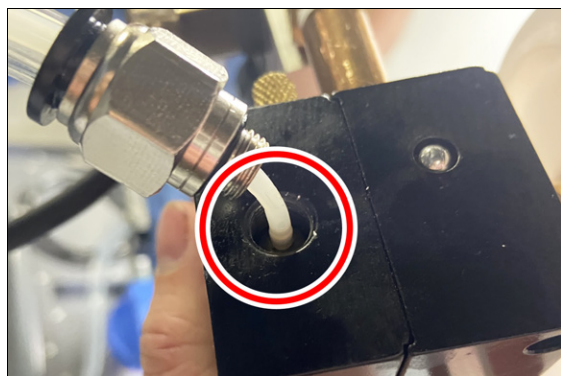


Figure 4-188: Capillary tube installed onto the barbed fitting.



Note: Make sure that the tube is fully installed onto the barbed fitting. If it isn't, it may result in system performance issues.

5. Screw the push-to-connect fitting back into the pump block.
6. Mount the pump with its magnetic base in a convenient location. We recommend using the access panel on the back of the machine column.



Figure 4-189: Pump mounted onto the access panel on the machine column.

7. Route the solenoid wire into the bottom of the electrical cabinet.

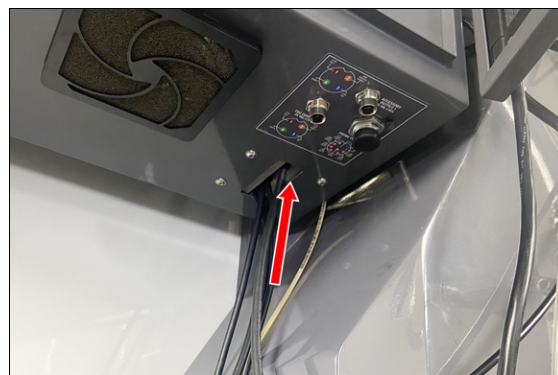


Figure 4-190: Solenoid wire routing into the bottom of the electrical cabinet.

8. In the bottom left corner of the electrical cabinet, plug the solenoid wire into the **XS36: MQL Control** connector. Pull the extra wire into the electrical cabinet, coil it up, and secure it with a cable tie.

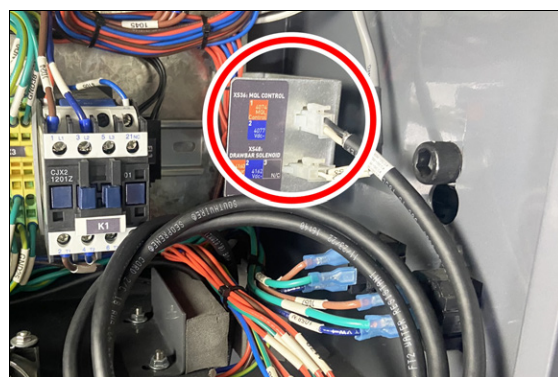


Figure 4-191: Solenoid wire connection inside of the electrical cabinet.

9. On the back of the machine, identify the air line that's connected to the machine's FRL (with the fitting installed on the end). Disconnect it from the FRL, and connect it to the inlet valve of the MQL's solenoid.
10. Identify the air line included with this kit, and connect it to the outlet valve of the MQL's solenoid. Connect the loose end of the air line to the FRL.

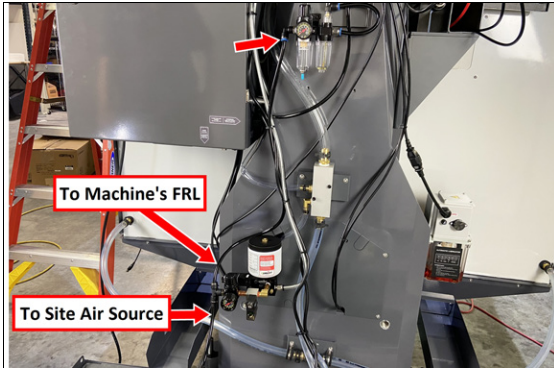


Figure 4-192: MQL's air line connections.

11. Identify the coolant included with this kit, and fill the coolant reservoir.

4.8.8 Install the Automatic Tool Changer (ATC)

Complete the following steps in the order listed:

Required Tools	115
Unpack the ATC Box	115
Prepare the Machine	115
Assemble the ATC	117
Install the ATC Electrical Cabinet	118
Level and Align the ATC	122
Required Tools.....	122
Test Tool Changes	127

Required Tools

- Adjustable torque meter, up to 20 Nm
- Metric hex wrench set (2.5 mm, 4 mm, and 6 mm)
- 22 mm or 7/8 in. socket
- Phillips screwdriver
- Socket extension, 6 in. minimum
- 10 mm and 12 mm hex wrench tip with socket for ratchet torque wrench

Unpack the ATC Box

1. Open the box and remove the foam cover. From the top level of foam, remove and set aside the ATC actuator assembly (PN 51856) and the ATC accessory kit

(PN 53065).

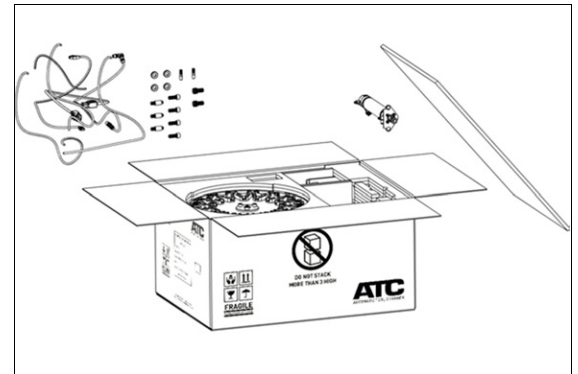


Figure 4-193: Removing the accessory kit and the actuator assembly from the top level of foam.

2. Remove the top level of foam from the box and discard it.

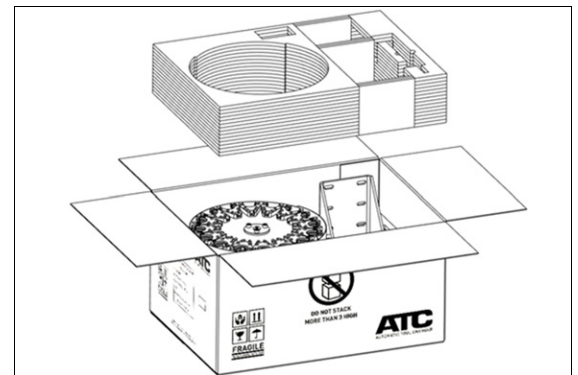


Figure 4-194: Removing the top level of foam from the crate.

3. Remove and set aside all remaining components from the box.

Prepare the Machine

1. Identify the accessory kit and the column mount assembly (PN 51857).

4: INSTALLATION

4.8 Install Accessory Components

2. From the accessory kit, remove the two 10 mm standoffs (PN 52492).

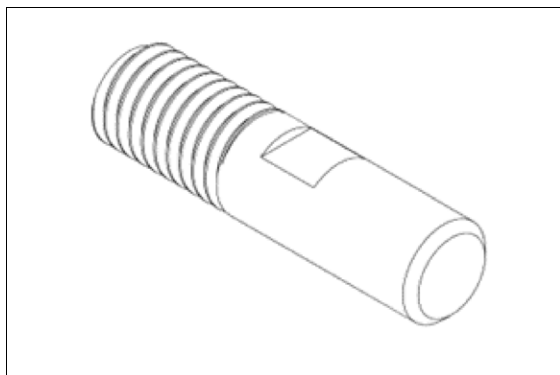


Figure 4-195: 10 mm standoffs pins (PN 52492).

3. On the left side of the machine's main column mounting area, identify the six threaded inserts as shown in the following image.

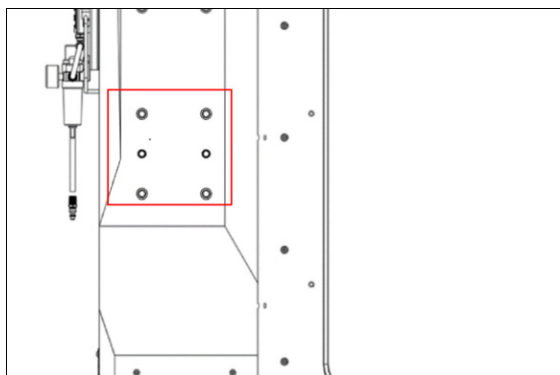


Figure 4-196: Threaded holes in the machine column.

4. Thread both 10 mm standoffs into the two center threaded holes as shown in the following image. Thread in the standoffs until the flats on the standoffs are flush to the column.

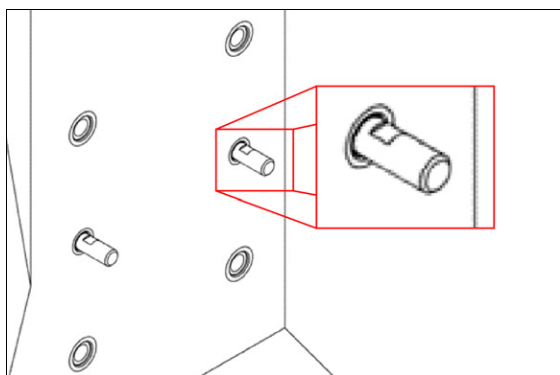


Figure 4-197: 10 mm slide pins threaded into the machine column.

5. If the machine's enclosure is already installed, remove

the 12 M6 × 12 flanged button head screws securing the ATC panel to the enclosure with a 4 mm hex wrench. Set the screws aside.

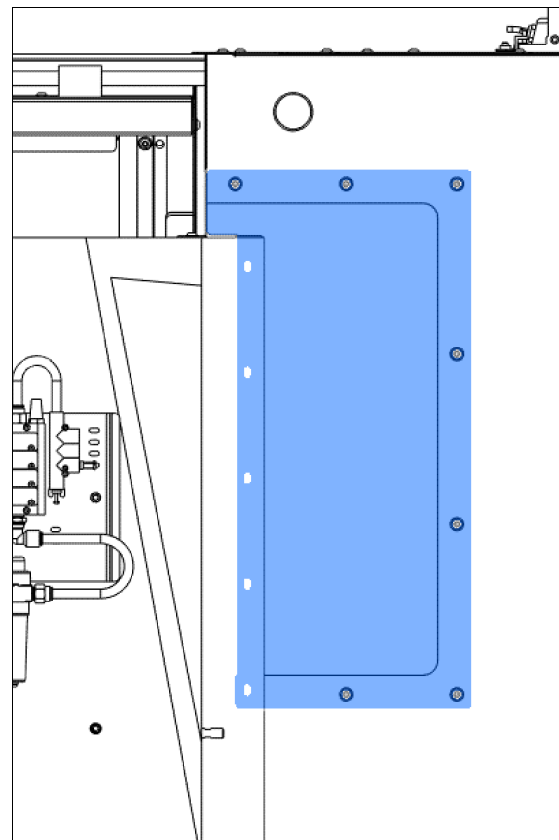


Figure 4-198: ATC panel on the machine's enclosure.

6. Mount the ATC column mount assembly to the column, aligning the central slots with the standoffs that you previously installed.

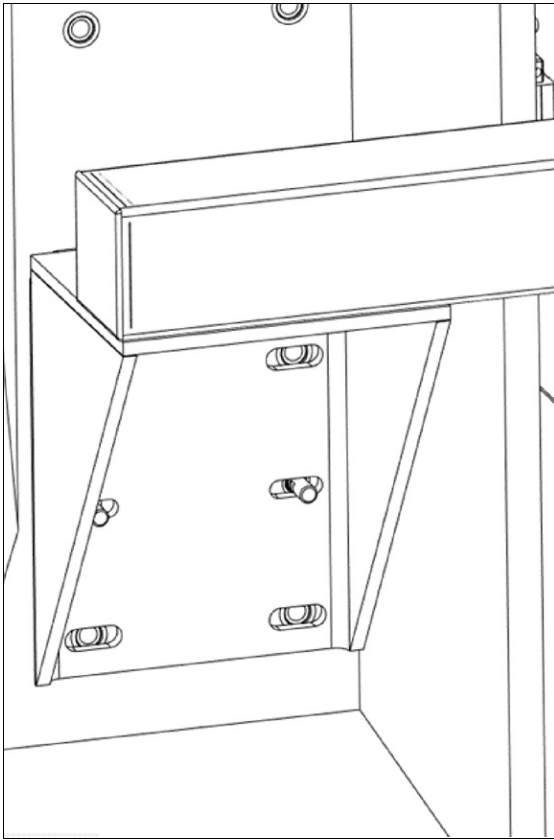


Figure 4-199: Column mount on the 10 mm slide pins.

7. From the accessory kit, remove four M12 washers (PN 52288) and four M12 × 30 mm screws (PN 52448).
8. Secure the ATC column mount assembly to the column by screwing four M12 × 30 mm screws and four M12 washers into the remaining threaded inserts, tightening them with a 10 mm hex wrench (not included in the accessory kit). Realign the column mount if necessary and, once it's fully aligned, completely tighten the four screws.

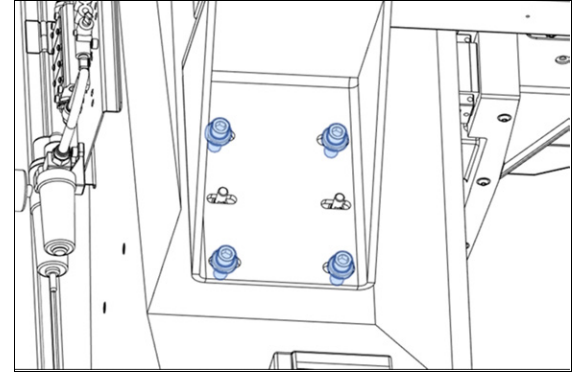


Figure 4-200: M12 screws and washers fastened onto the column mount assembly.

Assemble the ATC

1. From the accessory kit, remove two M14 × 25 socket head cap screws (PN 53055) and the 12 mm hex wrench.
2. Identify the ATC actuator assembly that you set aside earlier. Unscrew the thin nut from its piston rod, and set the nut aside.

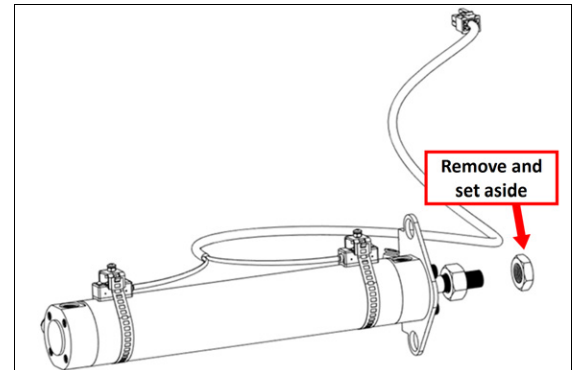


Figure 4-201: Nut removed from the piston rod.

3. Install the ATC actuator assembly on the left side of the ATC slide assembly with two M14 × 25 socket head cap screws and a 12 mm hex wrench.

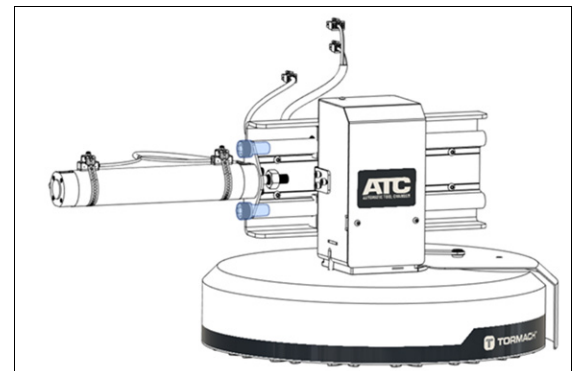


Figure 4-202: Actuator assembly installed onto the ATC's slide assembly.

4: INSTALLATION

4.8 Install Accessory Components

- Slide the motor box toward the piston until the motor box bracket fits into the piston rod. Secure the motor box to the piston rod using the thin nut that you set aside in Step 2. Tighten the lock nuts finger-tight for now.

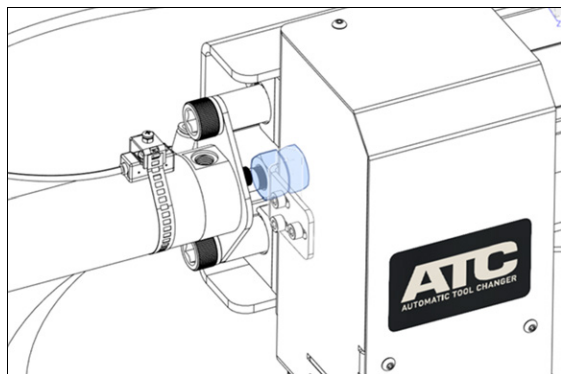


Figure 4-203: Securing the motor box to the piston rod.

- Identify the ATC tilt bracket on the column mount assembly. Remove the bracket from the assembly by removing the $M8 \times 100$ and $M8 \times 12$ socket head cap screws and their washers with a 6 mm hex wrench. Set aside the fasteners.

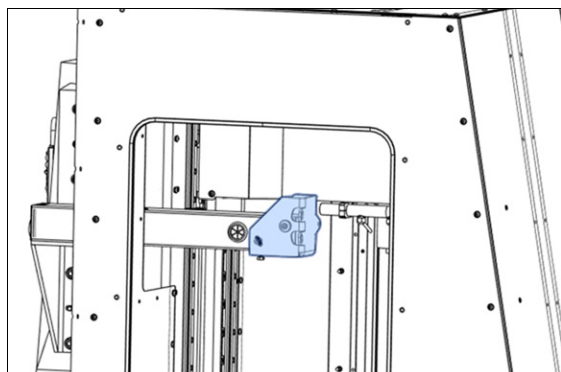


Figure 4-204: ATC tilt bracket on the column mount.

- From the accessory box, remove three $M8 \times 1.25 - 12$ screws (PN 50578) and three flat washers (PN 30531). Attach the tilt bracket to the ATC's slide plate with the three screws, three washers, and a 6 mm hex wrench. Loosen the M8 hex head screw at the bottom of the ATC tilt bracket if necessary.

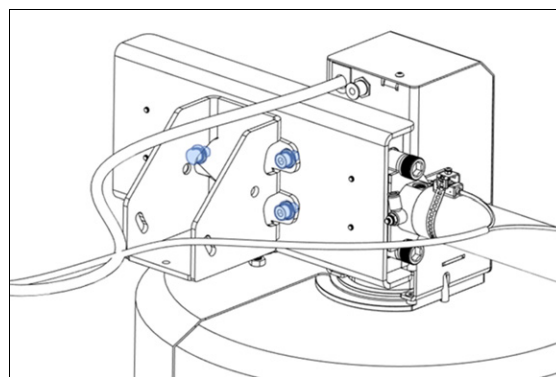


Figure 4-205: ATC tilt bracket installed on the slide plate.

- Push the actuator in to close the carousel's door.
- Using the fasteners that you set aside in Step 5, attach the ATC to the column mount assembly that's installed on the machine with a 6 mm hex wrench.

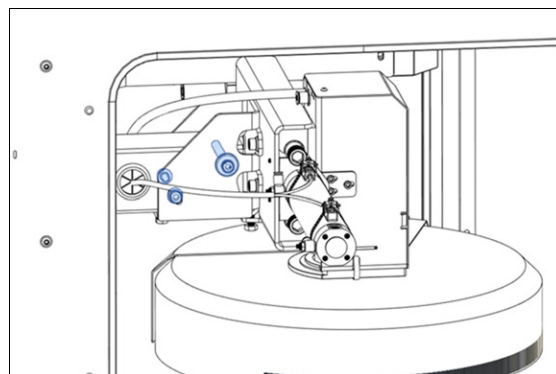


Figure 4-206: ATC attached to the column mount.

Install the ATC Electrical Cabinet

- From the accessory kit, remove three $M12 \times 15$ mm standoffs (PN 51974).

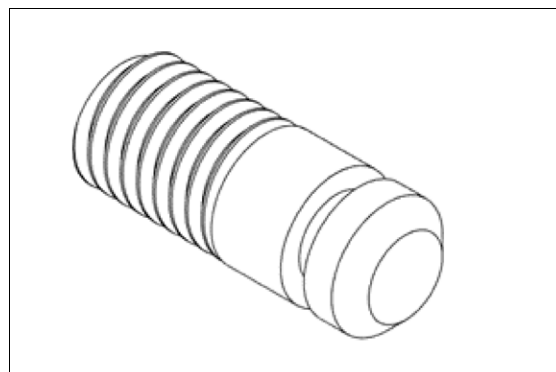


Figure 4-207: $M12 \times 15$ mm standoffs.

2. On the left side of the machine's main column mounting area, identify the upper arrangement of threaded inserts as shown in the following image.

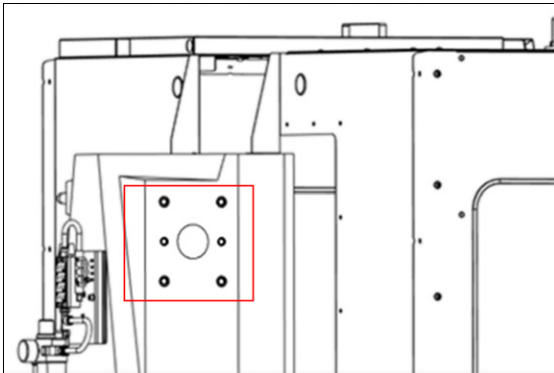


Figure 4-208: Threaded holes for the ATC electrical cabinet.

3. Thread the three M12 × 15 mm standoffs into the threaded holes as shown in the following image.

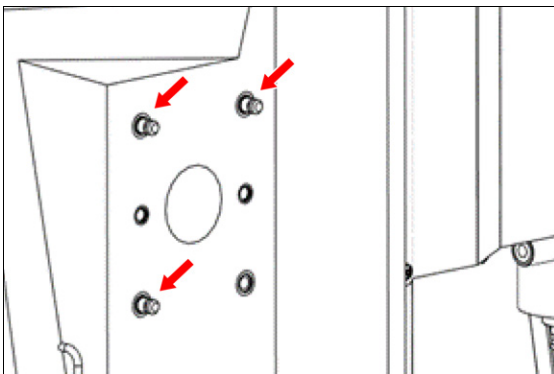


Figure 4-209: Installing the standoffs in the threaded holes.

4. Connect the black IEC cable (PN 51969) to the **ATC Power** connector on the right side of the machine's electrical cabinet. Bring the cable through the column as shown in the following image.

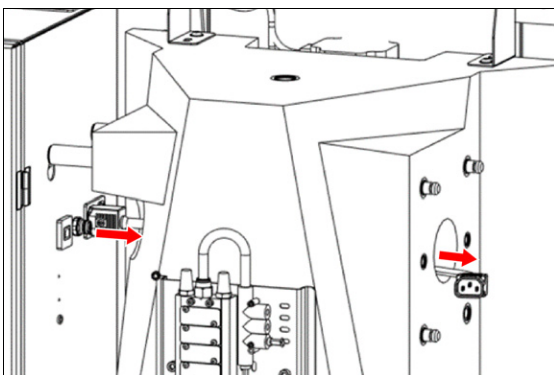


Figure 4-210: Connecting the black IEC cable to the machine's electrical cabinet.

5. Connect the EtherCAT cable (PN 51970) to the **ATC Communication** connector on the right side of the machine's electrical cabinet. Bring the cable through the column as shown in the following image.

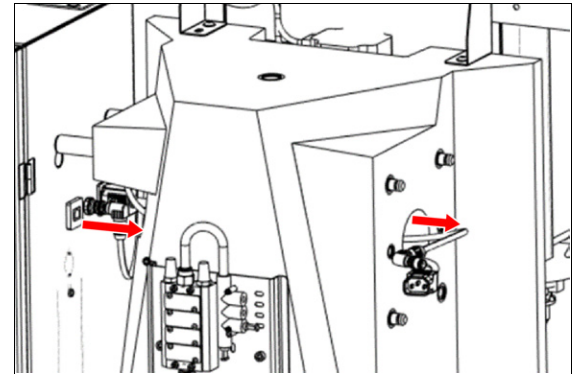


Figure 4-211: Connecting the EtherCAT cable to the machine's electrical cabinet.

6. Connect the ATC STO cable (PN 51965) to the **ATC STO** connector on the right side of the machine's electrical cabinet. Bring the cable through the column as shown in the following image.

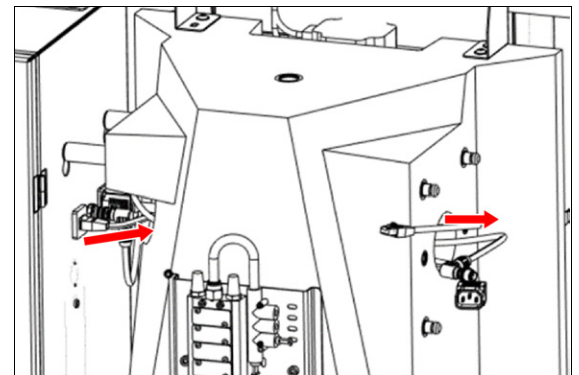


Figure 4-212: Connecting the ATC STO cable to the machine's electrical cabinet.

4: INSTALLATION

4.8 Install Accessory Components

7. Identify the ATC electrical cabinet (PN 51949). Align its three keyhole slots on the back with the three standoffs previously installed on the machine's column. Once the standoffs fit into the cabinet's slots, let the weight of the cabinet guide the standoffs into the narrow part of the slot. Adjust the cables so that they don't get pinched.

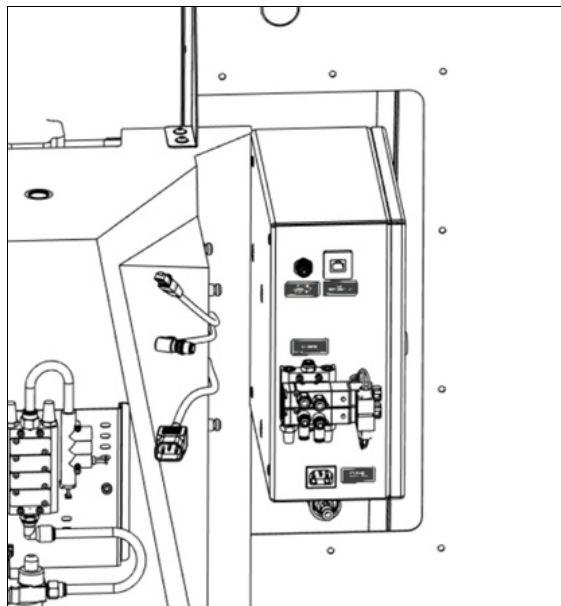


Figure 4-213: Installing the ATC's electrical cabinet onto the standoffs.

8. Connect the loose ends of the IEC cable, the EtherCAT cable, and the ATC STO cable to the **ATC Power**, **ATC Communication**, and **ATC STO** connectors on the outer left side of the ATC's electrical cabinet.

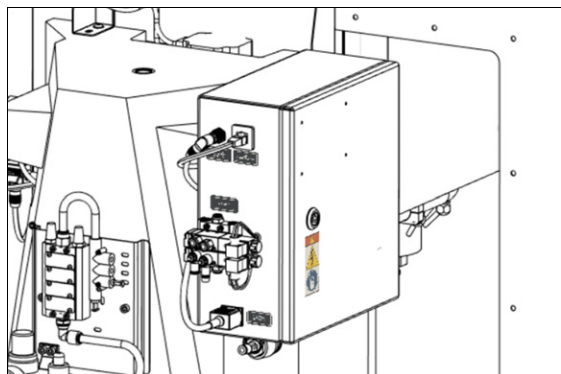


Figure 4-214: Connecting the IEC, EtherCAT, and ATC STO cables to the ATC's electrical cabinet.

9. Identify the loose end of the encoder/motor power cable and the tray in/out cable that are pre-installed on the ATC. Route the loose ends of the cables as follows:

- a. Route the **encoder/motor power cable** (PN 51967) through the grommet on the **right side** of the ATC column mount and out through the upper hole on the arm.
- b. Route the **tray in/out cable** (PN 51966) through the grommet on the **left side** of the ATC column mount and out through the upper hole on the arm.

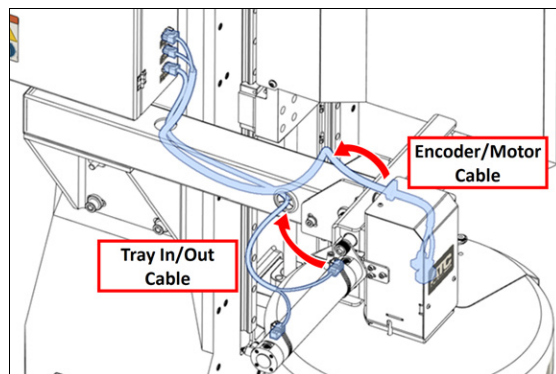


Figure 4-215: Cable routing from the ATC to the electrical cabinet.

- c. Connect the loose ends of the cables to the **ATC Tray Position Sensor**, **ATC Motor Encoder**, and **ATC Motor Power** connectors on the outer right side of the ATC's electrical cabinet.
10. Identify the air line labeled **Blaster**. Connect one end of the air line to the rear of the ATC's motor box. Route the loose end as follows:
 - a. Route the air line through the grommet on the **right side** of the ATC column mount and out through the plug in the rear hole on the arm.
 - b. Connect the loose end of the air line to the right port of the upper solenoid valve on the ATC's electrical cabinet.

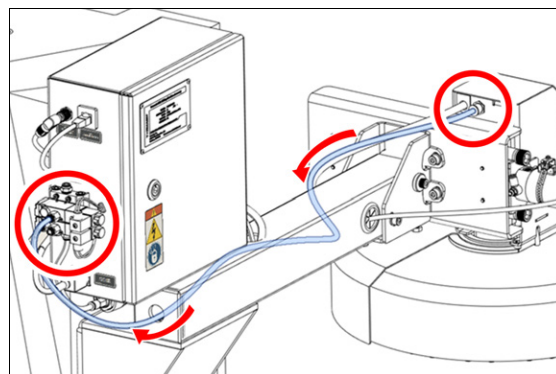


Figure 4-216: Blaster air line connections.

11. Identify the air line labeled **Tray In**. Connect one end of the air line to the fitting on the ATC actuator assembly that's closest to the motor box. Route the loose end as follows:
 - a. Route the air line through the grommet on the **left side** of the ATC column mount and out through the plug in the rear hole on the arm.
 - b. Connect the loose end of the air line to the left port of the lower solenoid valve on the ATC's electrical cabinet.

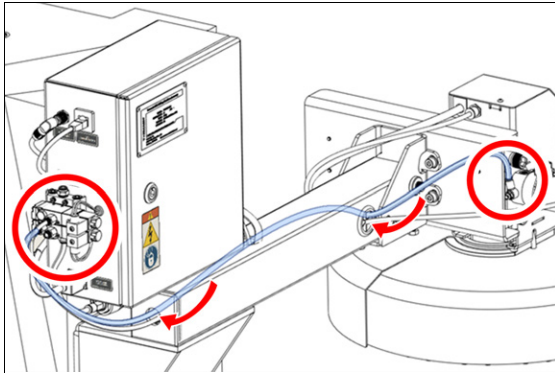


Figure 4-217: Tray In air line connections.

12. Identify the air line labeled **Tray Out**. Connect one end of the air line to the fitting on the ATC actuator assembly that's furthest from the motor box. Route the loose end as follows:
 - a. Route the air line through the grommet on the **left side** of the ATC column mount and out through the plug in the rear hole on the arm.
 - b. Connect the loose end of the air line to the right port of the lower solenoid valve on the ATC's electrical cabinet.

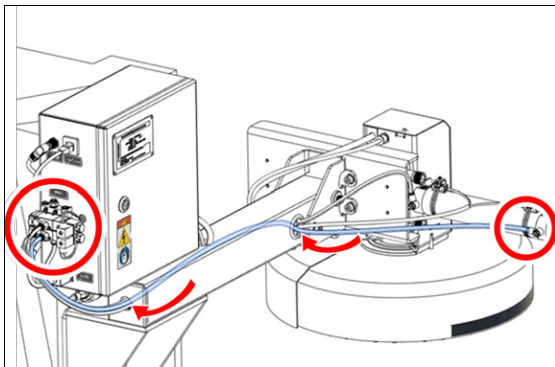


Figure 4-218: Tray Out air line connections.

13. Identify the air line labeled **Air Input**. Connect one end of the air line to the upper (main) fitting of the ATC's

pneumatic distributor, and connect the loose end to the upper port of the machine's pneumatic distributor.

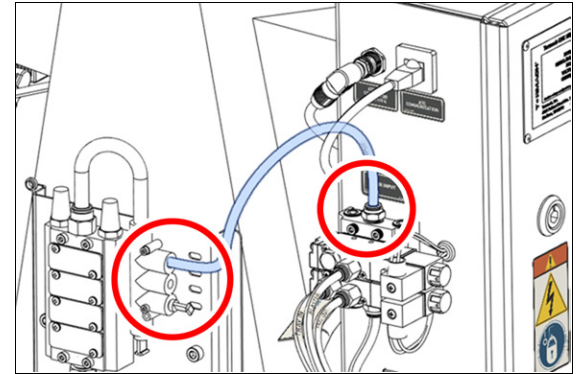


Figure 4-219: Air In air line connections.

4: INSTALLATION

4.8 Install Accessory Components

14. Depending on your machine configuration, do one of the following:

- **Enclosure Installation Completed:**

- a. Fasten the ATC mount cover panel (PN 52374) to the left rear panel using 12 M6 × 1.0 - 12 screws.

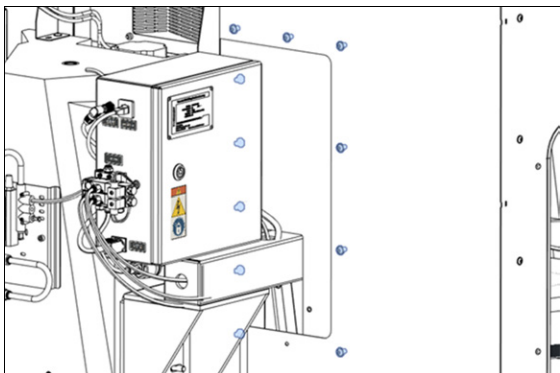


Figure 4-220: ATC mount cover panel installed onto the left rear panel.

- b. Identify the mount gap plate (PN 52450). Install it from the outside of the left rear panel using two M6 × 12 flanged button head screws.

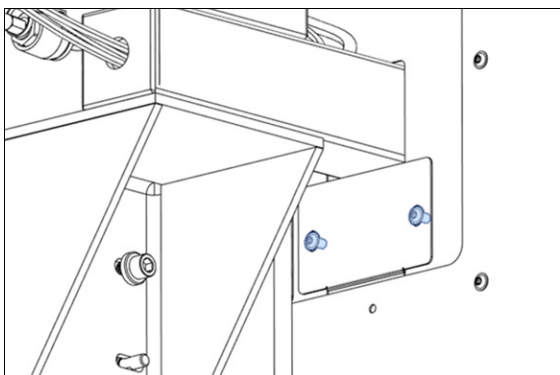


Figure 4-221: Mount gap plate installed onto the left rear panel.

- **Enclosure Installation in Progress:** Return to Install the Enclosure to complete the enclosure installation. Start with the section to install the enclosure panels.

Level and Align the ATC

Required Tools

- Adjustable torque meter up to 20 Nm
 - 6 mm hex tip for ratchet torque wrench
 - Precision square
 - Ratchet with 22 mm socket
- Wrench
 - Phillips screwdriver
 - BT30 tool holders
 - 1/2 in. collet for BT30 tool holder
 - 1/2 in. rod
1. Disconnect the air from the machine, and manually move the ATC to its tool change position (if the spindle interferes, power on the machine and jog the spindle to its highest position, and then power off the machine). Mount a tool holder with a 1/2 in. rod in the slot of the tool tray closest to the spindle, as shown below.

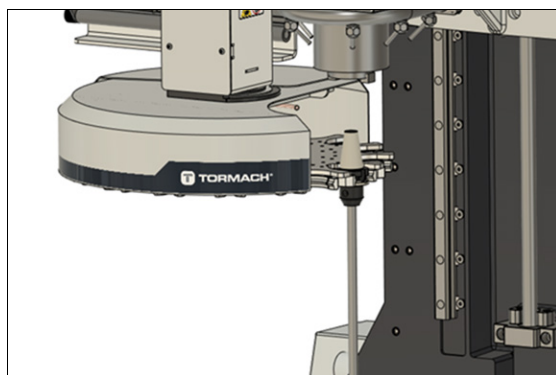


Figure 4-222: Tool holder with a 1/2 in. rod mounted in the tool tray.

2. Put the precision square on the machine table so that it's standing on its short end and aligned along the Y-axis (perpendicular to the table slots).

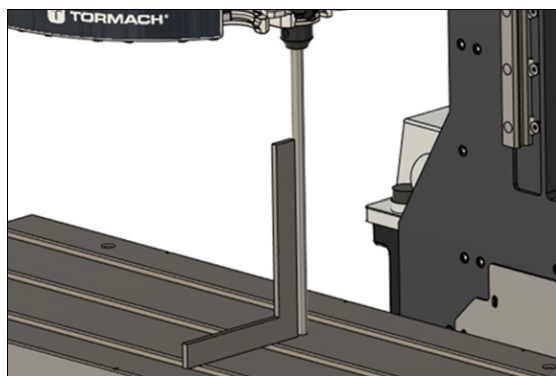


Figure 4-223: Precision square aligned along the Y-axis.

3. Adjust the tilt of the ATC along the X-axis:
 - a. Slightly loosen the three M8 screws on the mounting assembly and turn the bottom jack screw with a wrench.

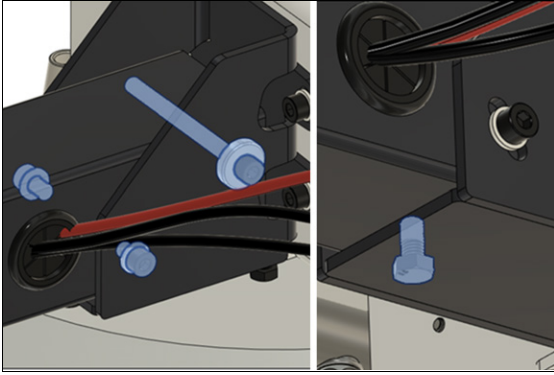


Figure 4-224: Screws used to adjust the tilt of the ATC along the X-axis.

- b. Repeat Step A until the rod is perfectly parallel with the precision square.
 - c. Retighten the three M8 screws, adjusting with a ratchet torque wrench with a 6 mm hex tip.
4. Turn the precision square so that it's aligned along the X-axis (parallel to the table slots).

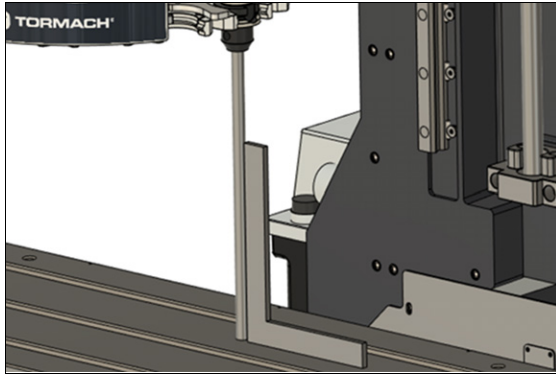


Figure 4-225: Precision square aligned along the X-axis.

5. Adjust the tilt of the ATC along the Y-axis:
 - a. Slightly loosen the three M8 screws that connect the tilt bracket and the side plate, and turn the lower jack screw with a wrench.

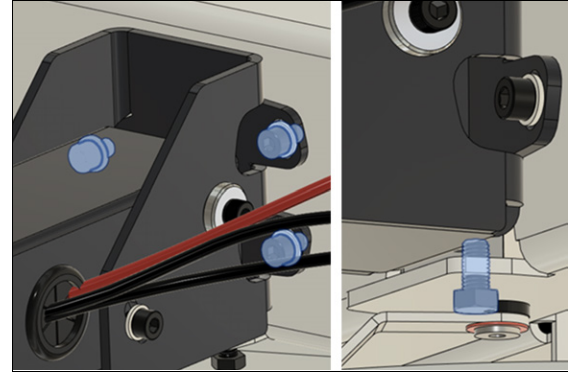


Figure 4-226: Screws used to adjust the tilt of the ATC along the Y-axis.

- b. Repeat Step A until the rod is perfectly parallel with the precision square.
 - c. Retighten the three M8 screws, adjusting with a ratchet torque wrench with a 6 mm hex tip.
6. Remove the precision square from the machine table and set it aside.
7. Manually move the ATC to its retracted position, and disconnect the EtherCAT communication cable from the ATC's electrical cabinet.
8. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the Emergency Stop button).
 - d. Bring the machine out of reset and reference it.
9. Manually move the ATC to its tool change position (with the piston fully extended), and slowly jog the spindle over the tool holder. Stop jogging just before contacting the tool holder. If the tool tray is offset, press the Emergency Stop button, and manually rotate the tool tray until it's aligned.

4: INSTALLATION

4.8 Install Accessory Components

10. Verify the X alignment of the ATC. Depending on the deviation in the tool on the X-axis with respect to the spindle center, move the M14 fine thread piston rod nuts surrounding the connection bracket of the motor box with your fingers, and move the ATC until the tool holder is perfectly aligned with the spindle in the tool change position (with the piston fully extended). Tighten both nuts with your fingers.

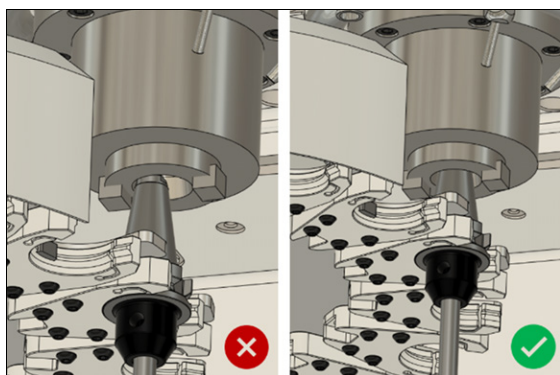


Figure 4-227: Examples of X alignment.

11. Jog the spindle up, manually move the ATC to an intermediate position, and tighten the two M14 fine thread nuts of the actuator stem between them as locknuts, with a wrench (holding the nut closest to the piston) and a ratchet with a 22 mm or 7/8 in. socket mounted on it with an extension (turning and tightening the nut furthest from the piston) as shown below.

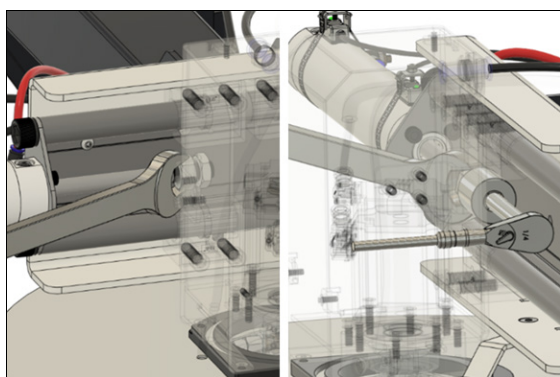


Figure 4-228: Adjusting the nuts on the actuator stem.

12. Manually move the ATC in and out from end-to-end on the actuator rod travel, and ensure that both the actuator sensors light up at the travel limits. If the sensors don't light up, adjust the position of the sensor by loosening the clamp screw, adjusting, and then retightening with a Phillips screwdriver.

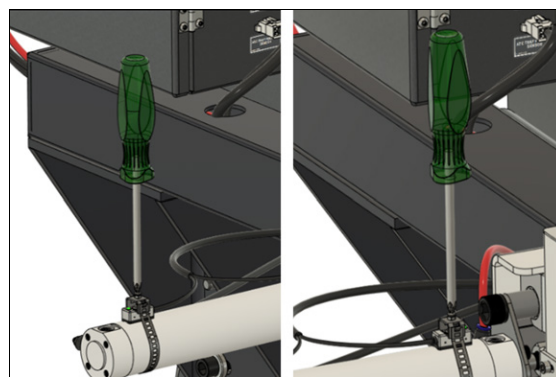


Figure 4-229: Adjusting the clamp screws.

13. If moving the ATC outward manually feels forced, the motor box bracket may be flexing the piston rod. Bring the ATC to its retracted position, and loosen the three M5 × 10 socket screws that hold the bracket to the motor box. When the bracket has settled on its own, retighten the screws. If the ATC movement feels smooth, go to the next step.

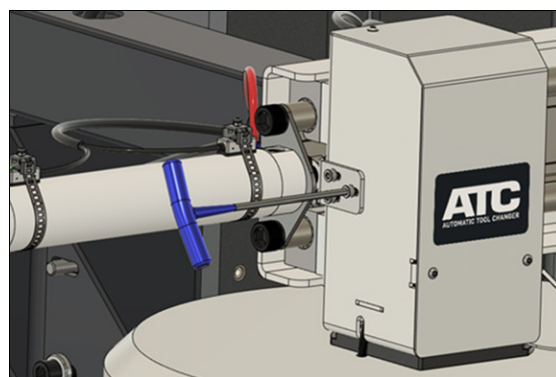


Figure 4-230: Adjusting the screws on the motor box bracket.

14. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
15. Wait for 8 seconds, and then reconnect the EtherCAT communication cable to the ATC electrical cabinet.

16. Power on the machine and the PathPilot controller.
 - a. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - c. Press the machine's Reset button (next to the Emergency Stop button).
 - d. Bring the machine out of reset and reference it.
17. Verify that, in the PathPilot interface, the **ATC** tab displays.



Figure 4-231: ATC tab in PathPilot.

18. If the tab doesn't display, verify that the machine is in setup mode. Use the key on the top of the operator console to switch between modes.
19. From the **Settings** tab, select the **ATC** radio button.

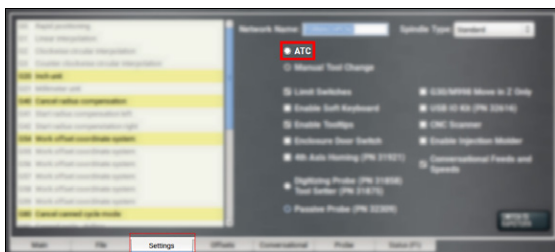


Figure 4-232: ATC radio button on the Settings tab.

20. Remove the tool holder from the tool tray, and manually move the ATC to its retracted position.
21. Reconnect the pressurized air to the machine (the ATC shouldn't move), and load the tool holder into the spindle. Disconnect the pressurized air from the machine.

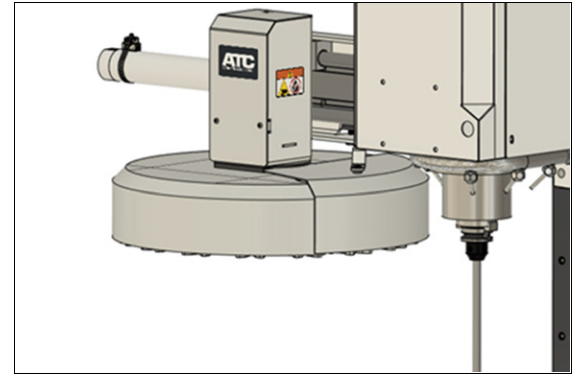


Figure 4-233: Tool holder with the rod loaded into the spindle.

22. Jog the spindle down and manually bring the ATC closer to its tool change position, without directly contacting the tool holder to the tray. From the PathPilot interface, on the **ATC** tab, select **Align Tool Tray**.

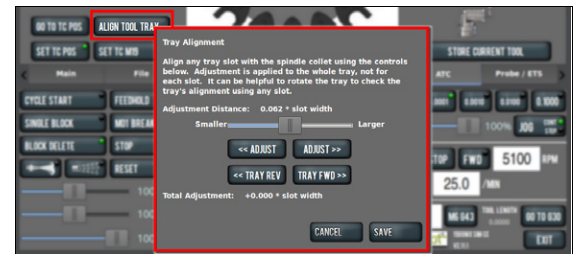


Figure 4-234: Tray Alignment dialog box.

4: INSTALLATION

4.8 Install Accessory Components

23. In the **Tray Alignment** dialog box, use the controls to rotate the tool tray until the tool holder is perfectly aligned vertically with the spindle. Once finished, select **Save**.

Note: If the machine isn't in setup mode, the controls in the **Tray Alignment** dialog box won't work. Use the key on the top of the operator console to switch between modes.



Figure 4-235: Examples of tool holder alignment vertically within the tool slots.

24. Jog the spindle up or down so that the tool holder slot is horizontally aligned within the tool tray slot. Verify this by manually moving the ATC, ensuring that the tool tray's slot contacts the tool holder in the spindle, as if you were going to make a tool change. If the movement feels strained, or if you notice the tool tray flexing up or down while doing this, manually remove the ATC from the tool holder, and readjust the height of the spindle by jogging the Z-axis.

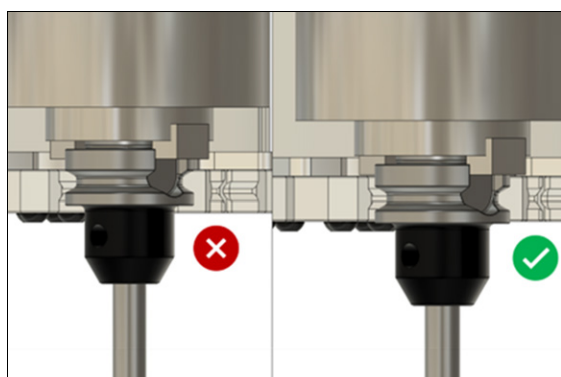


Figure 4-236: Examples of tool holder alignment horizontally within the tool slots.

25. From the PathPilot interface, on the **ATC** tab, select **Set TC POS**, and then select **OK**.

The height at which the spindle makes tool changes is saved.

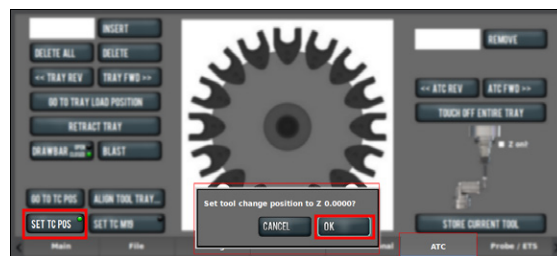


Figure 4-237: Set TC POS button on the ATC tab.

26. Manually move the ATC to its retracted position. From the PathPilot interface, on the **ATC** tab, select **Set TC M19**.



27. If the spindle hasn't previously been referenced, a dialog box displays with instructions to reference the spindle index sensor. Select **OK**, and wait for the spindle to rotate a few times to adjust the encoder.

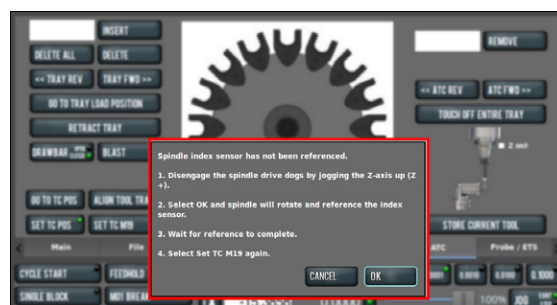


Figure 4-238: Spindle index sensor dialog box.

28. From the PathPilot interface, on the **ATC** tab, select **Go to TC POS**.

The spindle lowers to its tool change position.



Figure 4-239: Go to TC POS button on the ATC tab.

29. Manually move the ATC so that the tool tray holds the tool that's loaded into the spindle. From the PathPilot interface, on the **ATC** tab, select **Set TC M19** and, from the dialog box that displays, follow the instructions to rotate the tool holder clockwise and counterclockwise to define the central position of the tool holder within the tool tray's slot.

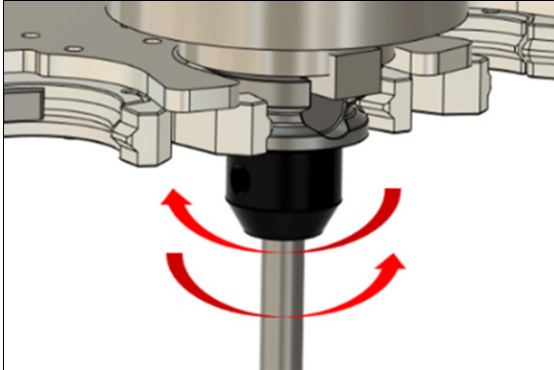


Figure 4-240: Rotating the tool holder.

30. Manually move the ATC to its retracted position, and jog the spindle up. Reconnect pressurized air to the machine, and remove the tool holder with the rod shaft from the spindle. The ATC is calibrated and is ready to perform a test tool change.

Test Tool Changes

1. Load an empty tool holder into the spindle. From the PathPilot interface, in the **Tool DRO** field, assign a tool number (for example, 1). Then, press **Enter** on the keyboard.
2. From the **ATC** tab, select **Tray Rev** or **Tray Fwd** to rotate the tool tray to an empty slot.



Figure 4-241: Tray rotation buttons on the ATC tab.

3. Select **Store Current Tool**.



Figure 4-242: Store Current Tool button on the ATC tab.

The spindle lowers, and the ATC moves to store the tool in the assigned holder.

If the tool didn't store smoothly, or if there was any sound or collision, disconnect the air from the machine and locate the exact point and reason for the collision, and verify the adjustment and alignment of the critical points mentioned earlier in this procedure.

4. From the PathPilot interface, in the **Tool DRO** field, type the tool number that you previously assigned (in our example, 1). Then, press **Enter** on the keyboard. In the dialog box that displays, select **Yes**. The ATC moves, and the spindle lowers to grab the selected tool. If the tool wasn't gripped smoothly, or if there was any sound or collision, disconnect the air from the machine and locate the exact point and reason for the collision, and check the adjustment and alignment of the critical points mentioned earlier in this procedure.
5. Repeat the steps in this section, adding more tools and making more changes between them, to completely verify the operation of the ATC.

4.8.9 Install the microARC 6

Complete the following steps in the order listed:

- Install the A-Axis Driver127
- Install the microARC 6 in the Machine. 131

Install the A-Axis Driver

⚠ WARNING! Electrical Shock Hazard: You must power off the machine before making any electrical connections. If you don't, there's a risk of electrocution or shock.

4: INSTALLATION

4.8 Install Accessory Components

1. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
2. Open the electrical cabinet door.
3. Locate the two screws next to the Z-axis driver. Remove the top screw and set it aside, and loosen the bottom screw with a 2.5 mm hex wrench.

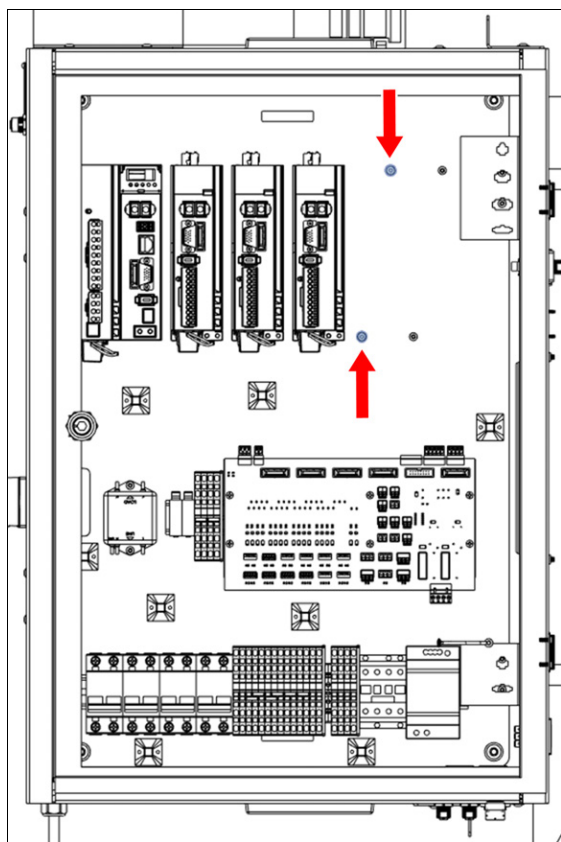


Figure 4-243: A-axis driver screws pre-installed in the electrical cabinet.

4. Remove the ground wire from the bottom screw. You'll connect it to the A-axis driver later in this procedure.
5. Find the A-axis driver included with this kit.

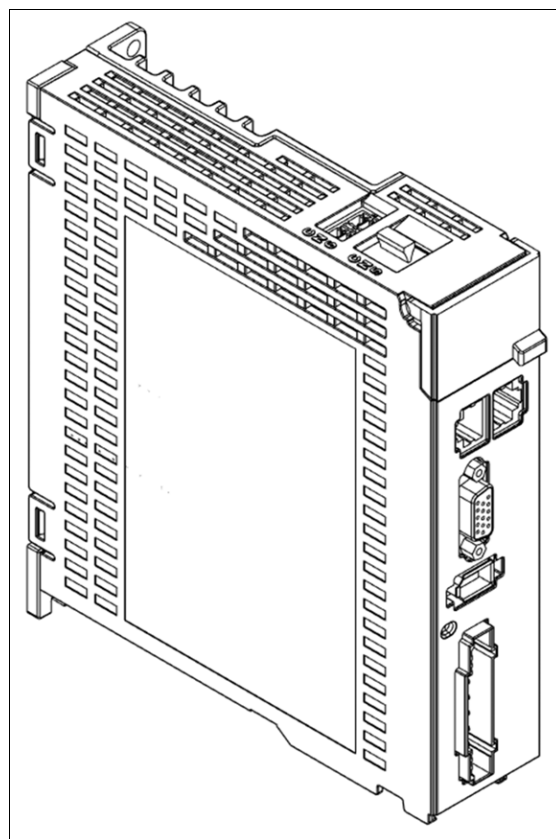


Figure 4-244: A-axis driver.

6. Install the A-axis driver into the electrical cabinet next to the Z-axis driver using the two screws that you identified in Step 3. Place the driver onto the loosened bottom screw and reinstall the top screw with a 2.5 mm hex wrench. Tighten both screws.

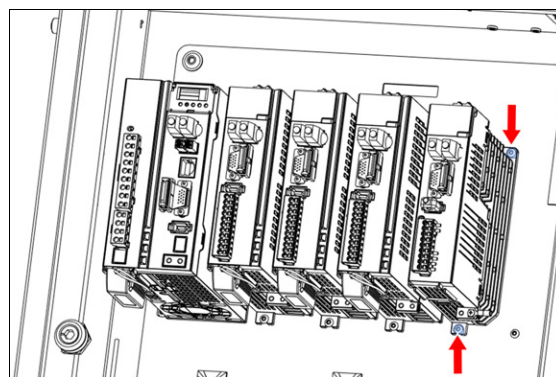


Figure 4-245: A-axis driver installed in the electrical cabinet.

- Identify the EtherCAT cable that's connected to the right port of the Z-axis driver. Disconnect the cable from the Z-axis driver and connect it to the output port on the A-axis driver.

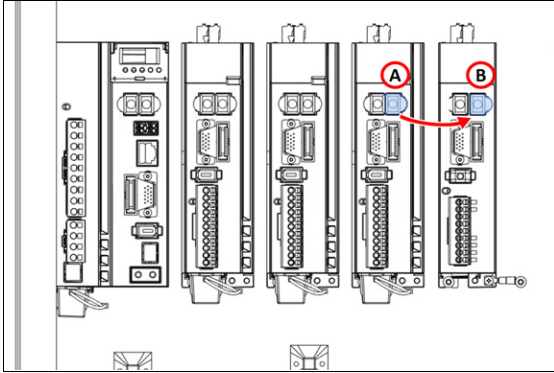


Figure 4-246: EtherCAT cable connection on the Z-axis and A-axis drivers.

- Identify the STO cable that's pre-installed in the electrical cabinet. Connect it to the A-axis driver.

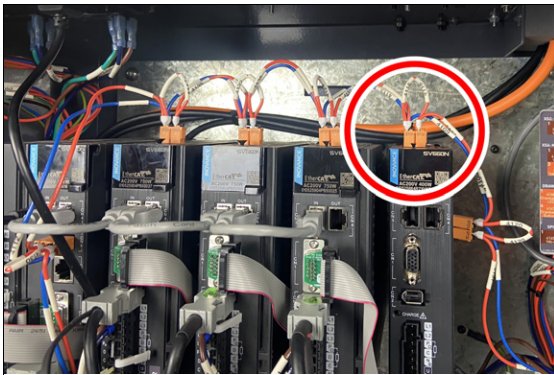


Figure 4-247: STO cable connected to the A-axis driver.

- Identify the EtherCAT jumper cable included in this kit. Connect it to both the Z-axis driver and the A-axis driver.

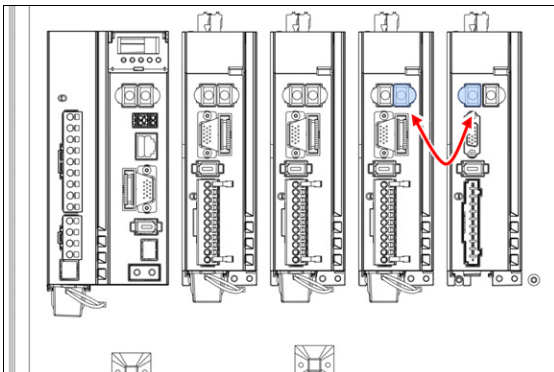


Figure 4-248: EtherCAT jumper cable connections on the Z-axis and A-axis drivers.

- Identify the 9-pin connector that's pre-installed in the

electrical cabinet's wiring harness. Connect it to the A-axis driver.

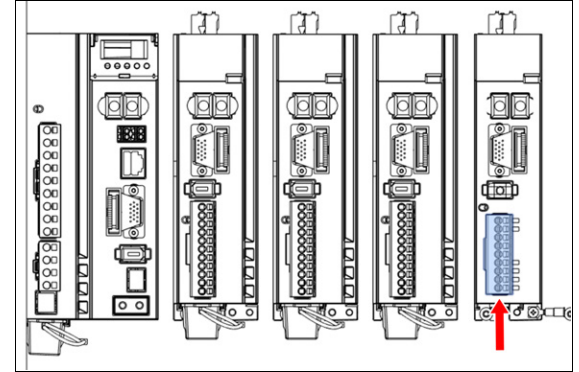


Figure 4-249: 9-pin connector connected to the A-axis driver.

- Identify the 15-pin I/O adapter provided with this kit. Connect it to the A-axis driver with both screws and a 1.5 mm hex wrench.

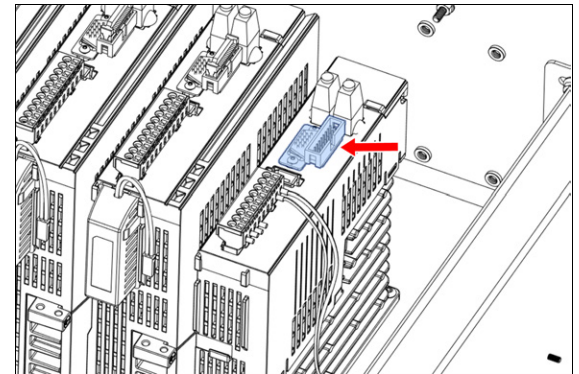


Figure 4-250: 15-pin I/O adapter connected to the A-axis driver.

- Identify the IDC ribbon cable that's included in this kit. Connect one end to the A-axis driver.

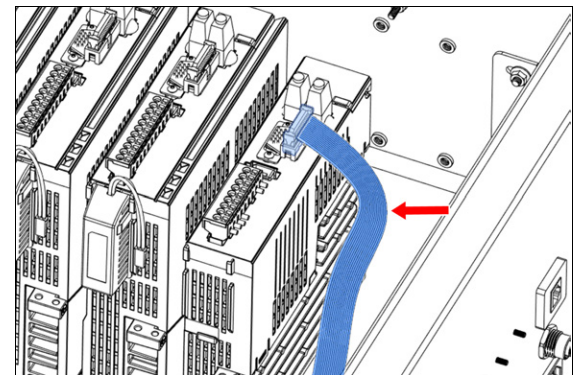


Figure 4-251: IDC ribbon cable connected to the A-axis driver.

4: INSTALLATION

4.8 Install Accessory Components

13. Connect the loose end of the IDC ribbon cable to the IDC header on the machine control board.

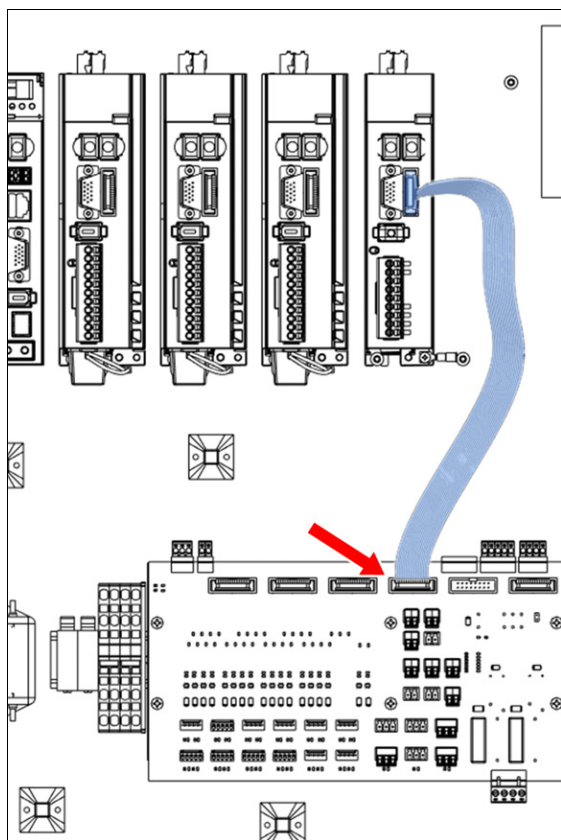


Figure 4-252: IDC ribbon cable connected to the machine control board.

14. On the top right panel of the enclosure, identify the **A-Axis Motor** and **A-Axis Encoder** knockout holes. Use a hammer and punch to remove the knockouts.
15. Identify the motor and encoder cables, which are shipped connected to the microARC itself. Disconnect them.
16. Remove the nut from the bulkhead connector for the power cable (the cable with the 4-pin connector). Put it in the **A-Axis Motor** hole, and thread the nut onto the bottom from inside the enclosure. Repeat this step to secure the encoder bulkhead into the top panel.

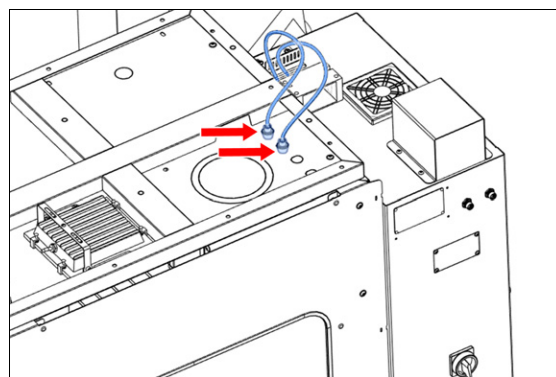


Figure 4-253: A-axis motor and encoder cables routed through the enclosure's knockout holes.

17. Route the loose end of the power and encoder cable through the channel on the top of the enclosure, and toward the electrical cabinet.
18. Identify the cable gland plate on the top right of the electrical cabinet. Loosen the four nuts that secure it to the cabinet, insert the encoder and power cables through the cable gland plate, and tighten the four nuts.

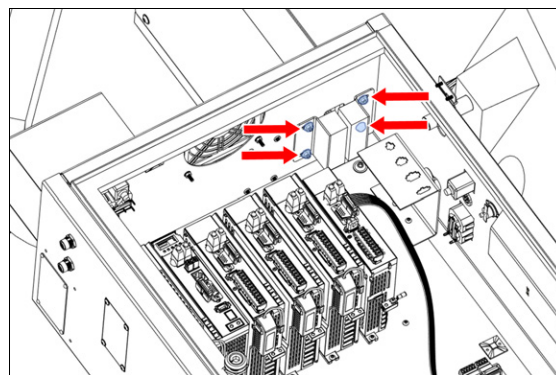


Figure 4-254: Cable gland plate screws.

19. Connect the IEEE 1394 cable from the encoder to the A-axis driver.

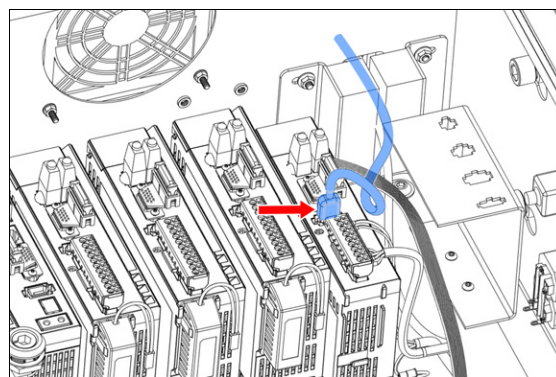


Figure 4-255: A-axis encoder cable connected to the A-axis driver.

20. On the 9-pin connector that you previously connected to the A-axis driver, connect the four motor power cables to the A-axis driver according to their labels (U, W, V, PE).

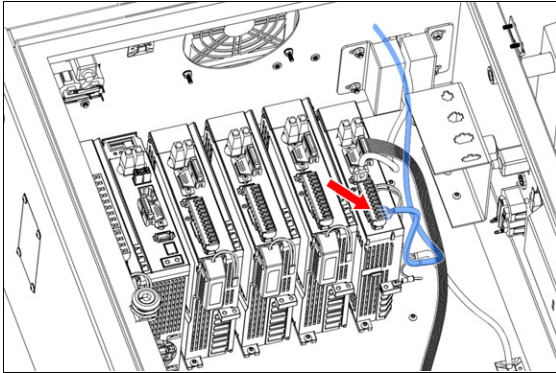


Figure 4-256: A-axis motor power wires connected to the A-axis driver.

21. Identify the ground cable that you set aside previously. Connect it to the A-axis driver and tighten the Phillips screw.

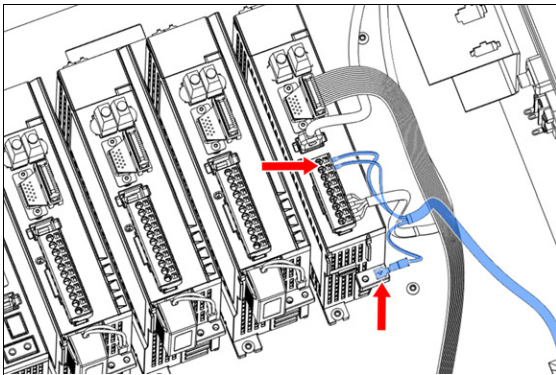


Figure 4-257: Ground wires connected to the A-axis driver.

Install the microARC 6 in the Machine

⚠ WARNING! Electrical Shock Hazard: You must power off the machine before making any electrical connections. If you don't, there's a risk of electrocution or shock.

1. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
2. If you haven't yet done so, clean off the machine table.

3. Install the handle onto the microARC with the included hardware and a 6 mm hex wrench.
4. Identify the T-slot alignment pin (PN 51851) included in this kit. Install it onto the bottom of the microARC with its screw (PN 51839) and a 2 mm hex wrench.

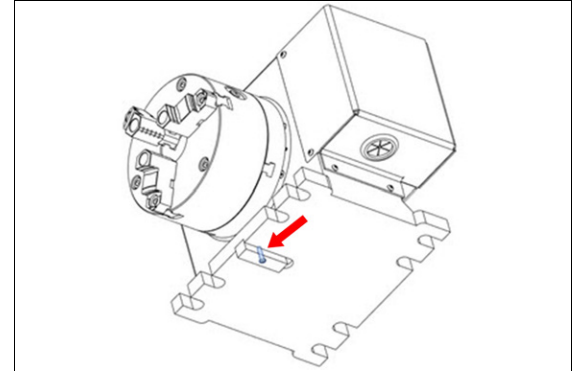


Figure 4-258: T-slot alignment pin installed.

5. Place the microARC 6 on the machine table.

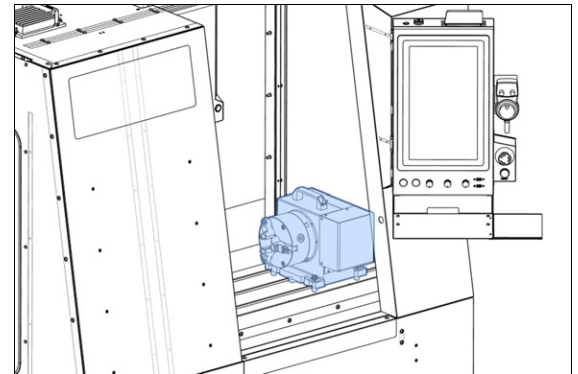


Figure 4-259: microARC on the machine table.

6. Secure the microARC to the machine table with the mounting hardware and a 3/8 in. hex wrench.

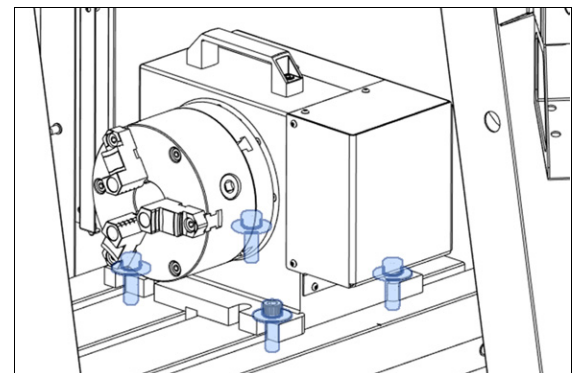


Figure 4-260: microARC secured to the machine table.

4: INSTALLATION
4.8 Install Accessory Components

- 7. Connect the loose ends of the power and encoder cables to the connectors on the microARC. Align the red dot on the cable and the connector.

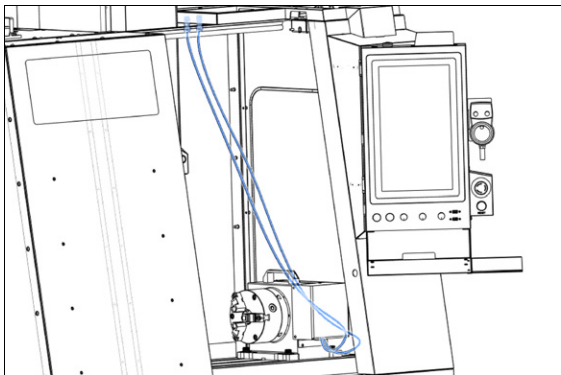


Figure 4-261: Power and encoder cables connected to the bulkhead connectors.

- 8. Power on the machine and the PathPilot controller.
a. Turn the Main Disconnect switch to ON on the side of the electrical cabinet.
b. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
c. Press the machine's Reset button (next to the Emergency Stop button).
d. Bring the machine out of reset and reference it.
9. Manually jog the A-axis to align the reference mark on the casting within the bracket on the reference label. Once aligned, from the PathPilot interface, select Reference A-Axis.

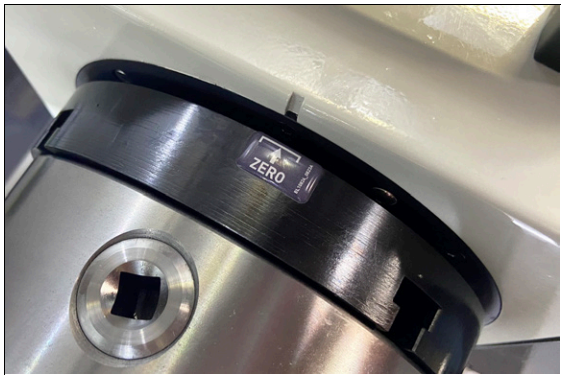


Figure 4-262: microARC aligned to the Zero label.

4.8.10 Install the Probe and Tool Setter

Complete the following steps in the order listed:

Before You Begin 132
Required Tools 132

Notes 132
Wireless Receiver Installation 132
Tool Setter Installation and Setup 134
Align the Tool Setter's Stylus 135
Reference the Tool Setter 135
Set G37 Position 136
Wireless Probe Installation and Setup 137
Adjust Probe Tip Concentricity 137
Set Probe Length and Diameter 138
Probe Status Lights Reference 139

Before You Begin

- Make sure that:
• The machine is powered on.
• The enclosure is installed.

Required Tools

- 1-2-3 block
• Metric hex wrench set
• Dial test indicator (0.0005 in. indicator or better) with magnetic base
• Flat-blade screwdriver

Notes

- Torque fasteners to the noted specification. If no specification is noted, hand tight is sufficient.

Wireless Receiver Installation

- 1. Identify the wireless receiver, bracket, cable, and hardware included in this kit.



Figure 4-263: Wireless receiver kit contents.

Note: The provided remote can be used for programming, but the receiver is already programmed. If you need assistance with programming the receiver, contact tech support.

2. You can install the wireless receiver into the enclosure in either of the following ways:
 - a. Use the provided bracket to mount the receiver to the enclosure panel. With this installation method, you're able to better position the receiver toward the spindle.
 - b. The receiver is magnetic, so you can just place it onto the enclosure. With this installation method, you have more flexibility in the placement of the receiver.
3. To mount the receiver with the provided bracket on the enclosure panel, first attach the bracket to the screw hole nearest to the enclosure door on the inside of the front right enclosure panel (behind the operator console) using the included hardware and a 4 mm hex wrench.

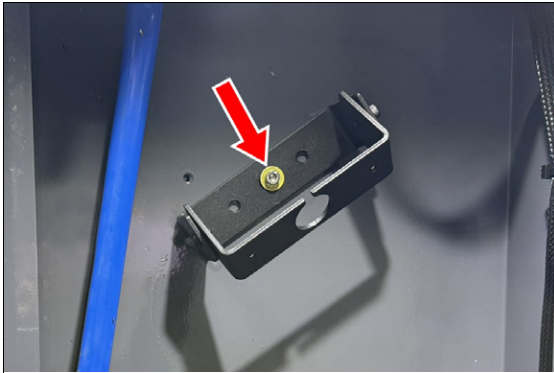


Figure 4-264: Bracket installed on the inside of the enclosure panel.

Note: There are two hole patterns available. You can use either of them to make sure that the probe has a good connection.

4. Attach the wireless receiver to the bracket using the included hardware and a 4 mm hex wrench.

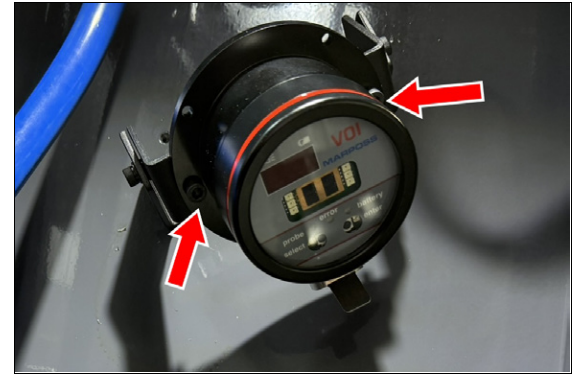


Figure 4-265: Wireless receiver mounted to the bracket.

5. Align the pin on the cable with the pin on the receiver. Connect the cable to the receiver, and lower bracket to secure it in place.



Figure 4-266: Cable connected to the wireless receiver.

6. Adjust the wireless receiver's bracket to point the receiver's panel towards the mill's spindle.
7. Remove the grommet on the top of the enclosure, and slide it onto the loose end of the wireless receiver's cable. Reinstall the grommet back onto the top panel of the enclosure, and pull the slack through.

4: INSTALLATION

4.8 Install Accessory Components

8. Route the wireless receiver's cable back towards the mill's electrical cabinet.

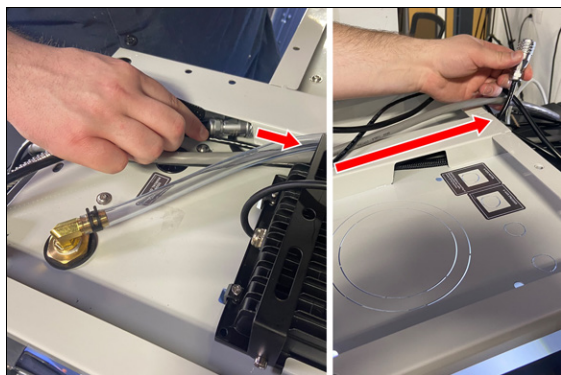


Figure 4-267: Wireless receiver's cable routing through the top panel on the enclosure.

9. Connect the wireless receiver's cable to the **Probe Control** connector on the bottom of the mill's electrical cabinet. Align the red dots on both the cable and the connector.



Figure 4-268: Red dot on the cable to align with the red dot on the connector.

10. Secure the wireless receiver's cable using zip ties.



Figure 4-269: Cable connection made and secured with Velcro cable ties.

Tool Setter Installation and Setup

1. Identify the electronic tool setter included in this kit. Remove the base off of the tool setter with a 4 mm hex wrench.



Figure 4-270: Base removed from the tool setter.

2. Install the tool setter's base ring to the machine table with the provided M12 × 1.75 - 30 socket head cap screw.

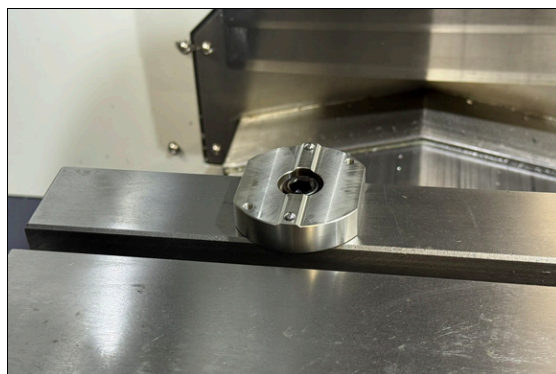


Figure 4-271: Base ring installed on the machine table.

3. Place the tool setter assembly over the base ring and secure it to the base ring by tightening the set screws.

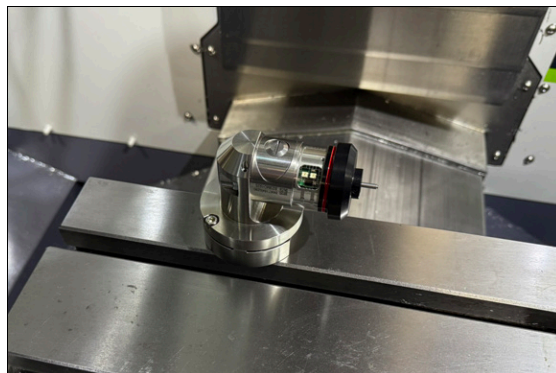


Figure 4-272: Tool setter installed onto the base ring.

4. Install the stylus onto the tool setter using a 1.5 mm hex wrench.

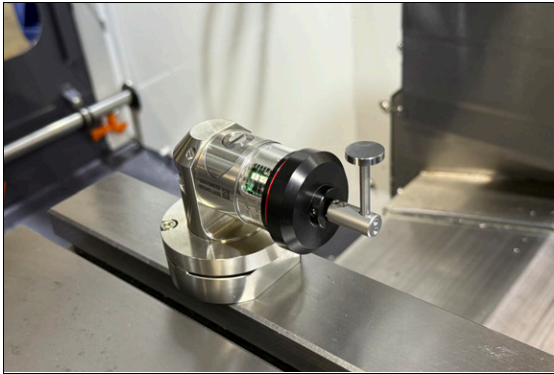
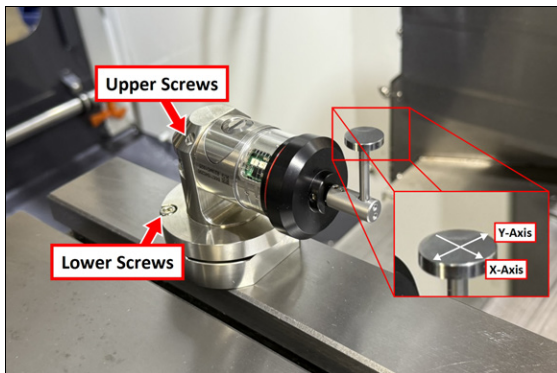


Figure 4-273: Stylus installed on the tool setter.

Align the Tool Setter's Stylus

The position of the stylus is controlled by two sets of screws on the tool setter:

- Use the **lower screws** to adjust the X-axis.
- Use the **upper screws** to adjust the Y-axis.



The adjustments are made completely separately from one another, but you can make them in any order. We recommend adjusting until the dial indicator shows movement of less than 0.0005 inches in both directions.

1. Mount a dial indicator on the spindle, and carefully jog the indicator's tip to the top of the tool setter's stylus.

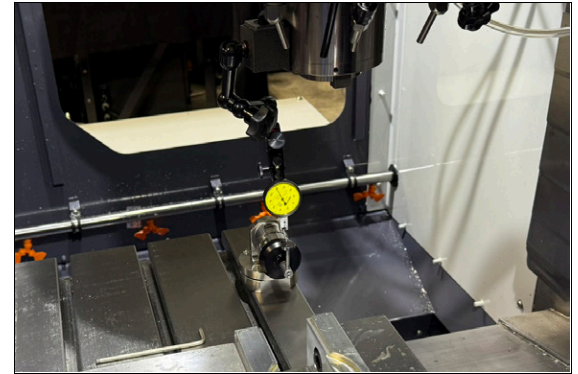


Figure 4-274: Dial indicator set up to check the flatness of the tool setter's stylus.

2. To adjust the X-axis of the tool setter, jog the indicator's tip to either the front or the back of the stylus and set the needle to zero. You'll always check from this side.
3. Sweep the indicator to the opposite side of the stylus and watch the needle.
4. Depending on the amount of movement, adjust the **lower screws** on the tool setter by slightly tightening one and loosening the other.
5. Jog the indicator's tip back to the opposite side of the stylus (where you originally started). Set the needle to zero, and sweep the indicator back to the opposite side of the stylus.
6. Continue adjusting and rechecking until the reading on the dial indicator is less than 0.0005 inches.
7. To adjust the Y-axis of the tool setter, jog the indicator's tip to either the left or the right of the stylus. You don't need to reset the indicator to zero — you'll just check for movement.
8. Sweep the indicator to the opposite side of the stylus and watch the needle.
9. Depending on the amount of movement, adjust the **upper screws** on the tool setter by slightly tightening one and loosening the other.
10. Continue adjusting and rechecking until the reading on the dial indicator is less than 0.0005 inches.

Reference the Tool Setter

1. Remove the tool setter's battery door using a flat-blade screwdriver or similar object.

4: INSTALLATION

4.8 Install Accessory Components

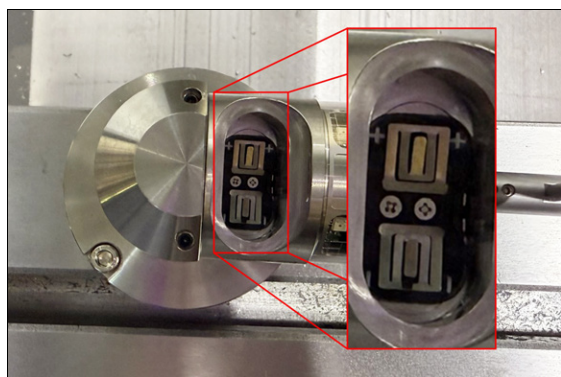


Figure 4-275: Battery door removed from the tool setter.

- Identify the two batteries included with this kit. Put both batteries into the tool setter. Replace the battery door onto the tool setter, and secure it with a screwdriver.

Note: Do not depress the tool setter's stylus while inserting the batteries. Depressing the stylus will cause the tool setter to enter settings mode. If the stylus is depressed, wait one minute for the tool setter to exit settings mode.

- Power on the machine and the PathPilot controller.
 - Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
 - Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
 - Press the machine's Reset button (next to the Emergency Stop button).
 - Bring the machine out of reset and reference it.
- If you haven't already done so, enter the diameter and length for the calibration tool (engraved on the side of the tool) into PathPilot. From the PathPilot interface, on the **Offsets** tab, enter details into tool 1000.
- Load the calibration tool into the spindle. From the PathPilot interface, in the **Tool DRO** field, type 1000 and press the **Enter** key on the keyboard.
- Jog the machine table so that the tool setter is under the tool, and slowly jog the Z-axis down until it's just above the tool setter.

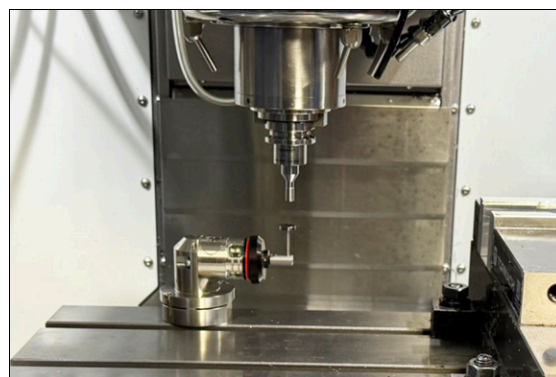


Figure 4-276: Calibration tool above the tool setter.

- From the PathPilot interface, on the **Probe/ETS** tab, open the **ETS Setup** tab. Then, select **ETS Spindle Ref.**

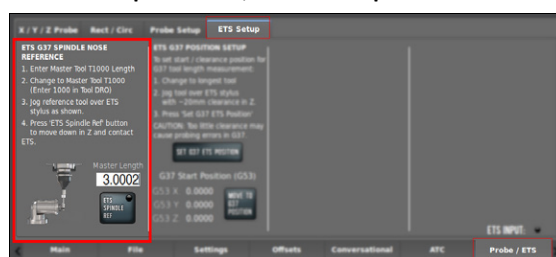


Figure 4-277: ETS Setup tab.

Set G37 Position

- Load the longest tool that you'll be using into the spindle. From the PathPilot interface, change to that tool.

NOTICE! If you use a shorter tool to set the G37 position, there's a risk of tool collision when using a longer tool.

- Jog the tool so that it's about 20 mm above the tool setter's contact pad.
- From the PathPilot interface, on the **ETS Setup** tab, find the **ETS G37 Position Setup** group, and select **Set G37 ETS Position**.

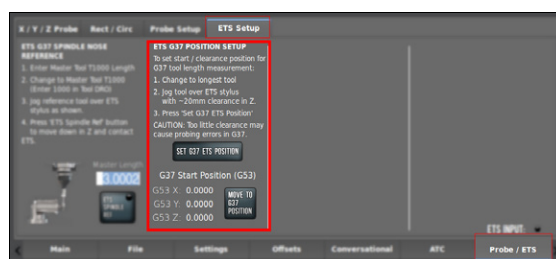


Figure 4-278: Set G37 ETS Position on the Probe tab.

The G37 position is now set.

4. Verify that the X, Y, and Z ETS position displayed in their DRO fields are accurate.



Note: The values displayed in these DRO fields are in G53.

Wireless Probe Installation and Setup

1. Identify the wireless probe included in this kit. Install it into the BT30 probe holder by tightening the two set screws opposite each other. Do not tighten the four-set-screw pattern at this time.



Figure 4-279: Installing the probe into the BT30 holder.

2. Thread the probe tip into the wireless probe.



Figure 4-280: Installing the probe tip.

3. Remove the probe's battery door using a flat-blade screwdriver or similar object.
4. Insert two batteries into the wireless probe. The probe lights should illuminate; if they don't, you may need to swap the battery placement.



Figure 4-281: Battery door removed off of the wireless probe.



Note: While installing the cover, be careful not to deflect the probe tip. If you do, leave the probe for 30 seconds until the lights turn off.

5. Load the probe into the spindle.

Adjust Probe Tip Concentricity

1. Place a dial indicator on the machine table, and carefully jog the indicator's tip into the probe's tip to check for concentricity.



Figure 4-282: Dial indicator set up to check the probe's tip concentricity.

4: INSTALLATION

4.8 Install Accessory Components

- Identify the two sets of screws on the probe body. When you loosen one set screw, tighten the opposite set screw. Make adjustments as needed to the screws, manually rotate the probe by hand, and check the alignment again. Aim for the best possible concentricity, targeting between 0.0005 in. and 0.001 in.

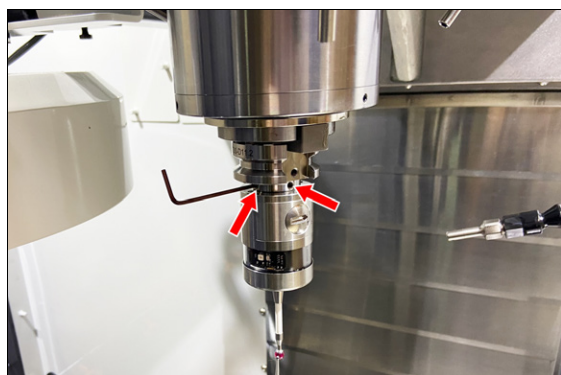


Figure 4-283: Both sets of screws are shown; not shown are each set's opposing screw.

Set Probe Length and Diameter

- Identify the calibration tool (PN 51149) included with this kit. Load the calibration tool into the spindle. Make note of the diameter and length, which is engraved on the tool itself.



Figure 4-284: Diameter and length measurements engraved on to the calibration tool.

- From the PathPilot interface, on the **Offsets** tab, enter the diameter and length for the calibration tool into tool 1000.
- Wipe off the machine table.
- Put a 1-2-3 block on the machine table.
- Verify that the machine is in setup mode. Use the key on the top of the operator console to switch between modes. For more information, go to "Operating Modes Reference" (page 31).

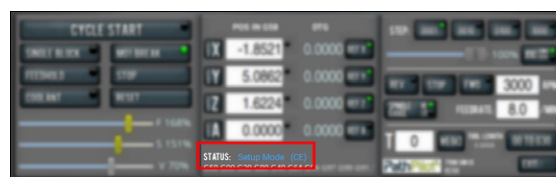


Figure 4-285: PathPilot indication of which mode the machine is set to.

Note: In setup mode, you don't need to press the hold-to-run button to jog the machine with the enclosure doors open.

- Jog the table until the block is under the calibration tool. Slowly jog the Z-axis down until it's tip drags on the 1-2-3 block.



Figure 4-286: Calibration tool near the top of the 1-2-3 block.

- Close the enclosure door.
- From the PathPilot interface, change to T1000.
- From the **Probe/ETS** tab, on the **Probe Setup** tab, select **Set Reference Height**.



Figure 4-287: Reference height section of the probe setup.

- Remove the calibration tool and load the probe into the spindle.
- From the PathPilot interface, change to T99. Make sure the probe LED turns green. While watching the LED, flick the probe tip to make sure that the probe responds.

12. Jog the table until the 1-2-3 block is under the probe. Slowly jog the Z-axis down until the probe's tip is just above the 1-2-3 block.



Figure 4-288: Probe tip near the top of the 1-2-3 block.

13. From the PathPilot interface, on the **Probe/ETS** tab, open the **Probe Setup** tab. Then, select **Move and Set Probe Length**.

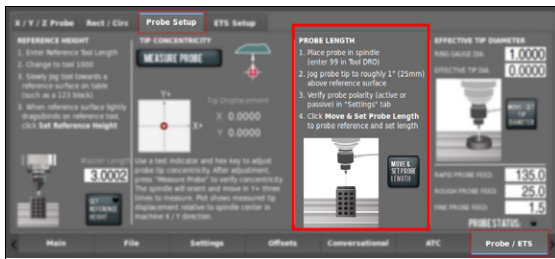


Figure 4-289: Probe length section of the probe setup.

14. Identify the ring gauge (PN 51100) included in this kit. Make note of the diameter, which is engraved on the side of the ring gauge.



Figure 4-290: Diameter measurement engraved onto the ring gauge.

15. Place the ring gauge on the machine table, and jog the spindle probe so that it's in the center of the ring gauge and 1/4 in. below the ring gauge's surface.

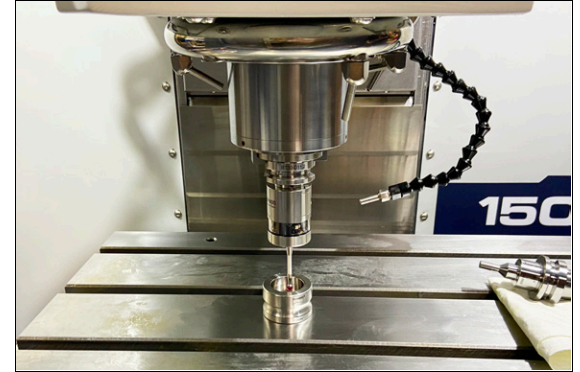


Figure 4-291: Ring gauge under the spindle.

16. Close the enclosure door.
17. From the PathPilot interface, on the **Probe** tab, enter the diameter of the ring gauge into the **Ring Gauge Diameter DRO** field. Then, select **Move/Set Tip Diameter**.



Figure 4-292: Effective tip diameter section of the probe setup.

Probe Status Lights Reference

Light	Status
Blinking green	The probe is on and triggered
Blinking red	Error
Blinking yellow	The probe's battery signal is low



SYSTEM BASICS

IN THIS SECTION, YOU'LL LEARN:

- About the main components of the machine and how it moves.



Before operating the machine in any way, you must read and understand this section.

CONTENTS

5.1 System Reference	142
5.2 Basic Controls Reference	143



TORMACH®

5: SYSTEM BASICS

5.1 System Reference

5.1 SYSTEM REFERENCE

To operate your machine, you must become familiar with the components of its system.

5.1.1 Machine Table

The machine table is 35" × 12.75" (890 mm × 325 mm).

Don't put more than 300 lb (136 kg) on the machine table.

Always verify that the workpiece and workholding devices are centered on the machine table.

The machine table has three T-slots along the X-axis, used to secure workholding devices (on which to secure your workpiece while machining):

- **T-Slots** 5/8" (15.9 mm) (three slots)
- **T-Slot Spacing** 3.9" (100 mm)
- **Center T-Slot** Precision ground to 0.625" (15.9 mm)

5.1.2 Spindle

The machine spindle uses a BT30 taper to hold BT30 tool holders.

- **Spindle Power** 4 hp (3 kW)
- **Minimum Speed** 250 rpm
- **Maximum Speed** 10,000 rpm

About the Spindle

The machine spindle gives power to the cutting tool, which allows it to remove material from the workpiece. The spindle motor drives the spindle through a 5 mm pitch HTD timing belt.

The machine uses a single-contact BT30 spindle taper. The tool holder contacts only the spindle taper, which keeps it in position. Because of this, there's a gap (2 mm) between the tool holder's flange and the end surface of the spindle nose. Operate the spindle either manually or by G-code commands (entered in the MDI Line DRO field or programmed into a G-code program). Manually controlling the spindle is useful when you're setting work offsets for tools that require the spindle to be running (like "wiggler"-style edgefinders or coaxial indicators).

The machine's spindle rotates either clockwise (forward) or counterclockwise (reverse) at a specified spindle speed.

5.1.3 Axes

The machine has three linear axes of motion, and one optional rotary axis, used for machining:

- The X-axis, which is (horizontally) along the long side of the machine table.
- The Y-axis, which is (horizontally) along the short side of the machine table.
- The Z-axis, which is (vertically) along the mill column.
- *(Optional)* The A-axis, which is the axis of rotation that is typically aligned to the X-axis.

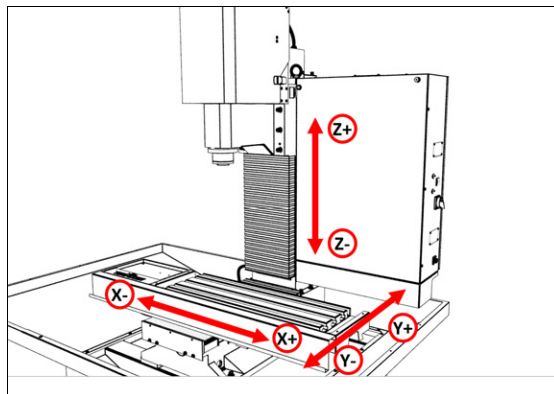


Figure 5-1: Axis directions on the machine.

Each axis has a different limit of travel:

- **X-Axis** 19.7" (500 mm)
- **Y-Axis** 13.8" (350 mm)
- **Z-Axis** 14" (356 mm)

5.2 BASIC CONTROLS REFERENCE

To safely and effectively operate your machine, you must become familiar with how it moves. The machine has two forms of basic controls: machine controls and the PathPilot interface.

5.2.1 Machine Controls

The following controls energize the machine's control electronics:

- The Main Disconnect switch, located on the right side of the electrical cabinet.

The Main Disconnect switch has two positions: **OFF** and **ON**. When it's in the **OFF** position, it separates the other machine control electronics from the mains electrical supply. When it's in the **ON** position, the other machine control electronics are able to receive power.

 **WARNING!** Before opening the electrical cabinet for maintenance or troubleshooting, you must lockout the mains power: Turn the Main Disconnect switch to the **OFF** position, and secure an approved lockout device through the lockout rings at the bottom of the switch.

- The blue Reset button and the red Emergency Stop button, located on the front of the machine.
When pushed in, the Emergency Stop button interrupts power to the spindle and axis drives, and stops the machine's motion. When the Emergency Stop button is twisted out, press the Reset button to enable the machine, allowing spindle and axis motion. The Reset button's LED turns on when the machine is enabled and the spindle and axis drives receive power.

5.2.2 PathPilot Interface

PathPilot is the primary means by which you interact with your machine. PathPilot controls all of the automatic motion of the machine axes and spindle, as well as some accessories. The PathPilot control system consists of:

- **Controller and Monitor** Shows the PathPilot interface (monitor, touch screen, or integrated console display)
- **Input Devices** Keyboard and mouse for navigation and data entry

- **Manual Control** Jog pendant or jog shuttle for manual axis movement

The specific hardware configuration depends on your machine model.



PATHPILOT INTERFACE OVERVIEW

IN THIS SECTION, YOU'LL LEARN:

- How PathPilot is organized, and where you can access each tool or feature.

CONTENTS

6.1 About PathPilot	146
6.2 Notebook Section	147
6.3 Persistent Controls	150
6.4 Keyboard Shortcuts	152
6.5 Manage PathPilot Versions	153

6: PATHPILOT INTERFACE OVERVIEW

6.1 About PathPilot

6.1 ABOUT PATHPILOT

PathPilot is a combination hardware and software system that you use to control your machine. The controller hardware runs the PathPilot software.

The PathPilot interface is divided into sections: the Notebook section is in the top half of the screen, and the Persistent Controls section is in the bottom half.

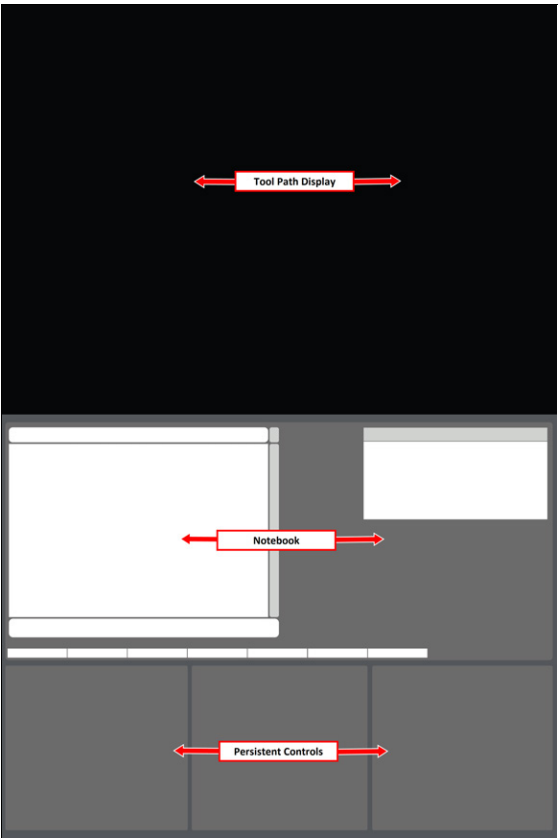


Figure 6-1: Sections in the PathPilot interface.

6.2 NOTEBOOK SECTION

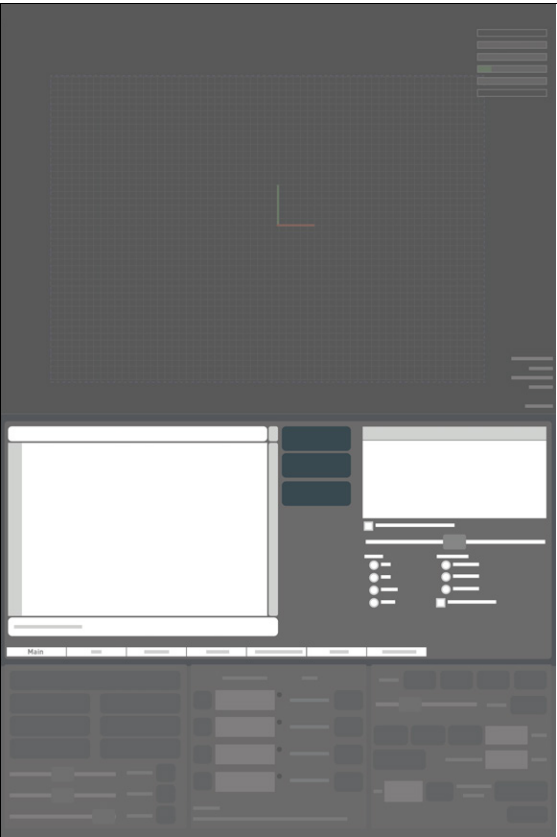


Figure 6-2: Notebook section.

The areas displayed in the Notebook section change depending on the activity that you're doing. Activities are grouped into the following tabs:

6.2.1 Main Tab	147
6.2.2 File Tab	147
6.2.3 Settings Tab	148
6.2.4 Offsets Tab	148
6.2.5 Conversational Tab	148
6.2.6 Probe/ETS Tab	148
6.2.7 Status Tab	149

6.2.1 Main Tab



Figure 6-3: Main tab.

By default, the Main tab is active when you power on the PathPilot controller. From the Main tab, you can do the following activities:

- Access G-code files that are already loaded into PathPilot, and open or close them.
For information, see "Access Recent G-Code Files" (page 157); "Close the Current Program" (page 157).
- Send G-code commands directly to the machine using the Manual Data Input (MDI) Line DRO field.
For information, see "Manually Enter Commands" (page 196).
- In a G-code program, do tasks like finding specific terms in the code, reading the code, or viewing the generated tool path.
For information, see "Search in the Code" (page 159); "Expand the G-Code Tab" (page 158); "Change the View of the Tool Path Display" (page 160).
- Make and restore backup files of your settings.
For information, see "Create Backup Files" (page 202); "Restore Backup Files" (page 203).

6.2.2 File Tab



Figure 6-4: File tab.

From the File tab, you can do the following activities:

- Transfer G-code files into the PathPilot controller.
For information, see "Transfer Files to and From the Controller" (page 156).
- Edit G-code files.
For information, see "Edit G-Code" (page 157).
- Load .nc files into PathPilot to run a program.
For information, see "Load G-Code" (page 211).
- Move files within the system.
For information, see "Preview G-Code Files" (page 156); "Manage System Files" (page 202).

6: PATHPILOT INTERFACE OVERVIEW

6.2 Notebook Section

6.2.3 Settings Tab

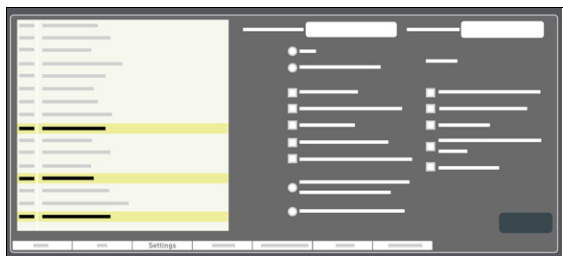


Figure 6-5: Settings tab.

From the Settings tab, you can do the following activities:

- Change the network name with which you're using PathPilot.
For information, see "Change the Network Name" (page 174).
- Change the screen's layout orientation (landscape or portrait).
For information, see "Change the Screen Orientation" (page 174).
- Configure PathPilot for the accessories you're using.
For information, see "Enable the On-Screen Keyboard" (page 176); "Enable the USB M-Code I/O Interface Kit" (page 177); "Use a USB Camera" (page 177); "Specify the Tool Change Method" (page 175); "Select the Spindle Type" (page 174) "Select the Spindle Type" (page 174).
- Turn on feeds and speeds suggestions when using conversational programming.
For information, see "Enable Feeds and Speeds Suggestions in Conversational Routines" (page 177).
- Specify the way in which you want to use a G30 move.
For information, see "Limit G30 Moves" (page 176).
- Identify the available G-code modes that you can use.
For information, see "View Available G-Code Modes" (page 187).

6.2.4 Offsets Tab



Figure 6-6: Offsets tab.

From the Offsets tab, you can do the following activities:

- Import and export .csv files of your tool table.
For information, see "Import and Export the Tool Table" (page 204).
- Work with a table of tool descriptions and tool offsets.
For information, see "Set Tool Length Offsets" (page 213).
- Use an Electronic Tool Setter (ETS) to measure tools.
For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 215).
- Preset a G30 position.
For information, see "Use a G30 Position" (page 195).
- Read the currently programmed work offsets.
For information, see "View Work Offsets" (page 187).

6.2.5 Conversational Tab



Figure 6-7: Conversational tab.

From the Conversational tab, you can do the following activities:

- Use different functions to create simple G-code programs in PathPilot.
For information, see "About Conversational Programming" (page 161).

6.2.6 Probe/ETS Tab



Figure 6-8: Probe tab.

From the Probe tab, you can do the following activities:

- Configure and control a probe to help perform certain functions.
For information, see "Use a Probe with PathPilot" (page 181).

- Configure and control an Electronic Tool Setter (ETS) to help perform certain functions.
For information, see Use an to Measure Tools.

6.2.7 Status Tab

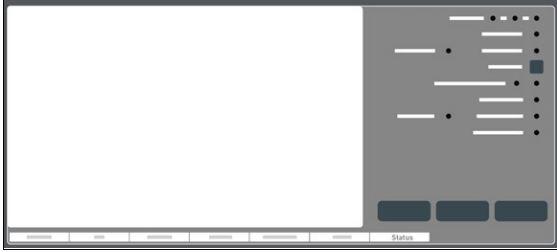


Figure 6-9: Status tab.

From the Status tab, you can do the following activities:

- View diagnostic machine information.
- Read error messages.
- Configure your internet connection.
For information, see "Enable an Internet Connection" (page 173).
- Update or install a previous version of PathPilot.
For information, see "Manage PathPilot Versions" (page 153).

6: PATHPILOT INTERFACE OVERVIEW

6.3 Persistent Controls

6.3 PERSISTENT CONTROLS

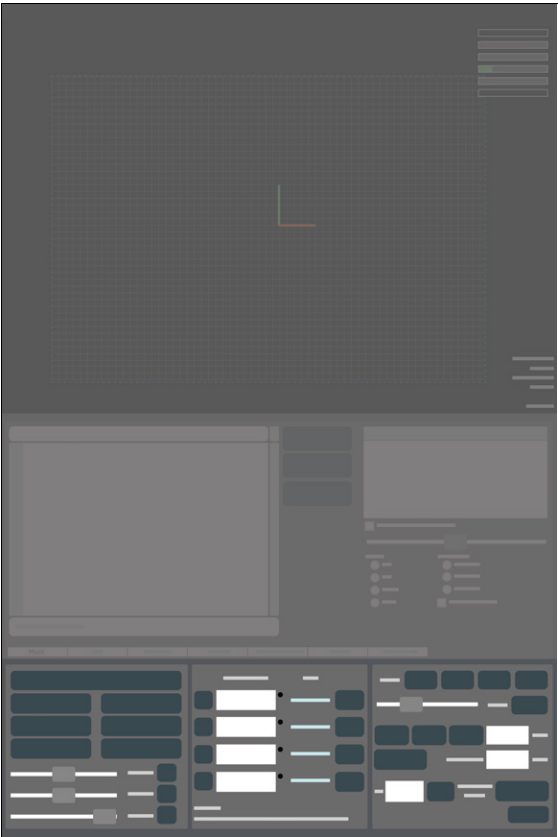


Figure 6-10: Persistent Controls section.

The areas that display in the Persistent Controls section don't change (unlike the Notebook section). They display regardless of the activity you're doing. Activities are grouped into the following areas:

6.3.1 Program Control Area	150
6.3.2 Position Status Area	150
6.3.3 Manual Control Area	151

6.3.1 Program Control Area



Figure 6-11: Program Control area.

From the Program Control area, you can do the following activities either before starting or while running a G-code program:

- Reset the machine.
For information, see "Bring the Machine Out of Reset" (page 188).
- Start, stop, or pause a G-code program.
For information, see "Start a Program" (page 190); "Stop Machine Motion" (page 191); "Use the Feed Hold Function" (page 192).
- Turn coolant on or off.
For information, see "Operate the Coolant Pump" (page 218).
- Use overrides to change the feed rate, spindle speed, and maximum velocity.
For information, see "Use the Feed Rate Override Function" (page 192); "Use the Maxvel Override Function" (page 193); "Use the Spindle Override Function" (page 194).
- Manually control a G-code program.
For information, see "Use M01 Break Mode" (page 193); "Use Single Block Mode" (page 194).

6.3.2 Position Status Area



Figure 6-12: Position Status area.

From the Position Status area, you can do the following activities either before starting or after running a G-code program:

- Reference the machine axes.
For information, see "Reference the Machine" (page 207).
- Create work offsets.
For information, see "Set Work Offsets" (page 217).
- Understand how you're jogging the machine.
For information, see "View the Active Axis to Jog" (page 188); "View the Current Machine Position" (page 189); "View the Distance to Go" (page 191).
- Quickly determine which G-code modes are active.
For information, see "View the Active G-Code Modes" (page 191).

6.3.3 Manual Control Area



Figure 6-13: Manual Control area.

From the Manual Control area, you can do the following activities either before starting or after running a G-code program:

- Move the machine axes.
For information, see "Jog the Machine" (page 208).
- Change the spindle speed or feed rate.
For information, see "Change the Spindle Speed" (page 195); "Change the Feed Rate" (page 195).
- View or edit information about the current tool.
For information, see "Change the Tool Number" (page 195); "Use a G30 Position" (page 195) "View the Tool Length" (page 196).

6: PATHPILOT INTERFACE OVERVIEW

6.4 Keyboard Shortcuts

6.4 KEYBOARD SHORTCUTS

The following table lists the keyboard shortcuts in PathPilot.

Keyboard Shortcut	Use to...
Alt+E	Edit the currently loaded G-code program (from any tab in the PathPilot interface)
Alt+Enter	Use the Manual Data Input (MDI) Line DRO field
Alt+F	Use the coolant function
Alt+R	Start a program
Esc	Stop a program
Shift+Alt+E	From the Main tab, quickly edit a G-code program with conversational programming
Space Bar	Feed hold the machine

6.5 MANAGE PATHPILOT VERSIONS

You don't need to install updates sequentially. You can update from any previous version to the current version of PathPilot. Depending on what you want to do, refer to the following sections:

- "Download and Install an Update File from the Controller" (below)
- "Install an Update File from a USB Drive" (below)
- "Install a Previous Version of an Update File" (on the next page)

6.5.1 Download and Install an Update File from the Controller

1. Confirm that the PathPilot controller is powered on and out of **Reset** mode.
2. Downloading and installing an update file requires an Internet connection. From the **Status** tab, confirm that the **Internet** button LED light is on. (To configure the network, select the LED light.) Then, select **Update**.

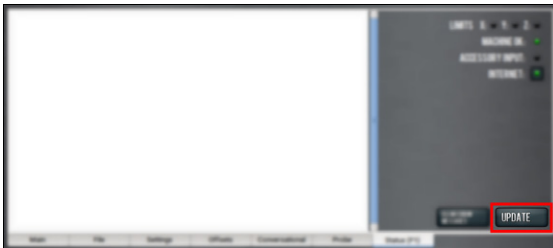


Figure 6-14: Update button on the Status tab.

3. From the **Software Update** dialog box, select **Check Online**.

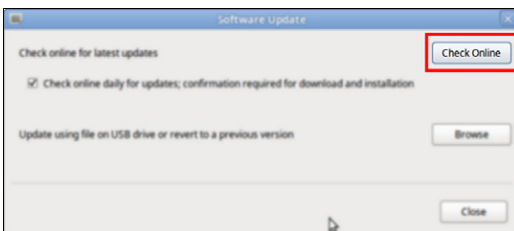


Figure 6-15: Software Update dialog box.

4. Select **Install**.

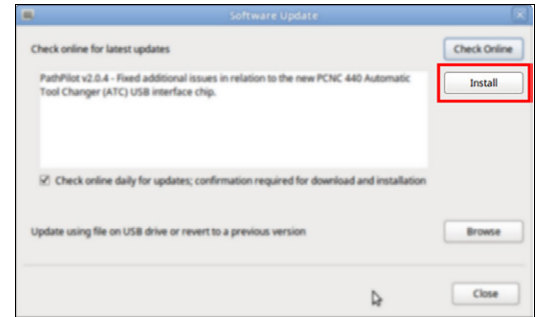


Figure 6-16: Install button on the Software Update dialog box.

The update file is downloaded, and a notification dialog box displays.

5. From the dialog box, select **OK**.
The update file is installed on the PathPilot controller.
6. Follow the on-screen instructions to restart the PathPilot controller.

6.5.2 Install an Update File from a USB Drive

1. From the PathPilot support center, download the most recent PathPilot update file.
2. Transfer the PathPilot update file to a USB drive.
3. Put the USB drive into the PathPilot controller.
4. Confirm that the PathPilot controller is powered on and out of **Reset** mode.
5. From the **Status** tab, select **Update**.

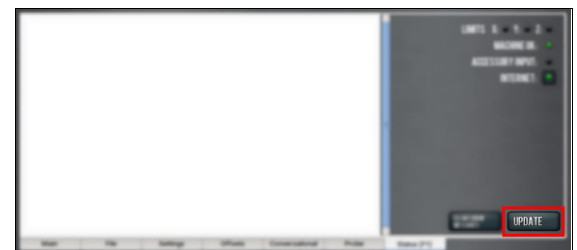


Figure 6-17: Update button on the Status tab.

6. From the **Software Update** dialog box, select **Browse**.

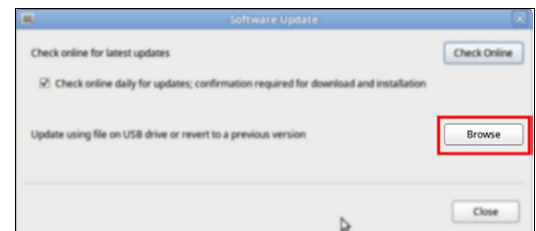


Figure 6-18: Software Update dialog box.

6: PATHPILOT INTERFACE OVERVIEW

6.5 Manage PathPilot Versions

- 7. From the **Browse** dialog box, select **USB**.



Figure 6-19: Browse dialog box.

- 8. Select the desired update file, and then select **Update**.
The update file is installed on the PathPilot controller.
- 9. Follow the on-screen instructions to restart the PathPilot controller.

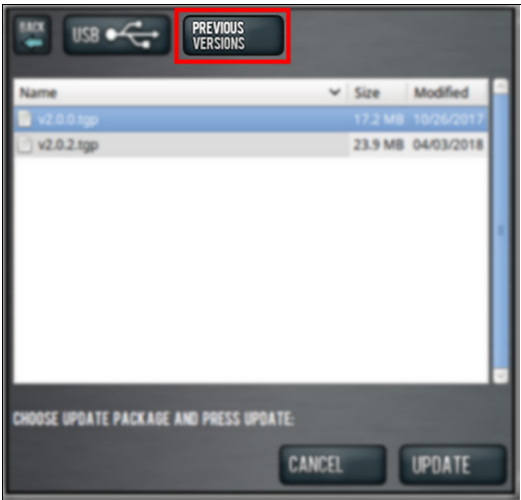


Figure 6-22: Browse dialog box.

- 5. Select the desired update file, and then select **Update**.
The update file is installed on the PathPilot controller.
- 6. Follow the on-screen instructions to restart the PathPilot controller.

6.5.3 Install a Previous Version of an Update File

- 1. Confirm that the PathPilot controller is powered on and out of **Reset** mode.
- 2. From the **Status** tab, select **Update**.

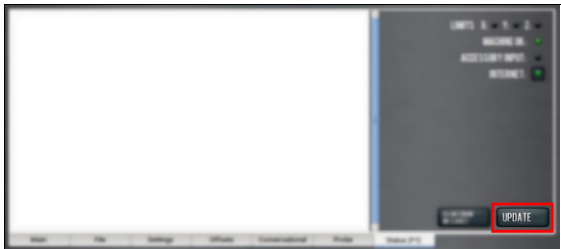


Figure 6-20: Update button on the Status tab.

- 3. From the **Software Update** dialog box, select **Browse**.

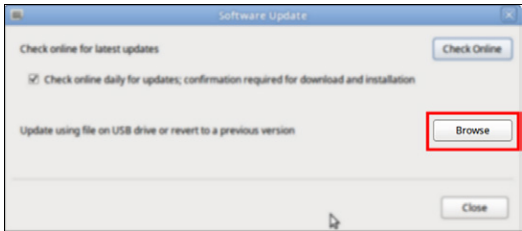


Figure 6-21: Software Update dialog box.

- 4. From the **Browse** dialog box, select **Previous Versions**.

PATHPILOT TOOLS AND FEATURES

IN THIS SECTION, YOU'LL LEARN:

- How to use PathPilot, depending on the activity that you want to do.

CONTENTS

7.1 Create and Load G-Code Files	156
7.2 Machine Settings and Accessories	173
7.3 Set Up G-Code Programs	181
7.4 Run G-Code Programs	188
7.5 Control G-Code Programs	192
7.6 System File Management	202

7: PATHPILOT TOOLS AND FEATURES
7.1 Create and Load G-Code Files

7.1 CREATE AND LOAD G-CODE FILES

To get started with PathPilot, you must first load or create a G-code file.

7.1.1 Load G-Code 156
7.1.2 Edit G-Code 157
7.1.3 Read G-Code 158
7.1.4 Use Conversational Programming 161

7.1.1 Load G-Code

To run a G-code program on a PathPilot controller, you must first verify that the file is on the controller. For more information on transferring and moving files, see "Transfer Files to and From the Controller" (below).

To load G-code:

- 1. From the File tab, in the Controller Files window, select the desired .nc file.
- 2. Select Load.

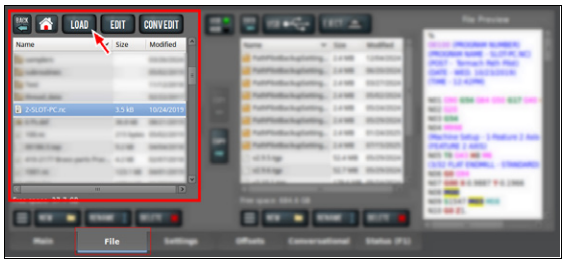


Figure 7-1: Controller Files window on the File tab.

Note: This function is only available for files stored on the PathPilot controller.

PathPilot loads the G-code file and opens the Main tab.

Transfer Files to and From the Controller

To run a G-code program, you must transfer the files to the PathPilot controller. You can either use a USB drive or PathPilot HUB (our cloud-based simulator) to transfer files. For more information on PathPilot HUB, go to hub.pathpilot.com.

To transfer files to and from the controller:

- 1. Either insert a USB drive into any open USB port, or sign in to PathPilot HUB.
- 2. From the File tab, select the file to transfer (either in the USB / HUB Files window or the Controller Files window).

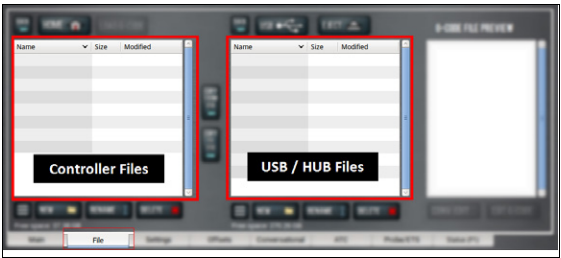


Figure 7-2: File tab.

Note: Select Back to move backward and either Home or USB to move to the highest level.

- 3. Select the location to which you want to copy the transferred file.
- 4. Select either Copy ← or Copy →.

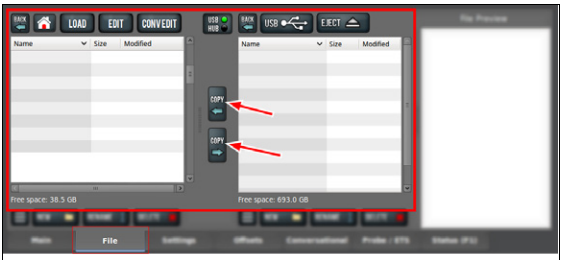


Figure 7-3: File tab.

Note: The file must have a unique name. If it doesn't, you must either overwrite the file, rename the file, or cancel the file transfer.

- 5. If you're using a USB drive, select Eject.
It's safe to remove the USB drive from the controller.

Preview G-Code Files

You can preview an .nc file that's either on the PathPilot controller or on a USB drive.

To preview G-code files:

- From the File tab, in the Controller Files window or the USB Files window, select an .nc file.
The text displays in the Preview window.

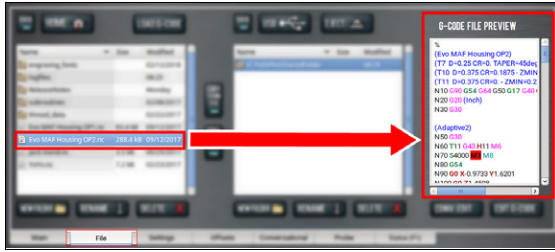


Figure 7-4: File tab.

Access Recent G-Code Files

You can load a recently loaded G-code file from the Main tab. For information, see "About the G-Code Tab" (on the next page).

To access recent G-code files:

1. From the **Main** tab, in the **G-Code** tab, select the **Recent Files** menu.

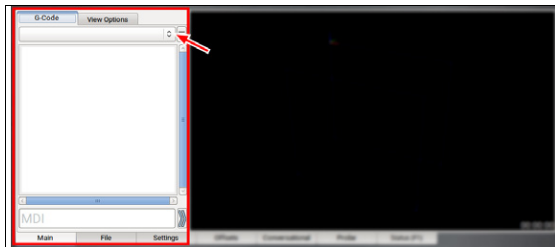


Figure 7-5: Recent Files menu on the Main tab.

The last five program files loaded into PathPilot display.

2. Select the name of the desired G-code program.
The G-code program loads.

Close the Current Program

1. From the **Main** tab, on the **G-Code** tab, select the **Recent Files** menu.
2. Select **Clear Current Program**.

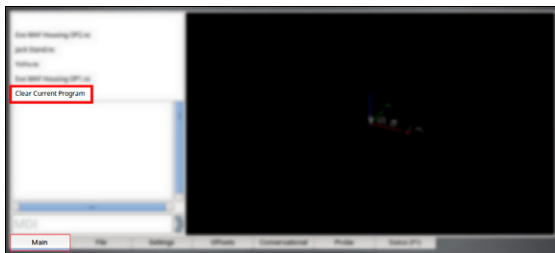


Figure 7-6: Recent Files menu on the Main tab.

The currently loaded G-code program closes.

7.1.2 Edit G-Code

In PathPilot, there are two ways to edit G-code:

- **Edit G-Code with a Text Editor**..... 157
- **Edit G-Code with Conversational Programming**..... 157

Edit G-Code with a Text Editor

You can edit .nc files that are on the PathPilot controller. If the .nc file is in the USB Files window, you must first transfer it to the controller; go to "Transfer Files to and From the Controller" (on the previous page).

To edit G-code with a text editor:

1. From the **Controller Files** window, highlight the .nc file and select **Edit G-code**.

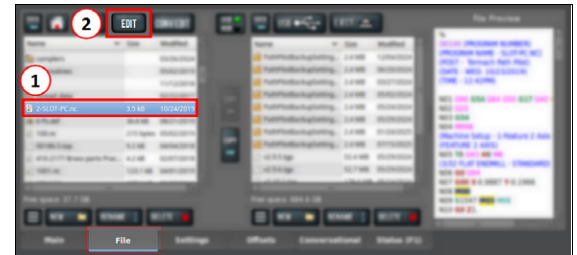


Figure 7-7: Edit G-code button on the File tab.

The file opens in a text editor.

2. Make and save the appropriate changes to the file.
3. Close the text editor.

Tip! To quickly edit an already loaded G-code program from the Main tab, you can use a keyboard shortcut: Shift+Alt+E.

Edit G-Code with Conversational Programming

You can edit .nc files that are on the PathPilot controller. If the .nc file is in the USB Files window, you must first transfer it to the controller; go to "Transfer Files to and From the Controller" (on the previous page).

To edit G-code with conversational programming:

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

- 1. From the **File** tab, select the .nc file.
 - 2. Select **Conv. Edit**.
- The file opens in a job assignment editor window: the program's job assignments are on the left and a preview of the program is on the right.

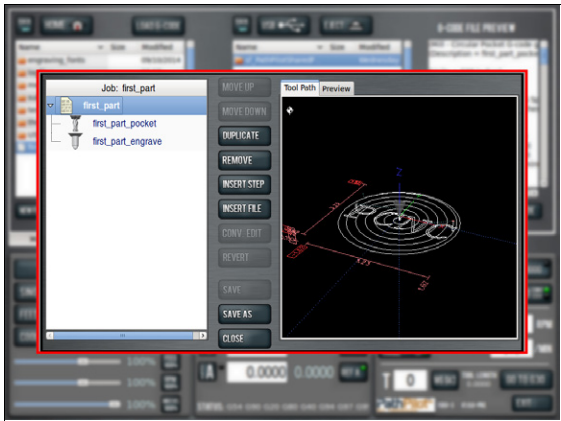


Figure 7-8: Job assignment editor.

- 3. Edit the file contents as needed. Do any of the following:
- | | |
|-----------------------------------|-----|
| Change the Step Order..... | 158 |
| Create a New Job Assignment..... | 158 |
| Load an Existing G-Code File..... | 158 |
| Edit a Job Assignment..... | 158 |
- 4. Select **Save**.
- The G-code program file is updated.

Change the Step Order

- Select **Move Up**, **Move Down**, **Duplicate**, or **Remove**.

Create a New Job Assignment

- 1. Select **Insert Step**.
- PathPilot opens the **Conversational** tab.
- 2. Create the new job assignment.
- 3. Select **Insert**.
- 4. (Optional) Edit the job assignment order in the program.

Load an Existing G-Code File

- 1. Select **Insert File**. You can insert G-code files that are hand-written, generated from CAM software, or generated from conversational programming in PathPilot.
- 2. Navigate to and select the .nc file that you want to insert.
- 3. Select **Open**.
- 4. (Optional) Edit the job assignment order in the program.

Edit a Job Assignment

- 1. Select the job assignment, and then select **Conv. Edit**. PathPilot opens the **Conversational** tab.
- 2. Edit the job assignment.
- 3. Select **Finish Editing**.

Tips

- To restore an edited job assignment to its original parameters: select **Revert**.

Note: **Revert** is only available for individual job assignments created in conversational programming.

- To undo all changes made to an entire G-code program: select **Close**. When prompted, select **Close Without Saving**.

7.1.3 Read G-Code

Once your G-code file is loaded into PathPilot, you can read it in the following ways:

- | | |
|---|-----|
| Expand the G-Code Tab..... | 158 |
| Search in the Code..... | 159 |
| Set a New Start Line..... | 159 |
| Change the View of the Tool Path Display..... | 160 |

Expand the G-Code Tab

You can change the size of the G-Code tab if you need more space to view the code. For more information on using the G-Code tab, see "About the G-Code Tab" (below).

To expand the G-Code tab:

- Select the **Window Expander**.

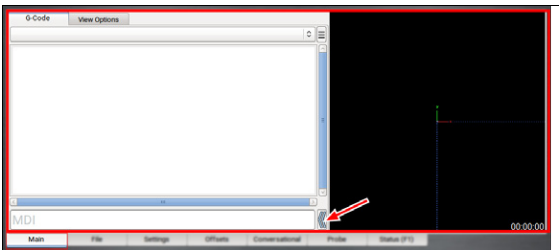


Figure 7-9: Window Expander on the Main tab.

The **Tool Path** display shrinks.

About the G-Code Tab

The G-Code tab displays the code of the currently loaded program file. Use the scroll bars to view the entire file. You

can make the G-Code tab larger. For information, see "Expand the G-Code Tab" (on the previous page).

PathPilot highlights certain lines of code of interest. When running a G-code program in single block mode, there may be as many as two lines of G-code highlighted, both with a different color:

- **Green Line** Indicates the start line (the line from which PathPilot starts the program).
To change the start line, go to "Set a New Start Line" (below).
- **Orange Line** Indicates the line of code that PathPilot is currently executing.

Search in the Code

You can use PathPilot to search the text of a G-code program file for specific numbers, codes, or other items of interest (like tools, feeds, and speeds).

To search in the code:

1. From **Main** tab, on the **G-Code** tab, select any line of code to use as a starting point.
2. In the **MDI Line DRO** field, type **FIND** followed by one of the following:
 - Any text. PathPilot searches for instances of the specific number or code.

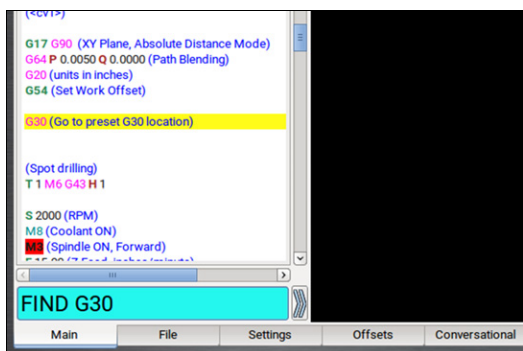


Figure 7-10: Search for a text command.

- **FEED.** PathPilot searches for instances of the actual word **Feed** and any **F** G-code command.

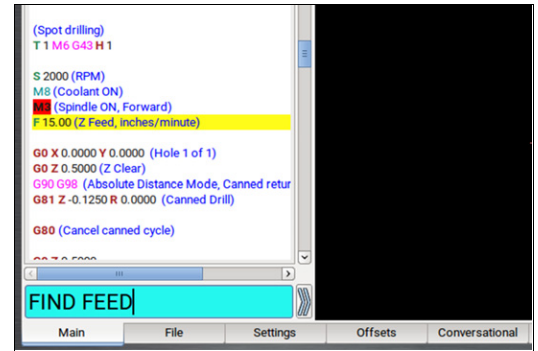


Figure 7-11: Search for a feed command.

- **SPEED.** PathPilot searches for instances of the actual word **Speed** and any **S** G-code command.
- **TOOL.** PathPilot searches for instances of the word **Tool** and any **T** G-code command.



Note: The find command is not case-sensitive.

3. Select the **Enter** key.
If PathPilot finds the information, the searched term is scrolled to and highlighted in the **G-Code** tab.
4. *(Optional)* Select **Enter**.
PathPilot finds the next instance of the searched text.
5. *(Optional)* Select **Enter+Shift**.
PathPilot finds the previous instance of the searched text.



Note: When the search reaches the end of the G-code file, it starts again from the beginning.

Set a New Start Line

The start line (the line from which PathPilot starts the program) is, by default, the first line of code in the program. To set a new start line:

1. From the **Main** tab, on the **G-Code** tab, do one of the following:

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

- Right-click any line in the program.

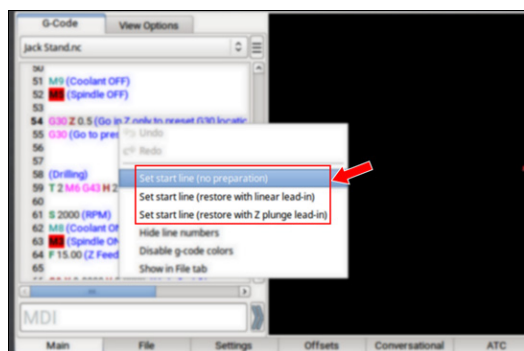


Figure 7-12: Accessing the Options menu by right-clicking.

- Tap the line. Then, select the **Options** menu.
- Select the desired lead-in move. For information, see "Lead-In Moves" (below).

Lead-In Moves

- Set start line (no preparation)** Keep the current tool in the spindle, with the current tool length applied. The machine executes the start line from the current position.



Note: We don't recommend this option for starting partway through a cut.



EXAMPLE

- Starting the program at a tool change.
- Starting the program with a different tool in the spindle than the program calls for (like if your tool broke, which you've replaced, but you'd rather not edit the entire program or the tool table entry).

- Set start line (restore with linear lead-in)** Perform a tool change (as required). The machine rapids in X and Y, then Z to the current position, then feeds in a straight linear line to the start line position.



Note: This option assumes that the current position is the lead-in position.



EXAMPLE

Quickly resuming work after stopping the program to make an adjustment to the machine setup (like clearing chips, removing an object, or turning on the coolant pump). Because the machine's already set up, you can position the tool near the stopping point.

- Set start line (restore with Z plunge lead-in)**

Perform a tool change (as required). The machine rapids in Z to G30 clearance height, rapids in X and Y to the start line position, then feeds in Z to the start line position.



EXAMPLE

Running a sub-section of a large program when the correct tool isn't loaded (and positioning the tool tip near the starting point is difficult, like with a long tool loaded). This option doesn't require you to jog to the exact lead-in position.

Change the View of the Tool Path Display

- From the **Main** tab, do one of the following:
 - Right-click the **Tool Path** display.

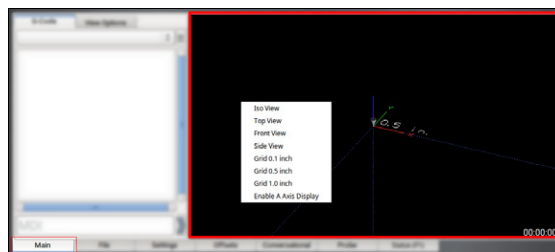


Figure 7-13: Tool Path display on the Main tab.

- Select the **View Options** tab.

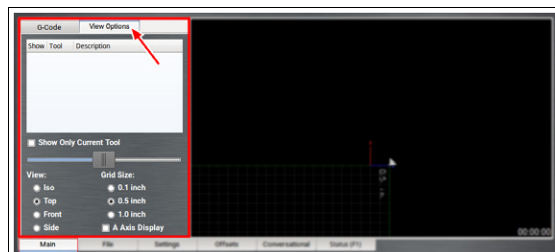


Figure 7-14: View Options tab on the Main tab.

2. Select a new view.
For information, see "About the Tool Path Display" (below).

About the Tool Path Display

The Tool Path display is a graphical representation of the currently loaded G-code file's tool path.

There are four available views:

- Front
- Iso
- Side
- Top

You can see grid lines behind the tool path while you are using either a Top, Front, or Side view. Depending on which programming mode you're in (G20 or G21), PathPilot defaults to one of the following grid line spacings:

- **G20 Mode** 1/2 in. intervals
- **G21 Mode** 10 mm intervals

In the Tool Path display, there are four different line types:

- **Dotted Blue Lines** Indicate the boundary box (the ends of travel of the axes).
- **Red Lines** Indicate the tool path as it is cut.



Note: The Tool Path display shows the program extents — the furthest points to which the tool will travel while running the program — of the currently loaded G-code file alongside the tool path lines.

- **White Lines** Indicate the preview lines.
- **Yellow Lines** Indicate the jogging moves.

To erase the jogging moves (yellow line) or the tool path (red lines), do one of the following:

- Double-click anywhere in the Tool Path display.
- Select Reset.

7.1.4 Use Conversational Programming

To create simple parts, use the conversational programming feature in PathPilot.

About Conversational Programming.....	161
Create a Face on a Part	161
Create a Profile on a Part	163
Create a Pocket on a Part	164
Create Hole Locations on a Part (Drill/Tap).....	166

Create Threads on a Part	169
Create Text to Engrave on a Part	170
Import a DXF File	171

About Conversational Programming

PathPilot includes G-code generators intended to make simple G-code programs:

- Programs for simple parts.
- Programs for parts made up of a collection of simple features.



Note: For complex parts, or parts with complex shapes, we recommend you use a CAD/CAM program.

The Conversational tab is divided into two sections:

- Parameters common to most operations, like speeds and feeds.



Note: DRO fields that are grayed out are not available for the specific conversational features.

- Parameters specific to each operation, like part geometry.

Create a Face on a Part

Using conversational programming, you can program PathPilot to take multiple cuts — each following the last — on an X/Y plane over a Z range. For information, see "About Facing" (on the next page).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The area from the rear, left corner of the workpiece to the rear, right corner of the workpiece must be clear of any obstructions from the **Z Start** position to the **Z End** position.
- The top of the workpiece must be free of any workholding devices.
- The value used in the **Z End** DRO field must be such that it is above the workholding device.
- The value used in the **Z Clear** DRO field must be such that it is above any obstruction in the tool path between the end of one pass and the beginning of the next.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

To create a face on a part:

1. From the **Conversational** tab, select the **Face** tab.
2. From the **Conversational DROs** group, set the parameters for the facing operation.



Figure 7-15: Conversational DROs on the Face tab.

3. Work through the program-specific DRO fields:
 - a. In the **X Start** DRO field and the **X End** DRO field, type the location of the workpiece edges. We recommend using the rear left corner of the part for the **X Start** value.
 - b. In the **Y Start** DRO field and the **Y End** DRO field, type the location of the workpiece edges. We recommend using the front right corner of the part for the **Y End** value.
 - c. In the **Stepover** DRO field, type the required distance between tool paths. To prevent uncut areas in the spiral corners, we recommend limiting this value to 80% of the tool diameter. For information, see "Facing Reference" (on the next page).
 - d. In the **Z Start** DRO field and the **Z End** DRO field, type the location of the first and last Z passes. For a single Z pass at the location typed in the **Z End** DRO field, type a value of 0 or a full Z range value into the **Depth of Cut** DRO field.
 - e. In the **Depth of Cut** DRO field, type the desired amount of material to remove.



Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).

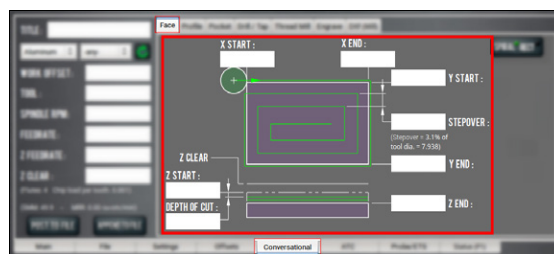


Figure 7-16: Program-specific DROs on the Face tab.

About Facing

Face milling is the process of cutting a surface that's perpendicular to the axis of the cutting tool. A facing program is usually used to cut an accurate, finished top surface on a rough piece of stock material. After a facing program is complete, tool marks remain — creating a fairly flat surface, with microscopic height differences.

Facing in PathPilot

When using a facing routine, each tool pass along the X-/Y-axis begins off to the side of the workpiece to avoid plunging into the workpiece. To compensate for this procedure, PathPilot sets lead-in tool paths outside of the workpiece using the part's work offsets, the tool's diameter, and the predetermined stepover value. PathPilot also adjusts the depth of cut to make sure each tool pass has the same depth, rather than cutting a short depth on the last pass of the program.

During a facing routine, PathPilot does the following:

1. Moves the machine to the predefined G30 position, or the tool change position.
2. If required, performs or requests a tool change.
3. Makes a rapid move in the X and Y direction to the beginning of the workpiece.
4. Makes a rapid move in the Z direction to the predefined Z Clear position.
5. Begins the cut in the X/Y plane at an adjusted Z depth of cut.



Note: The value entered into the Depth of Cut DRO field is adjusted within the Z range (the value entered into the Z End DRO field minus the value entered into the Z Start DRO field).

6. Makes cuts in a rectangular spiral from the workpiece perimeter to the workpiece center.

For information on using conversational programming in PathPilot to face a part, see "Create a Face on a Part" (page 161).

Facing Reference

PathPilot uses the following terms when creating a face on a part in conversational programming:

- **Stepover** Indicates how much space PathPilot creates between each spiral tool path.
- **Z Clear** Indicates the Z location that the tool moves (retracts) to when starting or ending a tool pass.

Create a Profile on a Part

Using conversational programming, you can program PathPilot to take multiple cuts — each following the last — on an X/Y plane over a Z range to form a boss. For information, see "About Profiling" (below).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The value used in the **Radius** DRO field must be between 0 and either:
 - One half of the boss' narrow width, or
 - The full radii on the long ends of the boss
- The value used in the **Z Clear** DRO field must be set to clear any obstructions between path changes.

To create a profile on a part:

1. From the **Conversational** tab, select the **Profile** tab.
2. From the **Conversational DROs** group, set the parameters for the profiling operation.



Figure 7-17: Conversational DROs on the Profile tab.

3. Work through the program-specific DRO fields:
 - a. In the **X Start** DRO field and the **X End** DRO field, type the location of the workpiece edges.
 - b. In the **Y Start** DRO field and the **Y End** DRO field, type the location of the workpiece edges.

- c. In the **X Profile Start** DRO field, the **X Profile End** DRO field, the **Y Profile Start** DRO field, and the **Y Profile End** DRO field, type the location of the profile's outer edges.
- d. In the **Stepover** DRO field, type the required distance between tool paths. If you want a single cut in the workpiece (to create a slot), type 0.
- e. In the **Radius** DRO field, type the required radius for the corners of the profile. For no corner radius, type 0.
- f. In the **Z Start** DRO field and the **Z End** DRO field, type the location for the first and last Z passes. For a single Z pass at Z End, type 0 — or a full Z range value — in the **Z DOC** DRO field.
- g. In the **Z DOC** DRO field, type the desired amount of material to remove.



Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).

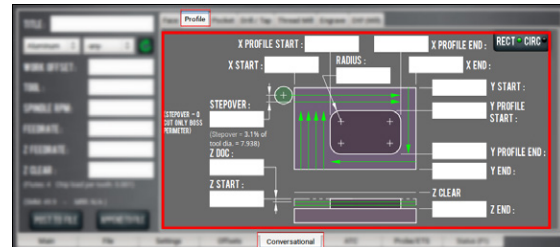


Figure 7-18: Program-specific DROs on the Profile tab.

About Profiling

A profiling program is usually used to create a circular or rectangular boss within a larger piece of stock material. The outer bound of the area is the stock material's perimeter. The inner bound of the area is the boss' perimeter.

Profiling in PathPilot

When using a profile routine, each tool pass along the X-/Y-axis begins off to the side of the workpiece to avoid plunging into the workpiece. To compensate for this procedure, PathPilot sets lead-in tool paths outside of the workpiece using the part's work offsets, the tool's diameter, and the predetermined stepover value. PathPilot also adjusts the depth

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

of cut to make sure each tool pass has the same depth, rather than cutting a short depth on the last pass of the program. When you're creating a profile on a part using conversational programming, PathPilot does the following in the order listed:

1. Retracts the tool to the **Z Clear** position.



Note: The first Z pass cuts at **Z Start** minus Depth of Cut adjusted.

2. Makes a rapid movement to the beginning of the section.
3. If required, makes a tool path around the perimeter of the boss to cut the programmed radii.



Note: Radius cuts use an adjusted feed rate to compensate for the difference between the tool's control point rate (at the tool center) and the actual rate at the radius surface.

4. Repeats Steps 1-3 for each predefined **Z Depth of Cut**.



Note: The last Z pass will cut at the **Z End** location.

For information on using conversational programming in PathPilot to create a profile, see "Create a Profile on a Part" (on the previous page).

Profiling Reference

PathPilot uses the following terms when creating a profile on a part in conversational programming:

- **Stepover** Indicates the tool path offset between section sweeps.
- **Z Clear** Indicates the Z location the tool moves to or retracts to when starting or ending a section change, section sweep, or Z pass.

Create a Pocket on a Part

Using conversational programming, you can program PathPilot to take multiple cuts — each following the last — on an X/Y plane over a Z range to form a circular or rectangular pocket. For information, see "About Pockets" (on the next page).

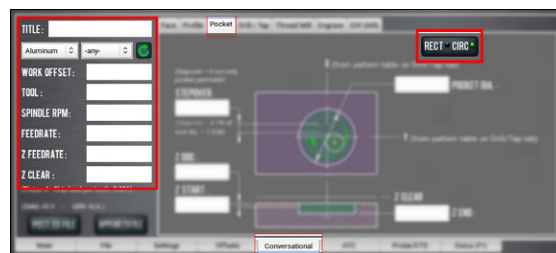
Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The value used in the **Radius** DRO field must be between 0 and either:
 - One half of the pocket's narrow width, or
 - The full radii on the long ends of the pocket

To create a circular pocket on a part:

1. From the **Conversational** tab, select the **Pocket** tab.
2. From the **Conversational DROs** group, set the parameters for the pocket operation.



3. Work through the program-specific DRO fields:
 - a. In the **X Center** DRO field and the **Y Center** DRO field, type the location of the pocket's center.
 - b. In the **Pocket Dia.** DRO field, type the required diameter for the pocket.



Note: The radius of the tool is used to set the tool path diameter.

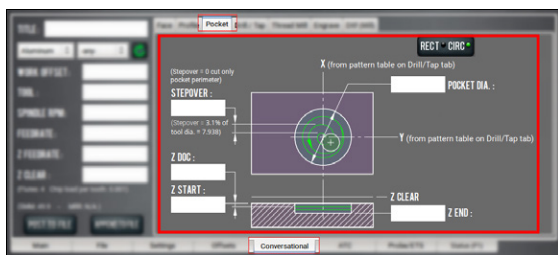
- c. In the **Stepover** DRO field, type the required distance between each rotation of the spiral cut. For a single cut around the inside perimeter of the pocket (to create a slot), type 0.
- d. In the **Z Start** DRO field and the **Z End** DRO field, type the location of the first and last Z passes. For a single Z pass at the location typed in the **Z End** DRO field, type a value of 0 or a full Z range value into the **Depth of Cut** DRO field.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

- e. In the **Z DOC** DRO field, type the desired amount of material to remove.

Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).



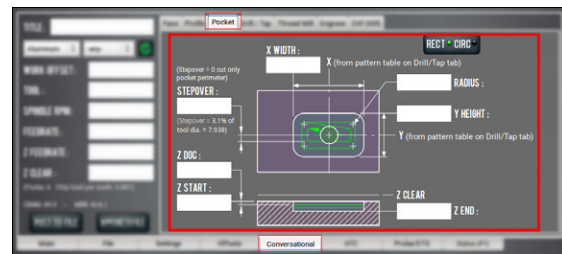
To create a rectangular pocket on a part:

1. From the **Conversational** tab, select the **Pocket** tab.
2. From the **Conversational DROs** group, set the parameters for the pocket operation.



3. Work through the program-specific DRO fields:
 - a. In the **X Start** DRO field, the **X End** DRO field, the **Y Start** DRO field, and the **Y End** DRO field, type the location of the pocket edges.
 - b. In the **Radius** DRO field, type the required radius for the corners of the pocket. For no corner radius, type 0.
 - c. In the **Stepover** DRO field, type the required distance between adjacent tool paths. For a single cut around the inside perimeter of the pocket (to create a slot), type 0.
 - d. In the **Z Start** DRO field and the **Z End** DRO field, type the location of the first and last Z passes. For a single Z pass at the location typed in the **Z End** DRO field, type a value of 0 or a full Z range value into the **Depth of Cut** DRO field.
 - e. In the **Z DOC** DRO field, type the desired amount of material to remove.

Note: The depth of cut is later adjusted within the Z range so that each pass in the Z range has the same depth (rather than the last Z pass having a short depth of cut).



About Pockets

A pocket program is usually used to remove a large amount of material from a part.

Creating Pockets in PathPilot

For more information about creating a pocket on a part using conversational programming, see of the following sections, depending on the shape of the pocket:

- "About Circular Pockets" (below)
- "About Rectangular Pockets" (on the next page)

For information on using conversational programming in PathPilot to make a pocket on a part, see "Create a Pocket on a Part" (on the previous page).

About Circular Pockets

PathPilot does one of the following, depending on the diameter of the tool:

- **Tool Diameter Larger Than Pocket Diameter**
PathPilot displays an error and does not create any G-code. You must select a different tool or edit the diameter of the pocket.
- **Tool Diameter Just Small Enough to Fit Within Pocket Diameter** PathPilot does the following in the order listed:
 1. Uses a straight Z plunge into the pocket center. You must use a center-cutting end mill.
 2. Makes a single pass around the perimeter of the pocket at the adjusted Z depth of cut.
 3. Continues to make single passes around the perimeter of the pocket.
- **Pocket Diameter More Than Two Times Tool Diameter** PathPilot does the following in the order

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

listed:

1. Uses a helical entry into the pocket center.
2. Makes a hole that is two times the diameter of the tool diameter in the pocket center.
3. Makes a spiral cut out from the pocket center to the pocket diameter.
4. Makes a cut around the perimeter of the pocket.

About Rectangular Pockets

PathPilot does one of the following, depending on the diameter of the tool:

- **Tool Diameter Larger Than Pocket Width** PathPilot displays an error and does not create any G-code. You must select a different tool or edit the width of the pocket.
- **Tool Diameter Just Small Enough to Fit Within Pocket Parameters** PathPilot does the following in the order listed:
 1. Uses a straight Z plunge into the pocket center. You must use a center-cutting end mill.
 2. Makes a single pass around the perimeter of the pocket at the adjusted Z depth of cut.
 3. Continues to make single passes around the perimeter of the pocket.
- **Length of Pocket More Than Two Times Diameter of Tool** PathPilot uses a linear ramp entry.
- **Pocket Parameters More Than Two Times Diameter of Tool** PathPilot uses a helical entry.

Create Hole Locations on a Part (Drill/Tap)

Using conversational programming, you can program PathPilot to make multiple holes on a part. For information, see "About Drilling and Tapping" (on the next page).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- In the **Conversational DROs** group, the value in the **Z Clear** DRO field must be set to clear any obstructions between hole changes.

To make a specific hole pattern of evenly spaced holes around a circumference (also known as a bolt pattern):

1. From the **Conversational** tab, select the **Drill/Tap** tab.

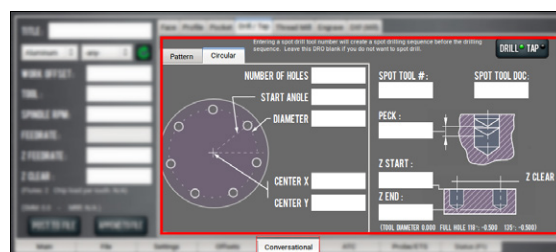


Figure 7-19: Drill/Tap tab on the Conversational tab.

2. From the **Drill/Tap** tab, select the **Circular** tab.
3. In the **Number of Holes** DRO field, type the number of holes (greater than 0) required for the pattern.
4. In the **Start Angle** DRO field, type the value of the angle from angle 0 (from **-90** to **90**).
5. In the **Diameter** DRO field, type the size of the circular pattern (as defined by a line through the center point of each hole).
6. In the **Center X** DRO field and the **Center Y** DRO field, type the location for the center of the hole.
7. Depending on if you're drilling or tapping the holes, do one of the following:
 - Go to "Create a Drilling Sequence" (on the next page).
 - Go to "Create a Tapping Sequence" (page 168).

Use the Location table to make a list of X and Y locations for each hole using the same tool, the same Z location, and the same values in the Conversational DROs group.



Note: You can create holes using different tools or different parameters. You must first post the first group of hole locations, enter the second group of hole locations, and then append the second group to the existing posted file.

To make a hole pattern based on X and Y locations on a part:

1. From the **Conversational** tab, select the **Drill/Tap** tab.

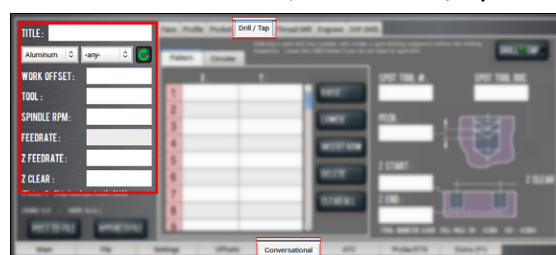


Figure 7-20: Drill/Tap tab on the Conversational tab.

2. From the **Drill/Tap** tab, select the **Pattern** tab.

3. In the **Location** table, select the row, then select the cell to edit.
Holes indicated in the **Location** table are completed from top to bottom.
4. Depending on if you're drilling or tapping the holes, do one of the following:
 - Go to "Create a Drilling Sequence" (below).
 - Go to "Create a Tapping Sequence" (on the next page).

Tips

- To rearrange the row order, select a row, and then select **Raise** or **Lower**.
- To clear all values in the table, select **Clear All**.
- To make sure that the value is a valid number, leave the cell. If the value isn't a valid number, it's erased, and an error displays on the **Status** tab.
- Before posting the file, make sure that there are none of the following:
 - X values without a Y value
 - Y values without an X value
 - An empty row before the last row with values

About Drilling and Tapping

A drilling and tapping program is used to create a series of holes in defined locations on a part.

Drilling and Tapping in PathPilot

PathPilot has the following options to define the locations:

- **Pattern** Use X and Y locations to make a list of hole locations.
- **Circular** Use a circumference to make a specific pattern of evenly spaced holes.

For information on using conversational programming in PathPilot to drill and tap holes, see "Create Hole Locations on a Part (Drill/Tap)" (on the previous page).

During a drilling routine, PathPilot uses one of the following canned G-code cycles, depending on the entries in each DRO field:

- **G81** Drill
- **G82** Drill with dwell
- **G83** Drill with peck



Note: The features can't be combined, because peck cancels dwell.

When using a tapping routine, PathPilot uses the G84 canned G-code cycle. G84 is similar to G81, but it commands a spindle reverse once it gets to the bottom of the hole.

It's important that the Z Feedrate matches the spindle RPM and tap pitch, so the rate is calculated from the Pitch and RPM DRO entries. The result is displayed in the Z Feedrate DRO (in the left panel) after the **Enter** key is selected in one of the RPM, Pitch, or TPU DRO fields.



Note: An auto-reversing tapping head typically uses a drilling cycle.

Create a Drilling Sequence

The Drill tab uses one of the following canned G8x cycles to drill a hole at each identified location:

- **G81** Drill
- **G82** Drill with dwell
- **G83** Drill with peck



Note: The features can't be combined, because peck cancels dwell.

Hole depth is usually defined as the full diameter portion of the hole, so you may need to consider the Z length from the drill point to the corner.

1. In the **Spot Tool #** DRO field, type the number of the spot drill.

If a valid tool number is used in the **Spot Tool #** DRO field, PathPilot makes a spot drilling sequence before the drilling sequence. In the spot drilling sequence, PathPilot uses the values indicated in the **Feedrate** DRO field, the **Spindle RPM** DRO field, and the **Z Clear** DRO field.



Note: To skip a spot drilling sequence, leave the **Spot Tool #** DRO field blank.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

2. In the **Spot Tool DOC** DRO field, type the depth of cut for the spot drilling sequence.



Note: To skip a spot drilling sequence, leave the **Spot Tool DOC** DRO field blank.

3. In the **Peck** DRO field, type the distance for each peck.



Note: Any entry greater than **0** typed in the **Peck** DRO field replaces G81 with G83 in the G-code. For information, see "Drilling and Tapping Reference" (below).

4. Set the parameters for the hole in the Z range:
 - a. In the **Z Start** DRO field, type the location for the first Z pass.
 - b. In the **Z End** DRO field, type the location for the last Z pass.

Create a Tapping Sequence

The Tap tab uses the G84 canned cycle — it's similar to the G81 drill cycle, but it commands a spindle reverse once it reaches the bottom of the hole.



Note: If you're using an auto-reversing tapping head, use a drilling sequence. Go to "Create a Drilling Sequence" (on the previous page).

1. In the **Dwell** DRO field, type the time — in seconds — for the tool to pause at the bottom of the hole before retracting.

A dwell gives the tool time to completely cut the bottom of the hole.



Note: Any entry greater than **0** typed in the **Dwell** DRO field replaces G81 with G82 in the G-code — unless there is an entry greater than **0** in the **Peck** DRO field.

2. Set the parameters for the threads: In the **Pitch (In)** DRO field or the **Threads/In** DRO field, type either the required pitch or the threads per inch.



Note: The **Pitch (In)** DRO field and the **Threads/In** DRO field are linked — after you type a value in one and press **Enter** on the keyboard, the other is auto-filled.

3. In the **Conversational DROs** group, make sure that the value in the **Z Feedrate** DRO field is the same as the value that you set in Step 2.
4. Set the parameters for the hole in the Z range:
 - a. In the **Z Start** DRO field, type the location for the first Z pass.
 - b. In the **Z End** DRO field, type the location for the last Z pass.

Drilling and Tapping Reference

PathPilot uses the following terms when drilling and tapping on a part in conversational programming:

- **Start Angle** Specifies the angle from angle 0. Angle 0 is a base (horizontal) line from the center point going right (east) to the circumference. The angle from the base line can be:
 - Positive or negative
 - Up to 90 degrees (or -90 degrees)

A negative angle produces a clockwise rotation; a positive angle produces a counterclockwise rotation.
 - Rotates the pattern either clockwise or counterclockwise

For example, to create a hex pattern with flats on the top and bottom, use a value of 0 in the Start Angle DRO field. To create a hex pattern with flats on the left and right sides, use a value of 30 (or -30) in the Start Angle DRO field.
- **Peck** The value isn't adjusted: the G83 routine feeds at the Z Feedrate, starting from Z Clear down to the Peck distance, then rapid retracts to Z Clear, and rapid returns to start the next Peck.



Note: The first and last peck will likely be shorter than the value typed into the Peck DRO field.

Create Threads on a Part

Using conversational programming, you can program PathPilot to take helical tool paths around a boss or inside a hole to create external or internal threads. For information, see "About Thread Milling" (below).

Before You Begin

Before you begin, you must verify that you enter the program values considering the following:

- The auto-filled DRO field values assume a full-form threaded tool. If you're using a fine-point threaded tool to cut coarse threads, you must modify the root diameter to account for the tool's smaller nose radius.
- The value used in the **Z Clear** DRO field must be such that it can clear any blockages in the path between the end of one Z pass and the beginning of the next.

To create threads on a part:

1. From the **Conversational** tab, select the **Thread Mill** tab.
2. From the **Conversational DROs** group, set the parameters for the thread milling operation.

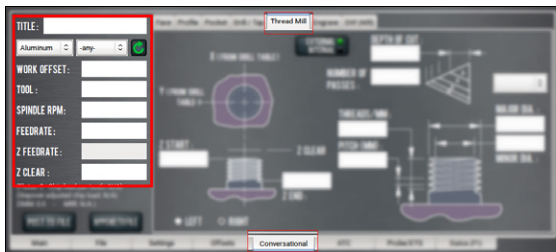


Figure 7-21: Conversational DROs on the Thread Mill tab.

3. Depending on the type of threads, do one of the following:
 - For external threading (creating threads on a boss, for example), select **External**.
 - For internal threading (creating threads inside a hole, for example), select **Internal**.
4. Work through the program-specific DRO fields:
 - a. From the **Quick Reference** drop-down, select the thread size.
The **Threads/In** DRO field, **Pitch (In)** DRO field, **Major Dia.** DRO field, and **Minor Dia.** DRO field auto-fill.

Note: The threads listed follow the current unit setting: either inches (G20) or millimeters (G21).

- b. In the **Z Start** DRO field, type the location of the first Z pass (where you want the thread to start).
- c. In the **Z End** DRO field, type the location of the last Z pass (where you want the thread to end).

Note: The tool actually goes beyond the value entered in the **Z End** DRO field, due to the cutting tip width and the Z component of the compound feed angle and thread depth.

- d. In the **Depth of Cut** DRO field or the **Number of Passes** DRO field, type a value to represent the amount of material to remove in each helical pass. For information, see "Thread Milling Reference" (on the next page).

Note: The **Depth of Cut** DRO field and the **Number of Passes** DRO field are linked — after you type a value in one and press **Enter** on the keyboard, the other is auto-filled.

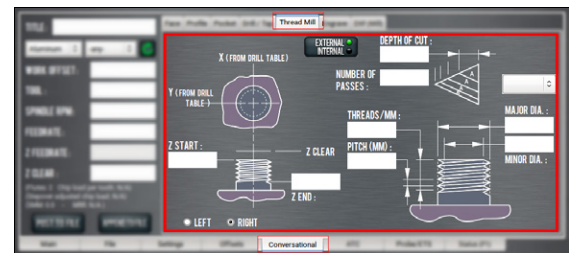


Figure 7-22: Program-specific DROs on the Thread Mill tab.

About Thread Milling

Thread milling is used to make helical tool paths on a part — either externally, like on a boss, or internally, like in a hole. The right-handed threads are based on pitch, diameter, and length.

Thread Milling in PathPilot

For information on using conversational programming in PathPilot to do thread milling, see "Create Threads on a Part" (above).

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files

Thread Milling Reference

PathPilot uses the following terms when creating a thread mill on a part using conversational programming:

- **Major Dia. and Minor Dia.** Set the start and end diameter of the thread peak and valley.
- **Depth of Cut** Sets the amount of material cut in each helical pass — the value is the distance (the change in radius) the tool is fed on the first pass. This first pass cuts a triangular area which is related to the chip load. Subsequent cut depths are set to cut the same amount of area, so the linear feed gets smaller for each pass. The tool is also fed in on a compound angle of 30 degrees, keeping the cuts to one face of the tool.
- **Z Clear** The location the tool moves or retracts to when starting or ending a Z pass.



Note: The Depth of Cut DRO field and the Number of Passes DRO field are linked — after you type a value in one and press **Enter** on the keyboard, the other is auto-filled.

Create Text to Engrave on a Part

Using conversational programming, you can program PathPilot to engrave a single line of text on a part. For example, you could use this feature to engrave True Type stick or outline fonts into things like simple plaques, control panels, or data plates. For information, see "About Engraving" (on the next page).

To create an engraving sequence on a part:

1. From the **Conversational** tab, select the **Engrave** tab.
2. From the **Conversational DROs** group, set the parameters for the engraving operation.

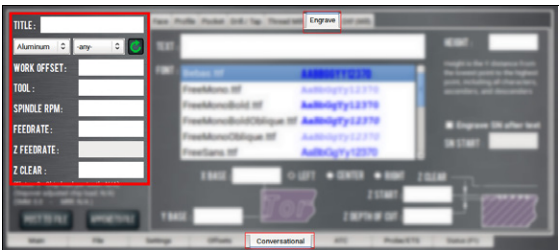


Figure 7-23: Conversational DROs on the Engrave tab.

3. Work through the program-specific DRO fields:
 - a. In the **Text** DRO field, type the desired text to engrave.

The text appears in the **Preview** window.

- b. From the **Font** list, select the desired font for the engraved text.



Note: To search the **Font** list, select a font and begin typing the font's name. PathPilot scrolls to the result.

The **Preview** window updates to display the font selected.



Note: You can add True Type font files to the PathPilot controller. For information, see "Transfer Files to and From the Controller" (page 156).

- c. Use the **Alignment** radio buttons to select the desired alignment of the text: either **Left**, **Center**, or **Right**. The **Preview** window updates to display the font selected.
- d. In the **Height** DRO field, type the distance in the Y direction from the top of the text to the bottom of the text.

PathPilot uses the height value, along with font data, to calculate scale for character paths in the G-code program.



Note: The value typed in the **Height** DRO field includes ascenders and descenders, but no the tool cutting diameter. For a more accurate value, subtract the diameter from the overall height.

- e. In the **X Base** DRO field and the **Y Base** DRO field, type the location of the left side of the first character's baseline.



Note: If any characters in the text have descenders, like **y** or **g**, they extend below the baseline.

- f. In the **Z Start** DRO field, type the location of the surface on which to engrave.

- g. In the **Z Depth of Cut** DRO field, type the desired depth the that the cutting tool is fed into the workpiece.
- h. In the **Z Clear** DRO field, type the value for the tool to move or retract to — in the **Z** direction — at the start and end of the engraving sequence and between characters.

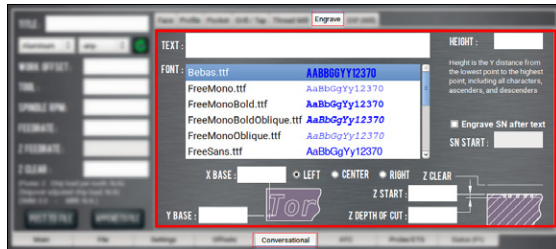


Figure 7-24: Program DROs on the Engrave tab.

About Engraving

Engraving is used to engrave a single line of text cut in a single horizontal pass along the X-axis of a part.

Import a DXF File

You can import a .dxf file (Drawing Exchange Format) into PathPilot to generate G-code, which can then cut the shape (or shapes) described in the .dxf file. For example, you could use this feature to engrave logos or artwork.

1. From the **Conversational** tab, select the **DXF** tab.

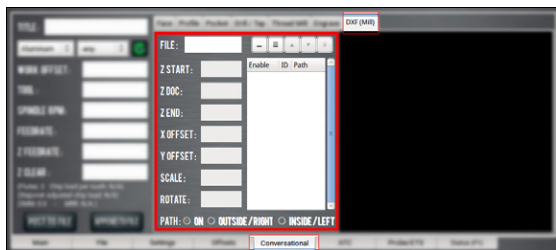


Figure 7-25: DXF tab on the Conversational tab.

2. Select the **File** DRO field.
The **File Selector** dialog box opens.
3. Select the .dxf file, and then select **Open**.
4. The shapes from the selected file are loaded into the **Preview** window.



Note: The .dxf file must already be transferred to the PathPilot controller. For information, see "Transfer Files to and From the Controller" (page 156).

5. In the **X Offset** DRO field and the **Y Offset** DRO field, type the offset value added in the **XY** direction from the bottom left corner of the .dxf drawing.
6. In the **Scale** DRO field, type the scale factor for the drawing. The value typed in the **Scale** DRO field is used as a multiplier for the .dxf dimensions, and is used for the entire drawing.



EXAMPLE

If you type 1.0 in the **Scale** DRO field, the .dxf is scaled at 100%.

If you type 2.0 in the **Scale** DRO field, the .dxf is scaled at 200%.

7. In the **Rotate** DRO field, type the rotation angle in degrees.
The rotation angle is applied around the Z-axis of the drawing's origin.
8. Select one of the following to set the cutter compensation to be applied to the tool path:
 - **On:** The tool moves along the path.
 - **Outside / Right:** Offsets the tool path right of the drawing path, seen from the direction where the tool enters the path.
 - **Inside / Left:** The opposite of **Outside / Right**.

Working with Layers and Shapes

The .dxf file contains shapes grouped into layers. In the **Shape Selection** tree view window, you can enable or disable individual layers and complete layers. You can select shapes either from the tree view window or in the **Preview** window.

Change the Layer or Shape Cut Order

- Use the **Up Arrow** and **Down Arrow** buttons above the **Shape Selection** tree view window.
Shapes or layers higher in the tree view window are cut earlier than those below it. The order in which the shapes are cut is the same as the order of the enabled shapes in the tree view window and the cyan path in the **Preview** window.

7: PATHPILOT TOOLS AND FEATURES

7.1 Create and Load G-Code Files



Note: If a layer is selected, the whole layer is moved up or down. Shapes can't be moved between layers.

Adjust the Tree View Window

- Use the **Fold** and **Unfold** buttons to collapse and expand the layer and shape tree in the tree view window.

Working in the Preview Window

The **Preview** window uses the following colors:

- **Cyan** Selected paths
- **Gray** Disabled paths
- **White** Drawing path
- **Magenta** Cut path
- **Dark Cyan Stippled Line** Tool path between cuts
- The coordinates use the following colors:
 - **Red** X-axis
 - **Green** Y-axis
 - **Blue** Z-axis

7.2 MACHINE SETTINGS AND ACCESSORIES

Before running a G-code program, you must first make sure that the machine settings are properly configured.

7.2.1 Enable an Internet Connection	173
7.2.2 Change the Network Name	174
7.2.3 Select the Spindle Type	174
7.2.4 Change the Screen Orientation	174
7.2.5 Specify the Tool Change Method	175
7.2.6 Limit G30 Moves	176
7.2.7 Enable the On-Screen Keyboard	176
7.2.8 Enable Tooltips	177
7.2.9 Enable the USB M-Code I/O Interface Kit	177
7.2.10 Enable Feeds and Speeds Suggestions in Conversational Routines	177
7.2.11 Specify Probing and Tool Measuring Options	177
7.2.12 Use a USB Camera	177

7.2.1 Enable an Internet Connection

If desired, you can enable an internet connection on your PathPilot controller. An internet connection allows you to receive automatic PathPilot updates and transfer files with PathPilot HUB instead of a USB drive.

To enable an internet connection:

1. From the PathPilot interface, on the **Status** tab, select **Internet**.



Figure 7-26: Internet button on the Settings tab.

The **Network Configuration** dialog box displays.

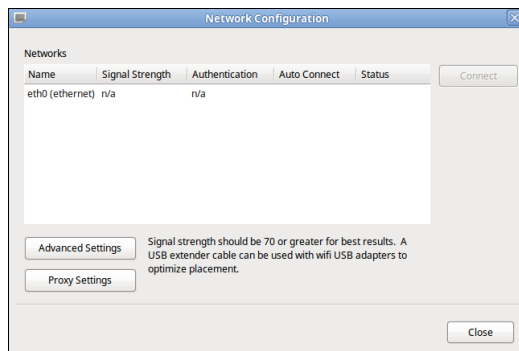


Figure 7-27: Network Configuration dialog box.

2. From the **Network Configuration** dialog box, in the **Networks** list, select the network you want to use. Then, select **Connect**.



Note: Wi-Fi connection signal strengths are indicated on a scale of 0 to 100, with 100 being the strongest. PathPilot continually refreshes the signal levels to help you find the best placement for your Wi-Fi network adapter. Ethernet connections are indicated by a prefix in the following format: eth[NUMBER]. For example, **eth1**.

The PathPilot operating system connects to the internet using the network you specified. It continues to detect and connect to the Wi-Fi network, even after power cycles.

Enable Automatic Updates



Note: Automatic updates require an internet connection. If you haven't yet enabled it, go to "Enable an Internet Connection" (above).

If desired, you can enable automatic updates for PathPilot. To enable automatic updates:

1. From the PathPilot interface, on the **Status** tab, select **Update**.

The **Software Update** dialog box displays.

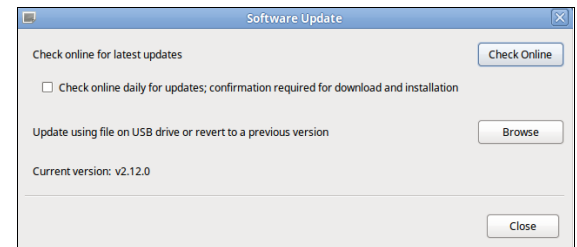


Figure 7-28: Software Update dialog box.

2. From the **Software Update** dialog box, select the **Check online daily for updates; confirmation required for download and installation** checkbox.
3. Select **Close**.

When future updates are available, the **Status** tab displays a notification.

7: PATHPILOT TOOLS AND FEATURES
7.2 Machine Settings and Accessories

7.2.2 Change the Network Name

If you're connected to a network using either the Ethernet jack or the (optional) Wireless Network Adapter (PN 38207), the PathPilot controller appears on your network as network-attached storage. The default network name of the controller is TORMACHPCNC.

To change the network name:

- 1. From the Network Name field, type a new network name.

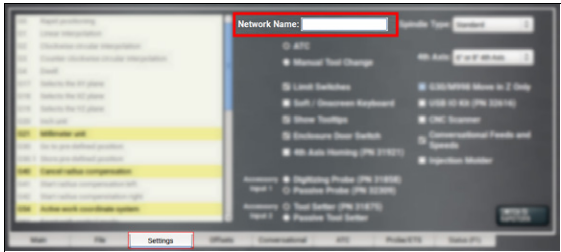


Figure 7-29: Network Name field on the Settings tab.



Note: The network name must be unique within your network.

- 2. Select the Enter key.
- 3. For the change to take effect, you must restart the controller.

7.2.3 Select the Spindle Type

If you have an additional spindle (separate from the standard spindle), you must first select it in PathPilot.

To select the spindle type:

- From the Settings tab, from the Spindle Type drop-down, select the appropriate spindle option.

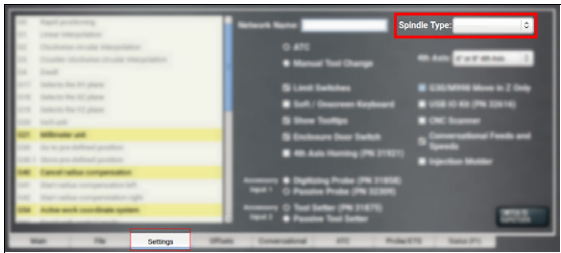


Figure 7-30: Spindle Type field on the Settings tab.

7.2.4 Change the Screen Orientation

A vertical orientation for 1920 x 1080 monitors is supported in PathPilot v2.10.0 and later. For more information on the portrait layout, go to "About Portrait Screen Layout" (below). To change the screen orientation:

- 1. From the PathPilot interface, on the Settings tab, select Portrait from the Layout drop-down menu. Restart the controller.

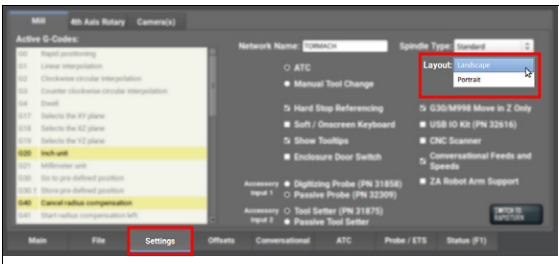


Figure 7-31: Layout drop-down menu on the Settings tab.

- 2. Rotate the monitor to the portrait orientation. You can rotate it either left or right, depending on what's easier for your setup.
- 3. While the controller is restarting, specify which direction you've rotated the monitor. Select Apply. If the result is unexpected, click Restore Previous Configuration on the confirmation dialog and choose a rotation direction again.

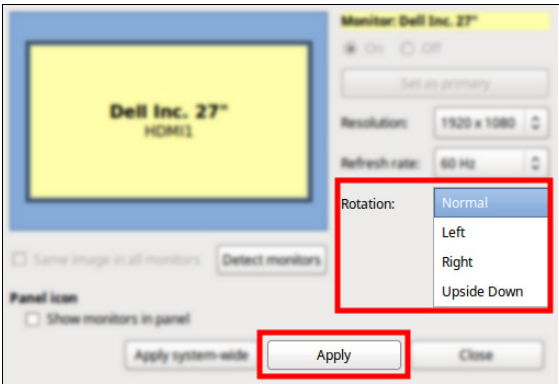


Figure 7-32: Monitor configuration dialog box.

The controller restarts in portrait layout.

About Portrait Screen Layout

Portrait layout provides some key advantages:

- A larger tool path window that's always visible at the top of the screen, regardless of which tab you have active.

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories

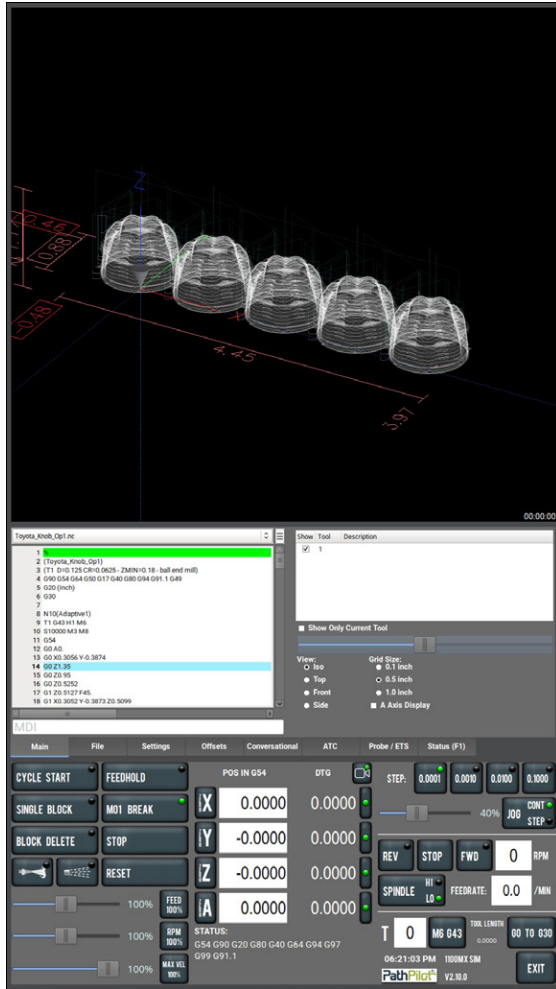


Figure 7-33: Tool Path window in portrait screen layout.

- A wider G-code window to more easily read the loaded G-code file and, if enabled, line numbers.
- The tool path window's view options are always visible for much easier access.
- When browsing G-code files using the File tab, file previews display on the top portion of the screen.

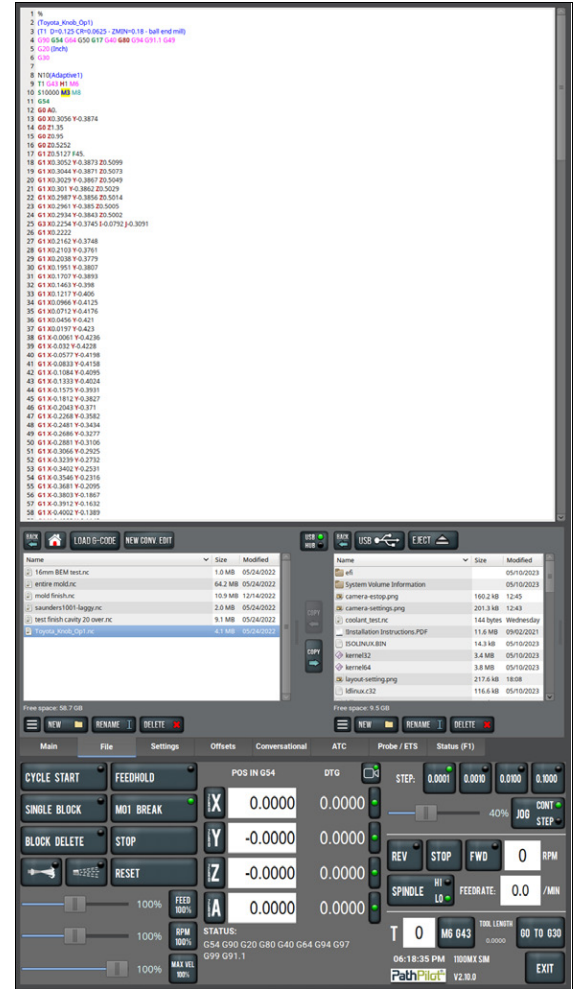


Figure 7-34: File tab G-code preview in portrait screen layout.

7.2.5 Specify the Tool Change Method

When PathPilot finds an **M06** command in a G-code program, it has different behaviors depending on the specified tool change method.

To specify the tool change method:

- From the **Settings** tab, select the appropriate tool change method for your machine.

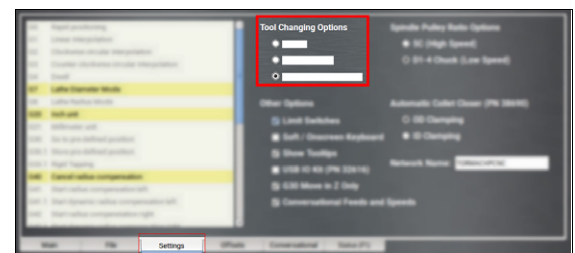


Figure 7-35: Tool change method options on the Settings tab.

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories

About Automatic Tool Changes

If you're using an Automatic Tool Changer (ATC) to make tool changes, PathPilot does the following:

- 1. Looks for an ATC.
In the PathPilot interface, the ATC tab displays.
- 2. When PathPilot finds a Txx M06 command in the G-code program, the ATC loads the specified tool into the spindle.

About Manual Tool Changes

If you're making manual tool changes, PathPilot pauses when it finds an M06 command in the G-code program. While it's paused, PathPilot does the following:

- 1. The Cycle Start button flashes.
- 2. The Tool Path display shows the requested tool number.

7.2.6 Limit G30 Moves

You can limit G30 moves so that only the Z-axis moves. For information, see "About G30" (page 196).
To limit G30 moves:

- From the **Settings** tab, select **G30/M998 Move in Z Only**.

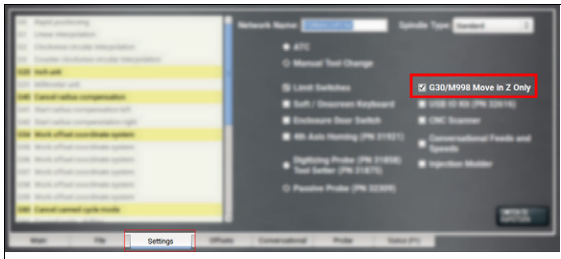


Figure 7-36: Settings tab.

About G30

A G30 command in a G-code program moves the machine to a preset position. For more information on setting a G30 position, see "Use a G30 Position" (page 195).
Use a G30 move to start a coordinated movement of the axes. You can limit the movement to only the Z-axis. For information, see "Limit G30 Moves" (above).



Tip! It's useful to program a G30 move right before a tool change so that the machine can jog to a safe tool change position.

7.2.7 Enable the On-Screen Keyboard

If you have an (optional) Touch Screen Kit (PN 35575), you can use a soft keyboard to type information in the PathPilot interface. For information, see "About Soft Keyboards" (below).

To enable and use the soft (on-screen) keyboard:

- 1. From the **Settings** tab, select **Soft / On-Screen Keyboard**.

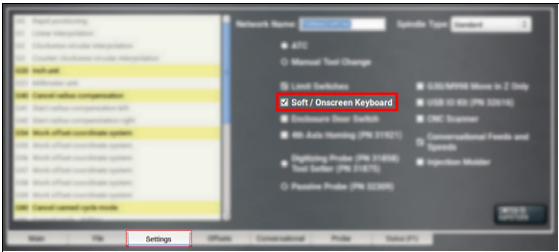


Figure 7-37: Settings tab.

- 2. To resize the keyboard, select a corner of the keyboard and drag.
- 3. To reposition the keyboard, select the **Anchor** key and drag the keyboard anywhere on the screen.



- 4. To close the keyboard, select the **X** key.



About Soft Keyboards

If you enabled a soft keyboard (on-screen keyboard) in the PathPilot interface to use with an optional touch screen or operator console, a keyboard opens when you select any field where keyboard input is required.
The keyboard displays a wide range of keys: both uppercase and lowercase, symbols, arrow keys, caps lock, backspace and delete, and more.

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories



Figure 7-38: Soft (on-screen) keyboard.

7.2.8 Enable Tooltips

PathPilot displays expandable tooltips for many areas of the interface. Hovering over an item, like a DRO field or a button, displays helpful information about the item.

To enable or disable tooltips:

1. From the **Settings** tab, select or clear **Show Tooltips**.

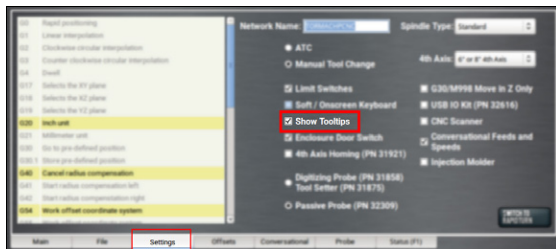


Figure 7-39: Show Tooltips checkbox.



Note: If you disable the tooltips, you can still display them for specific items. Hover over an area of the interface, and select the Shift key on the keyboard.

7.2.9 Enable the USB M-Code I/O Interface Kit

If you have a USB M-Code I/O Interface Kit (PN 32616), you must first enable it in the PathPilot interface.

To enable the USB M-Code I/O Interface Kit:

- From the **Settings** tab, select **USB IO Kit (PN 32616)**.

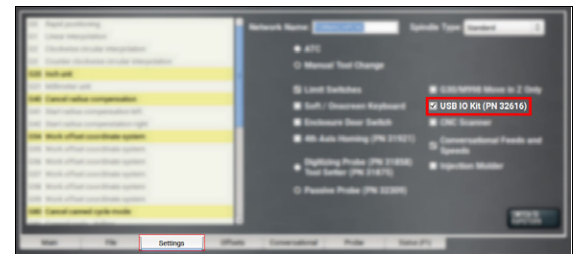


Figure 7-40: Settings tab.

7.2.10 Enable Feeds and Speeds Suggestions in Conversational Routines

You can use PathPilot to automatically calculate feeds and speeds. For more information, see "Use Feeds and Speeds Suggestions" (page 197).

- From the **Settings** tab, select **Conversational Feeds and Speeds**.

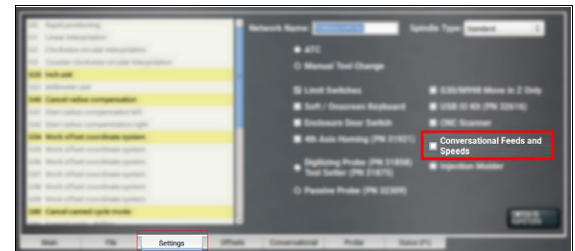


Figure 7-41: Settings tab.

7.2.11 Specify Probing and Tool Measuring Options

If you have any of the following accessories, you must first specify which you're using in the PathPilot interface:

- Wireless Probe and Tool Setter Kit (PN 51785)

To specify a probe or a tool setter:

- From the **Settings** tab, select the correct probing or tool measuring options for both **Accessory Input 1** and **Accessory Input 2**.

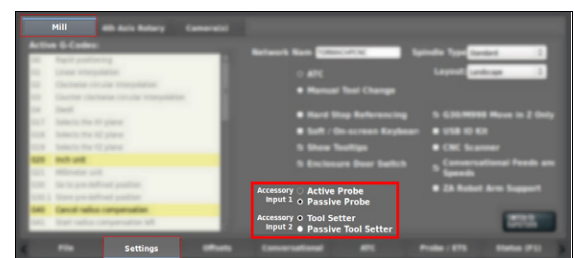


Figure 7-42: Settings tab.

7.2.12 Use a USB Camera

After plugging in the USB camera, navigate to the camera settings. From the PathPilot interface, in the **Settings** tab, open

7: PATHPILOT TOOLS AND FEATURES
7.2 Machine Settings and Accessories

the Camera(s) tab. Identify the Camera Status read-only dialog box.



Figure 7-43: USB camera status.

As cameras are plugged in and unplugged, the Camera Status area is refreshed. To test compatibility of any USB camera, plug it in and watch the Camera Status area for the camera name and details.

Note: If a camera isn't shown after plugging it in or starting a video recording, it might require too much power from the USB ports on the controller. This is very likely when more than one camera is used. Try using a powered USB hub to add the camera(s).

When a USB camera is plugged in, it's analyzed for supported video and audio formats, frame sizes, and frame rates. If the camera supports it, PathPilot uses H.264 compression; otherwise, it uses Motion JPEG. If the USB camera has a microphone, PathPilot records audio as well as video. The preferred format is compressed AAC, but uncompressed PCM is used as a fallback.

About USB Cameras

Recording video and audio from USB cameras is supported in PathPilot v2.10.0 and later. You can use up to four cameras simultaneously to record from different vantage points.

Note: All cameras are started and stopped at the same time — if you don't want a camera to record, you must unplug it.

USB cameras are compatible with all machine types, but older controllers may lack the processing power and memory needed for camera support. Controllers require 4GB of memory for camera functionality. Use the ADMIN MEMORY MDI command to verify the memory size of a controller.

You can purchase a Tormach USB Camera (PN 51240) with a metal case, mounting bracket, and 15-foot USB cable. Other USB cameras may work (see below), but do not include any technical support.

Manual Recording

To start or stop a manual recording, either:

- Use the controls in the Manual Recording area of the Camera(s) tab.

When a manual recording is stopped, a file save-as dialog appears prompting you for the file name base to use.



Figure 7-44: Manual recording controls.

- Select the Video Camera Recording button in the Persistent Controls section.



Figure 7-45: Video Camera Recording button.

Whenever PathPilot is recording from a USB camera and/or the virtual screen camera, the LED on this button is green. If PathPilot is recording and the button is pressed:

- If a program is running and not paused at an M00/M01, the recording is aborted.
- If a program is not running, but the machine is moving, the recording is aborted.
- Otherwise, if a manual recording is in progress, it is stopped and a file save as dialog will appear. If an automatic e-stop loop recording is in progress, it is aborted since no e-stop occurred.

To include a screen recording:

1. Toggle the Include PathPilot screen in recordings checkbox in the Camera Settings area of the Camera(s) tab to enable or disable screen recording.



Figure 7-46: Camera settings.

To take a picture (using all of the USB cameras at once):

1. Select **Snapshot** in the **Manual Recording** area of the **Camera(s)** tab.
The **Main** tab displays.
2. Review the camera images, which display on top of the **Tool Path** area. The camera images refresh every 0.5 seconds.
3. Align the cameras or adjust lighting to your preference, and then select the **Shutter** button.

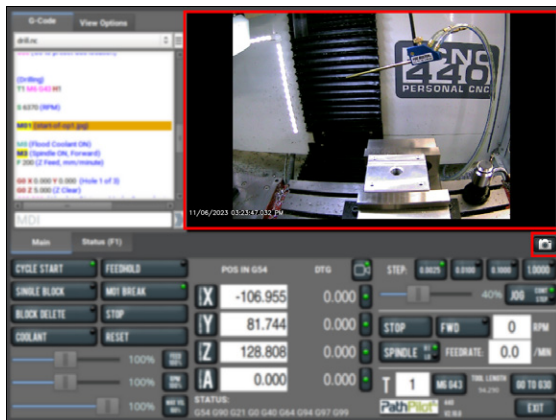


Figure 7-47: Example of taking a photo.

Automatic E-Stop Loop Recording ("Dashcam")

E-stop loop recording enables analysis of the previous 30 seconds after an E-stop. When enabled, recording is automatically started after reset.

To enable or disable the recording of emergency stops:

1. Toggle the **Automatic e-stop loop recording** checkbox in the **Camera Settings** area of the **Camera(s)** tab.



Note: This feature is enabled by default.

Automatic E-stop loop recording starts when the **Reset** button is selected. If you selected **Video Camera Recording** to abort a previous E-stop loop recording, select **Reset** to start it again.

To view E-stop videos:

1. A slight delay occurs after an E-stop while the video is saved to the **E-stop Videos** folder. Select the video file, and then select **Load G-Code** to view it.

Note: The E-Stop Videos folder is automatically monitored for internal drive space use. If the folder size grows beyond 5 GB, the oldest video files are automatically deleted until the folder size becomes less than 5 GB.

Review Video and Image Files

1. On the **File** tab, select the video or image file and select **Load G-Code**.

A video player application starts or the image preview is displayed.

Alternatively, you could transfer the video or image files to a Windows or macOS computer for review.

File Naming Convention

For manual and automatic E-stop recordings, the base file name for the recording has automatically chosen suffixes appended for each camera.

For example, if you stop a manual recording of two cameras, specify "Left Bracket Op1" as the name, and enabled screen recording, you'll see the following files:

File Name	Description of File
Left Bracket Op1_0.mp4	Camera 0 mp4 video file
Left Bracket Op1_0.log	Troubleshooting log for camera 0
Left Bracket Op1_1.mp4	Camera 1 mp4 video file
Left Bracket Op1_1.log	Troubleshooting log for camera 1
Left Bracket Op1_PP.mp4	PathPilot screen recording mp4 video file
Left Bracket Op1_PP.log	Troubleshooting log for screen recording

7: PATHPILOT TOOLS AND FEATURES

7.2 Machine Settings and Accessories

G-Code Commands

PathPilot supports three new M-codes to control cameras within G-code programs: M301, M302, and M303. Example use cases:

- Record only across each M01 stop where the operator needs to flip a workpiece or change a tool.
- Create short videos that focus on unique aspects of the program to reduce later video editing.
- Record USB IO integration operations with robots or other devices (pneumatic vises, etc.).
- Monitor progress on a workpiece by including M303 throughout the program.

File Naming Conventions

Recordings or pictures created by M301/M302/M303 have automatically generated file names, with the base file name taken from the running G-code file. Video files are saved alongside the G-code file. The suffix for each file uses a time stamp format. This makes it easy to distinguish multiple runs of the same G-code program.

For example, if engrave.nc is running and uses M301 and M302 to create one recording on a machine with one camera, and screen recording is enabled, you'll see the following files:

File Name	Description of File
engrave_2023-02-21_16_58_33_0.mp4	Camera 0 mp4 video file
engrave_2023-02-21_16_58_33_0.log	Troubleshooting log for camera 0
engrave_2023-02-21_16_58_33_PP.mp4	PathPilot screen recording mp4 video file
engrave_2023-02-21_16_58_33_PP.log	Troubleshooting log for screen recording
engrave_2023-02-21_17_43_22.jpg	Picture taken by a single M303 later in the program

Use M01 to Take Pictures

In addition to displaying information like pictures or messages during an M01 break, you can also use a USB camera (if installed) to take a picture.

To use M01 to take pictures:

1. Add `M01 (op1_setup.jpg)` into your G-code program.
 2. Run the G-code program.
 3. When PathPilot executes the M01 it looks to see if the comment contains a file name.
 - If there isn't a file name: The comment is shown as instructional text across the tool path.
 - If there is a file name, but the file doesn't exist yet and the extension is .jpg, .png, or .jpeg: The USB cameras are initialized and shown in the tool path display.
 4. Select the **Shutter** button to take the picture and create the op1_setup.jpg file.
- In future runs of the G-code program, **op1_setup.jpg** will display to the operator for instructional purposes on the workpiece.

For more information, see "Display Information and Capture Images During an M00 or M01 Break" (page 244).

7.3 SET UP G-CODE PROGRAMS

Before running a G-code program, you must first make sure that the machine is properly set up for the specific G-code program.

7.3.1 Use a Probe with PathPilot	181
7.3.2 Set Tool Length Offsets	183
7.3.3 Set Work Offsets	186
7.3.4 View Work Offsets	187
7.3.5 View Available G-Code Modes	187

7.3.1 Use a Probe with PathPilot

Use the Probe tab in the PathPilot interface to automate functions with a probe.

Set Up the Probe

Before using the functions on the Probe tab, you must first do the following:

1. Verify that tool number 99 (the probe tool) is in the spindle.
2. Disable the spindle to prevent any accidental spindle starts with the probe in the spindle.
3. Verify that the feed rate is appropriate for probing moves.

Note: All probing moves occur at a feed rate specified by the DRO fields on the Probe Setup tab.

4. Press the probe tip and make sure that, from the PathPilot interface, on the Probe tab, the Accessory Input light comes on.

This indicates that the probe polarity is correctly specified.

If the Accessory Input light does not come on, you must change the probe polarity setting. For information, see "Specify Probing and Tool Measuring Options" (page 177).

Use a Probe to Find a Feature's Location

To find the location of a workpiece or vise in the current work offset coordinates:

1. From the PathPilot interface, on the **Probe** tab, select the **X/Y/Z Probe** tab.
2. Position the probe near the workpiece or vise.
3. One at a time, select **Find X+**, **Find X-**, **Find Y+**, **Find Y-**,

or **Find Z-**.

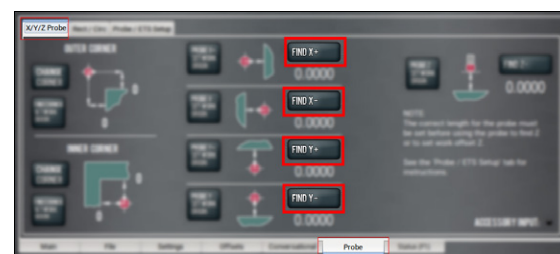


Figure 7-48: Probe tab.

The axis is probed, and the location of the probed surface is displayed.

Use a Probe to Set Work Offset Zeroes

You can set the work offsets of a workpiece or vise jaw using a probe.

Set the X and Y Work Offset Zero on the Corner of a Feature

1. From the PathPilot interface, on the **Probe** tab, select the **X/Y/Z Probe** tab.
2. Position the probe so that it is below the surface of the feature and 1 in. away from the vice jaw corner in the **X** and **Y** directions.
3. Select **Find Corner, Set Work Origin**.



Figure 7-49: Probe tab.

The axes are probed, and the location of the probed surface is set as the current work offset's X/Y origin.



Note: Select **Change Corner** to change the corner on which to probe.

Set the Work Offset Zeroes on a Feature

1. From the PathPilot interface, on the **Probe** tab, select the **X/Y/Z Probe** tab.
2. Position the probe near the workpiece or vise.

7: PATHPILOT TOOLS AND FEATURES

7.3 Set Up G-Code Programs

- One at a time, select **Probe X+**, **Set Work Origin**, **Probe X-**, **Set Work Origin**, **Probe Y+**, **Set Work Origin**, **Probe Y-**, **Set Work Origin**, or **Probe Z-**, **Set Work Origin**.

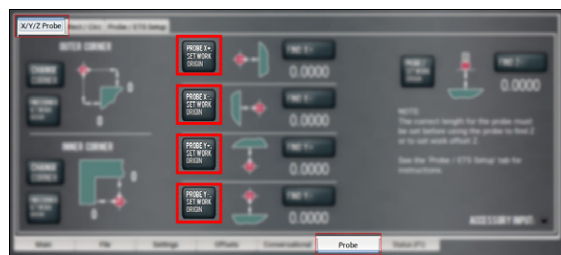


Figure 7-50: Probe tab.

The axis is probed, and the location of the probed surface is set as the current work offset's origin.

Use a Probe to Find the Center of a Feature

You can find the center of a pocket, slot, or boss on a part using a probe.

Find the Center of a Pocket

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe near the center of the pocket.
- Select **Find Center, Set Work Origin** as shown in the following image.



Figure 7-51: Probe tab.

Find the Center of a Slot

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe near the center of the slot.
- Depending on the slot, do one of the following:
 - To probe the slot in the **X** direction only, select **Find Center, Set Work Origin** as shown in the following image.

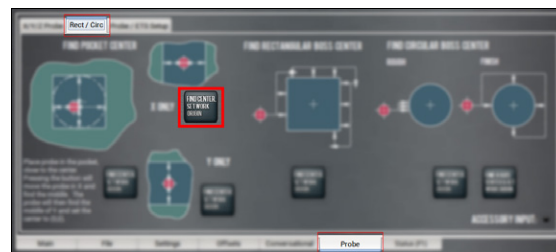


Figure 7-52: Probe tab.

- To probe the slot in the **Y** direction only, select **Find Center, Set Work Origin** as shown in the following image.



Figure 7-53: Probe tab.

Find the Center of a Rectangular Boss

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe below the top surface of the boss and on the left-hand side.
- Select **Find Center, Set Work Origin** as shown in the following image.



Figure 7-54: Probe tab.

The probe moves around the edge of the workpiece to find the center.

Find the Center of a Circular Boss

- From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
- Position the probe below the top surface of the boss and on the left-hand side.

3. Select **Find Center, Set Work Origin** as shown in the following image.



Figure 7-55: Probe tab.

The probe moves around the workpiece three times to determine the approximate center of the curve, and then makes four additional move to confirm the center of the circle.

Find the Center Rotation of an A-Axis

1. From the PathPilot interface, on the **Probe** tab, select the **Rect/Circ** tab.
2. Position the probe directly above the A-axis center of rotation.
3. Select **Find A Axis Center & Set Work Origin**.

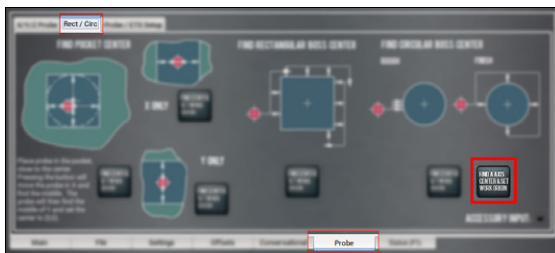


Figure 7-56: Probe tab.

The probe moves around the round workpiece mounted in the A-axis to find the center rotation of the A-axis.

7.3.2 Set Tool Length Offsets

Before running a G-code program, PathPilot must know the length of the tools that are required for the program. For more information on using tool length offsets, see "About Tool Offsets" (page 213).



Note: You can import a .csv file with tool length offset data. For information, see "Import and Export the Tool Table" (page 204).

To set tool length offsets:

1. Verify that the machine is powered on and out of reset.
2. Put a tool into a tool holder, and set it aside to measure. For information, see "Set Up Tooling" (page 212).

3. From the PathPilot interface, on the **Offsets** tab, verify that the **Tool** tab is selected.
4. Find the **Tool Table** window.

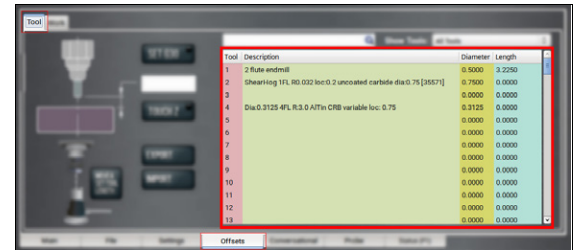


Figure 7-57: Tool Table window on the Offsets tab.

5. Depending on your workflow, you can measure your tools using any of the following methods:
 - **Use a Tool Height Setter** For information, see "Use a Tool Height Setter to Measure Tools" (page 215).
 - **Use an Electronic Tool Setter** For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 215).
 - **Touch Off of a Known Reference Height** For information, see "Touch Off the Tool Length Offsets" (page 213).

About Tool Offsets

Tool offsets allow you to use various tools while still programming with respect to the workpiece. Tools can have different lengths (and, while using cutter radius compensation, different diameters).

The most common tool offset is the tool length offset: when you change tools, PathPilot must account for the difference in tool length. In CNC machines, the tool length offset is applied using a G43 command.

The tool length offset is the distance from the cutting edge of the tool to the shoulder of the tool holder.

Before you begin a G-code program, you must verify the lengths of the tools in the program, and make sure that the lengths agree with the tool length offsets set in PathPilot:

- Each time you change tools, you must apply a new tool length offset in PathPilot.

7: PATHPILOT TOOLS AND FEATURES
7.3 Set Up G-Code Programs

- Each time you replace a tool, you must remeasure its length, and apply a new tool length offset in PathPilot.

NOTICE! You must always verify that the physical length of a tool agrees with the tool length offset value set in PathPilot. If you don't, there's a risk that the tool length offset misrepresents the currently active tool in the spindle, which may result in a machine crash or damaged tooling, workpieces, or fixtures.

Touch Off the Tool Length Offsets

Touch off the tool length offsets by using a reference surface with a known height, which gives you a basis to measure any other tool lengths. Use any surface that is parallel (within 0.02 mm) to the machine table. For example:

- A 1-2-3 Block Set (PN 31950)
- Box parallel

There are two steps to touch off the tool offsets. Complete the following steps in the order listed:

Set a Known Reference Height 184
Measure Tools Using a Known Reference Height 184

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

- Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.
- Verify that the drive dogs won't contact the reference surface before the end face of the spindle.
- Set a new, unused work offset (like G55). From the PathPilot interface, on the Main tab, in the MDI Line DRO field, type a work offset. Then select the Enter key. For information, see "Set Work Offsets" (page 217).
- If there's already a tool in the spindle, remove it.
- From the PathPilot interface, in the Tool DRO field, type 0. Then select the Enter key.
- Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.

- Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
- While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.

Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 208).

- From the PathPilot interface, in the Z-axis work offset DRO field, type the thickness of the piece of paper. Then select the Enter key.



Figure 7-58: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

- To set the tool length offset, go to Measure Tools Using a Known Reference Height.

Measure Tools Using a Known Reference Height

This procedure sets the tool length offset using a known reference height. If you have not yet done so, you must first set the Z zero position; go to Set a Known Reference Height.

To measure tools using a known reference height:

- Verify that the reference surface is still on the machine table with the piece of paper.
- From the PathPilot interface, on the Offsets tab, find an unused tool number in the Tool Table window. Then, type a description for the tool you're measuring.
- Put the tool holder into the spindle.
- From the PathPilot interface, in the Tool DRO field, type the number of the tool. Then select the Enter key.



Figure 7-59: Tool DRO field.

5. Slowly jog the Z-axis down (-Z) until it is 0.04 in. (1 mm) from the reference surface.
6. Continue to slowly jog the Z-axis while slowly moving the piece of paper back-and-forth on the reference surface.
7. Stop jogging the Z-axis when you feel a light pull on the piece of paper, which indicates that it is in contact with the tool.
8. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table**, select the tool for which you previously wrote a description.
9. In the **Touch Z** DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

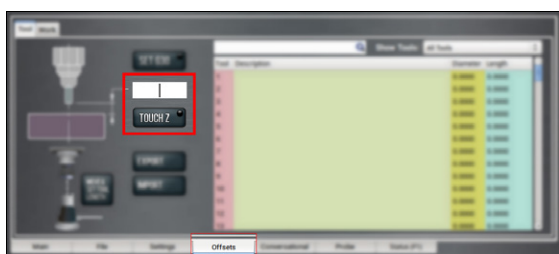


Figure 7-60: Touch Z DRO field and button.

10. Select **Touch Z**.
The length of the tool is stored in the **Tool Table** window.
11. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.
12. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
13. Jog the Z-axis up (+Z).
You've completed the procedure to measure a tool offset. Repeat this procedure for any remaining tooling you have. Once you're done adding tool length offsets, switch back to your work coordinate system.

Use an Electronic Tool Setter (ETS) to Measure Tools

An ETS is a device used to measure the length of a cutting tool. To use an ETS to measure tools:

1. Put the ETS on the known reference surface below the spindle.
2. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
3. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.

4. Put a tool holder into the spindle.
5. From the PathPilot interface, type the tool number in the **Tool DRO** field. Then select the **Enter** key.

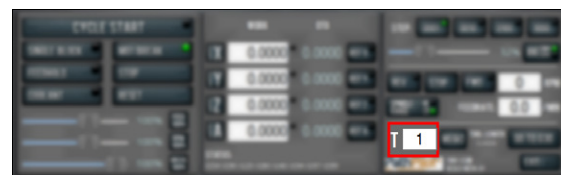


Figure 7-61: Tool DRO field.

6. Jog the Z-axis down (-Z) until it is above the ETS.
7. From the **Offsets** tab, on the **Tool** tab, select **Move and Set Tool Length**.

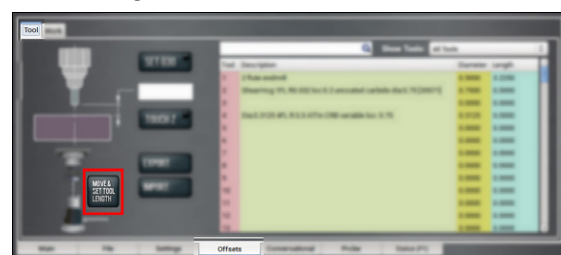


Figure 7-62: Tool tab on the Offsets tab.

Note: Regardless of the initial feed rate, the final touch off feed rate while using an ETS is 2-1/2 in. per minute (IPM).

8. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.

Use a Tool Height Setter to Measure Tools

This procedure sets the tool length offset using a known reference height and a Tool Height Setter (PN 39682).

Complete the following steps in the order listed:

- Set a Known Reference Height** 185
- Verify the Calibration of the Tool Height Setter**186

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

1. Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.

7: PATHPILOT TOOLS AND FEATURES

7.3 Set Up G-Code Programs

2. Set a new, unused work offset (like G55). From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type a work offset. Then select the **Enter** key. For information, see "Set Work Offsets" (page 217).
3. If there's already a tool in the spindle, remove it.
4. From the PathPilot interface, in the **Tool** DRO field, type 0. Then select the **Enter** key.
5. Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.
6. Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
7. While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.



Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 208).

8. From the PathPilot interface, in the **Z-axis** work offset DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

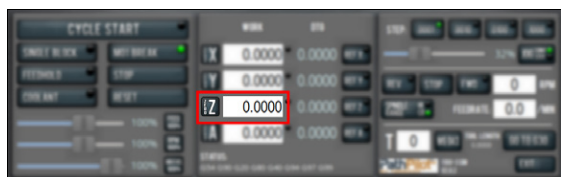


Figure 7-63: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

Verify the Calibration of the Tool Height Setter

The higher side of the Tool Height Setter is precision ground. You can use it as a reference surface to calibrate the tool.



Figure 7-64: Tool Height Setter.

1. Use the provided dowel pin to compress the setting face of the Tool Height Setter to the level of the ground reference surface.
2. Adjust the indicator dial's bezel to read zero. Make note of how many times the indicator rotates around the dial.
3. Measure the height of the ground reference surface from the bottom surface of the Tool Height Setter with a calipers. Note the measured height for later.
4. Carefully, without moving the bezel, put the Tool Height Setter on the reference surface that's on the machine table.
5. Measure the tools using a known reference height.

7.3.3 Set Work Offsets

To set the current axis location to zero in the active work coordinate system:

- Select **Zero [Axis]**.

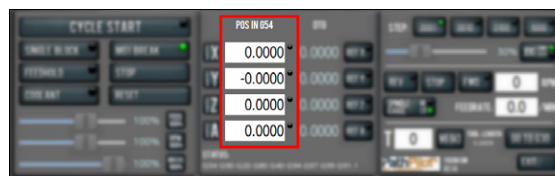


Figure 7-65: Work Offset DRO fields.

To change work offsets:

1. On the **Main** tab, in the **MDI Line** DRO field, type the new work offset to activate (for example, G55). Then select the **Enter** key.

- The new work offset displays in the following locations in the PathPilot interface:
 - The **Status** read-only DRO field.
 - Above the **Work Offset** DRO fields.



Figure 7-66: Work offset indicated in the PathPilot interface.

Note: The values in the **Work Offset** DRO fields update to indicate the new location of each axis in the new work offset.

For more information on using work offsets, see "About Work Offsets" (page 217).

About Work Offsets

Work offsets allow you to think in terms of X, Y, and Z coordinates with respect to the part, rather than thinking of them with respect to the machine position. This means that you can jog the machine to an arbitrary location (like the end of a workpiece) and call that location zero. You can save up to 500 work offsets in PathPilot. The naming structure varies based on the offset number, as detailed in the following table.

Work Offset Naming		
Offsets 1-9 (Use either name)		
Offset	Extended Name	Name
1	G54.1 P1	G54
2	G54.1 P2	G55
3	G54.1 P3	G56
4	G54.1 P4	G57
5	G54.1 P5	G58
6	G54.1 P6	G59
7	G54.1 P7	G59.1
8	G54.1 P8	G59.2
9	G54.1 P9	G59.3

Work Offset Naming		
Offsets 10-500 (Use extended name)		
Offset	Extended Name	Name
10	G54.1 P10	Not used
11	G54.1 P11	Not used
...		
499	G54.1 P499	Not used
500	G54.1 P500	Not used

7.3.4 View Work Offsets

To view the current work offset:

- From the **Offsets** tab, on the **Work** tab, identify the **Work Offsets Table** window.

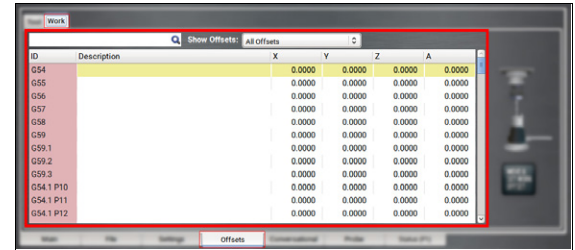


Figure 7-67: Work Offsets Table window.

The active work offset is highlighted.

To change the current work offset, go to "Set Work Offsets" (page 217).

7.3.5 View Available G-Code Modes

The G-Code Description window shows a list of all available G-code modes.

To view available G-code modes:

- From the **Settings** tab, find the **G-Code Description** window.

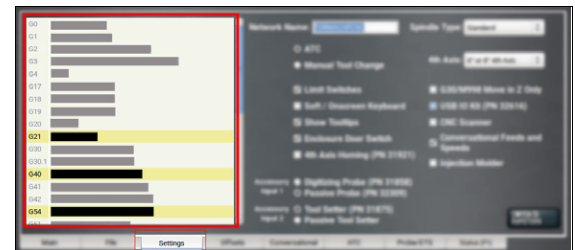


Figure 7-68: G-code Description window on the Settings tab.

7: PATHPILOT TOOLS AND FEATURES
7.4 Run G-Code Programs

7.4 RUN G-CODE PROGRAMS

While running a G-code program, use the following controls:

7.4.1 Bring the Machine Out of Reset188
7.4.2 View the Active Axis to Jog188
7.4.3 Jog the Machine188
7.4.4 View the Current Machine Position189
7.4.5 Reference the Machine190
7.4.6 Start a Program190
7.4.7 Stop Machine Motion191
7.4.8 Operate the Coolant Pump191
7.4.9 View the Active G-Code Modes191
7.4.10 View the Distance to Go191

7.4.1 Bring the Machine Out of Reset

- Select Reset.



Figure 7-69: Reset button.

For more information on reset mode, see "About Reset Mode" (below).

About Reset Mode

When the machine is first powered on, or after an emergency stop, the Reset button flashes. When you select the flashing Reset button, PathPilot verifies communication to the machine and does the following activities:

- Brings the machine out of an emergency stop condition
- Clears alarms
- Clears the tool path backplot
- Resets all modal G-codes to their normal state
- Rewinds the currently loaded G-code program
- Stops machine motion, but is not a replacement for the Emergency Stop button

You can select the Reset button any time while the machine is on.

7.4.2 View the Active Axis to Jog

To find which axis is active while jogging your machine:

- Identify the light next to the Work Offset DRO fields.



Figure 7-70: Work Offset DRO fields.

For information, see "Jog the Machine" (page 208).

7.4.3 Jog the Machine

To switch between jogging modes:

- From the Manual Control area, in the Jog group, select Jog.

PathPilot toggles between continuous velocity mode and step mode.

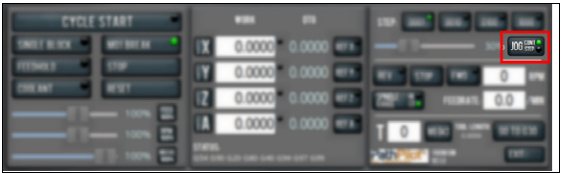


Figure 7-71: Jog button.

When the Cont green light is on, continuous velocity mode is selected.

When the Step green light is on, step mode is selected.

To use continuous velocity mode:

- Set the velocity: drag the Jog Speed slider.



Figure 7-72: Jog Speed slider.

For more information on continuous velocity mode, see "About Continuous Velocity Jogging" (page 208).

To use step mode, select the step size. Do one of the following, depending on your accessories:

- In the Manual Control Area, in the Jog group, select the step size.

The Step button's light comes on, indicating which step size is active.



Figure 7-73: Step buttons (in G20 mode).

- On the (optional) Jog Shuttle, press the Step button to toggle the currently selected step size.
In the PathPilot interface, the **Step** button's light comes on, indicating which step size is active.

For more information on step mode, see "About Step Jogging" (page 208).

Jog in Continuous Velocity Mode

In continuous mode, the machine jogs at a continuous velocity.
To select continuous velocity mode:

- In the **Manual Control** area, select **Jog**.



Figure 7-74: Continuous velocity jogging controls.

When the **Cont** green light is on, continuous velocity mode is selected.

When the **Step** green light is on, step mode is selected.

To set the velocity:

- Drag the **Jog Speed** slider.



Figure 7-75: Jog Speed slider.

About Continuous Velocity Jogging

While jogging in continuous velocity mode, the machine moves at a constant speed for as long as:

- A keyboard key is pressed
- The Jog Shuttle outer ring is twisted away from the neutral position
- The Operator Console's pendant wheel is turned in the desired direction

This is useful when you're doing things like:

- Roughly positioning the machine (for example, to move the spindle head away from the workpiece).
- Moving the machine a certain distance at a constant speed (for example, to align a vise).

Jog in Step Mode

In step mode, the machine jogs in steps, which range based on the programming mode you're using:

- Imperial (G20) Mode** 0.0001 in. to 0.1000 in.
- Metric (G21) Mode** 0.01 mm to 10 mm

To select the step size:

- In the **Manual Control Area**, select the step size.
The **Step** button's light comes on, indicating which step size is active.

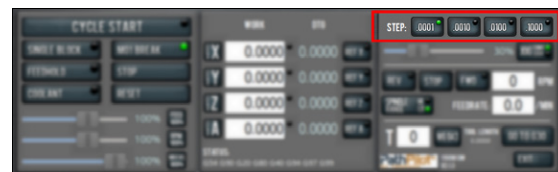


Figure 7-76: Step buttons (in G20 mode).

About Step Jogging

While jogging in step mode, the machine moves one step at a time. The jog step sizes range depending on the programming mode you are using:

- Imperial (G20) Mode** 0.0001 in. to 0.1000 in.
- Metric (G21) Mode** 0.01 mm to 10 mm

Step jogging mode is useful to finely move the machine, like when you're indicating a workpiece or manually setting tool lengths.

The jog keys on the keyboard only move the machine in steps when step mode is indicated in PathPilot. The inner wheel on the jog shuttle always moves the machine in steps, regardless of which mode is indicated in PathPilot. The Operator Console's pendant moves the machine in the step size that's selected with the three-position switch.

7.4.4 View the Current Machine Position

- Identify the **Work Offset** DRO fields.

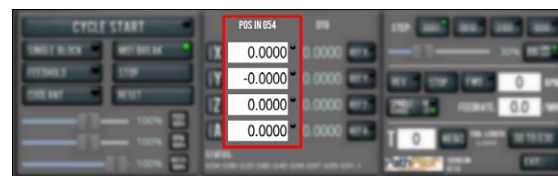


Figure 7-77: Work Offset DRO fields.

The position is expressed by the currently active work offset coordinate system (like G54 or G55).

When the machine isn't moving, you can edit the DRO fields.

For more information on setting work offsets, go to "Set Work Offsets" (page 217).

7: PATHPILOT TOOLS AND FEATURES

7.4 Run G-Code Programs

7.4.5 Reference the Machine



Note: The machine automatically references when it's powered on.

1. Verify that the machine can freely move to its reference position (at the ends of travel).
2. To verify that the tooling is clear of any possible obstructions, reference the Z-axis before referencing the other axes: from the PathPilot interface, select **Ref Z**.



Figure 7-78: Reference buttons.

3. Once the spindle is clear of any possible obstructions, continue referencing all axes.



Note: You can select the buttons one after another. Once the machine references one axis, it'll move on to the next.

After each axis is referenced, its button light comes on.

For more information on referencing the machine, see About Referencing.

About Referencing

The axes are referenced during assembly and, aside from the A-axis, do not need re-referencing after powering on or once the Emergency Stop button is released. You must reference the X-, Y-, or Z-axis or the ATC at the following times:

- After replacement of a linear motion component such as linear rails, ballscrew, or servo motor
- Disconnection of an encoder battery and powering off of the machine
- Disconnection of the encoder cable from the servo motor

When referencing the X-, Y-, and Z-axis, the machine moves to the end of travel, presses against the bumper on the ballscrew until torque increases, and then backs off to the index pulse of the encoder.

You must reference the A-axis only if the rotary table is removed from the machine.

When referencing the A-axis, the machine lines up the index marks on the body and face plate, then backs off to the index pulse of the encoder.

To reference the ATC, select the **Align Tool Tray** button on the **ATC** tab. When referencing, an ATC pocket is aligned to the flange of a tool holder in the spindle until both parts of the ATC fork open evenly when engaging the flange of the tool holder.



Figure 7-79: Align Tool Tray button on the ATC tab.

7.4.6 Start a Program

- From the PathPilot interface, in the **Main** tab, select **Cycle Start**.

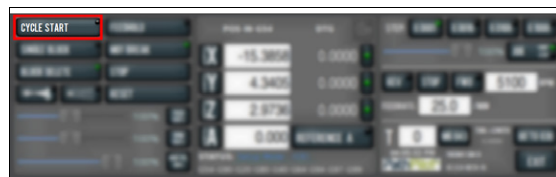


Figure 7-80: Cycle Start button.

For more information on starting a program, see "About Cycle Start" (below).

If you can't start a program, go to "Cycle Start Reference" (below).

About Cycle Start

While a program is running, the Cycle Start button's light is on. The Cycle Start button's light flashes if motion is paused during the program. The following modes may pause motion during a program:

- Single block
- Feed hold
- M01 break

If machine motion pauses a single block, feed hold, or M01 break, the Cycle Start button flashes until it's selected again.

Cycle Start Reference

The Cycle Start button doesn't operate if you select it:

- While you're not in the Main tab. For information, see "Main Tab" (page 147).

- Before you've loaded a G-code program. For information, see "Load G-Code" (page 211).
- Before referencing the machine. For information, see "Reference the Machine" (page 207).

7.4.7 Stop Machine Motion

- From the **Program Control** area, select **Stop**.

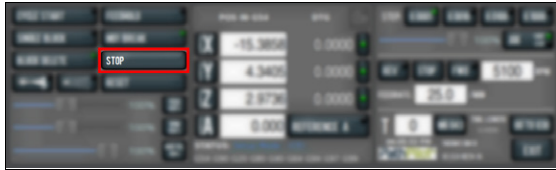


Figure 7-81: Stop button.

7.4.8 Operate the Coolant Pump

To turn coolant on or off:

- Select **Coolant**.

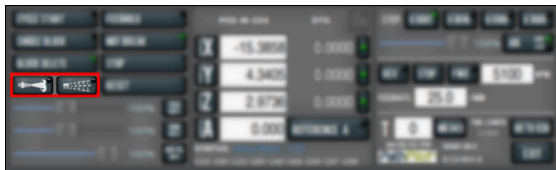


Figure 7-82: Coolant button.

For more information on turning on and off coolant, see "About Coolant" (page 218).

About Coolant

In the PathPilot interface, the Coolant button controls the machine's coolant pump power outlet. The Coolant button's light shows the current state of the outlet: the light is on when the outlet has power; the light is off when the outlet does not have power.



Note: The Coolant button is equivalent to using an M08 (coolant on) or M09 (coolant off) command in the G-code program.

Use the Coolant button before or after a program is running, while a program is running, or while you are using manual data input (MDI) commands.

7.4.9 View the Active G-Code Modes

To find the currently active G-code modes and the currently active tool at a glance:

- Identify the **Status** read-only DRO field.



Figure 7-83: Status read-only DRO field.

For more information on G-code modes, go to "View Available G-Code Modes" (page 187).

7.4.10 View the Distance to Go

To view the distance to go:

- Identify the **DTG** read-only DRO fields.

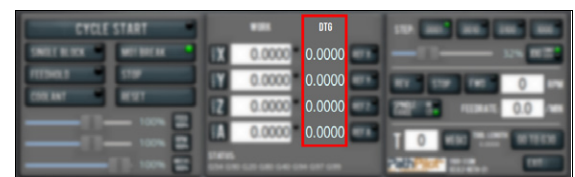


Figure 7-84: DTG read-only DRO fields.

The value is the remaining distance in any programmed move.

For more information on using the **DTG** read-only DRO fields, see "About Distance to Go" (below).

About Distance to Go

While a program is running, the DTG read-only DRO fields show the remaining distance in each move.

After using the feed hold function or the maxvel override function, look at the distance to go. This read-only DRO field is useful to prove out a part program.

7: PATHPILOT TOOLS AND FEATURES

7.5 Control G-Code Programs

7.5 CONTROL G-CODE PROGRAMS

If necessary, use the following controls to add to your G-code program:

7.5.1 Use the Feed Hold Function	192
7.5.2 Use the Feed Rate Override Function	192
7.5.3 Use M01 Break Mode	193
7.5.4 Use the Maxvel Override Function	193
7.5.5 Use Single Block Mode	194
7.5.6 Use the Spindle Override Function	194
7.5.7 Change the Feed Rate	195
7.5.8 Change the Spindle Speed	195
7.5.9 Change the Tool Number	195
7.5.10 Use a G30 Position	195
7.5.11 View the Tool Length	196
7.5.12 Manually Enter Commands	196
7.5.13 Copy Recently Entered Commands	197
7.5.14 Use Feeds and Speeds Suggestions	197
7.5.15 Use Cycle Counters (M30 and M99)	200

7.5.1 Use the Feed Hold Function

- Select **Feed Hold**.

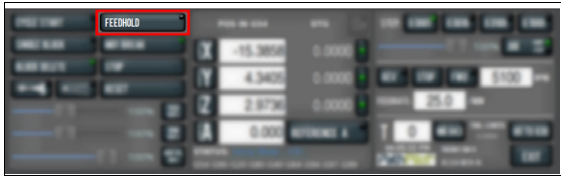


Figure 7-85: Feed Hold button.

**Tip!** Use the **Spacebar** key to quickly activate the feed hold function.

For more information on using the feed hold function, see "About Feed Hold" (below).

About Feed Hold

When the feed hold function is active, the Feed Hold button's light is on.

The feed hold function pauses machine motion — aside from the spindle — and the Cycle Start button flashes. For information, see "About Cycle Start" (page 190).

**Note:** If the machine isn't moving, the feed hold function doesn't have an effect.

You can use the feed hold function either while a program is running or while you are using manual data input (MDI) commands. If the program is running a spindle-synchronized move, the feed hold function is delayed until the move is complete.

7.5.2 Use the Feed Rate Override Function

To use the feed rate override function:

- Using the **Feed Rate Override** slider, change the programmed feed rate by a specific percentage.



Figure 7-86: Feed Rate Override slider.

**Note:** Percentages range from 1-200%.

To remove the feed rate override function:

- Select **Feed 100%**.
The feed rate returns to 100% of its programmed value (it's no longer overridden).

For more information on the feed rate override function, see "About Feed Rate Override" (below).

About Feed Rate Override

You can use the feed rate override function while you're doing any of the following activities:

- Using manual data input (MDI) commands
 - Jogging
 - Running a program with G01, G02, or G03 commands
- The feed rate override function does not affect G00 (rapid) commands. It's ignored if:
- The program is running a spindle-synchronized move
 - An M48 (disable feed and speed overrides) command is used

To indicate lack of motion or unusual levels, the slider turns yellow when it's either at 0% or above 100%. The Feed Rate Override slider and Feed 100% button work similarly to the spindle override controls. They affect the commanded feed rate by a percentage from 1-200%. The feed rate override works for MDI, jogging, and G-code program G01/G02/G03 moves. The override has no effect on G00 (rapid) moves.

7.5.3 Use M01 Break Mode

- Select **M01 Break**.

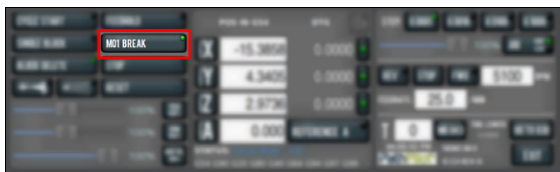


Figure 7-87: M01 Break button.

For more information on using M01 break mode, see "About M01 Break" (below).

About M01 Break

When the M01 break mode is active, the M01 Break button's light is on. When the M01 break mode is inactive, the M01 Break button's light is off.

M01 break mode enables any M01 (optional stop) commands that are programmed in the G-code file. You can turn M01 break mode on or off either before starting a program or while a program is running.

- **When M01 Break is Active** Machine motion stops after PathPilot reaches an M01 command, and the Cycle Start button flashes. For information, see "About Cycle Start" (page 190).
- **When M01 Break is Inactive** PathPilot ignores all programmed M01 commands.

Display Information and Capture Images During an M00 or M01 Break

Display Information with Images

If the comment occurs on a line with **M00** or **M01**, and contains a file name with a .jpg or .png extension, PathPilot displays the image in the Tool Path display when the program reaches the M00 or M01 break.

To display an image during an M00 or M01 break:

1. Move an image file with a .jpg or .png extension to the PathPilot controller in one of the following locations:
 - In the same folder as the G-code program
 - In an images folder within the G-code program's folder
 - In an images folder within the home directory
2. Program an M00 or M01 break, and, using parentheses, type the full file name of the image (including its extension).



EXAMPLE

M01 (Op1_Setup.jpg) displays the image file on the Tool Path display.

3. The image file displays on the Tool Path display.

Display Information with Text

To display a message on the Tool Path display:

1. Program an M00 or M01 break, and, using parentheses, type a message that you'd like to display on the screen.



EXAMPLE

M01 (Check coolant nozzles are pointed correctly) displays *Check coolant nozzles are pointed correctly* across the bottom of the Tool Path display.

2. The message displays on the Tool Path display.

Capture Images with a USB Camera

In addition to displaying information like pictures or messages during an M01 break, you can also use a USB camera (if installed) to take a picture.

To use M01 to take pictures:

1. Add **M01 (op1_setup.jpg)** into your G-code program.
2. Run the G-code program.
3. When PathPilot executes the M01 it looks to see if the comment contains a file name.
 - If there isn't a file name: The comment is shown as instructional text across the tool path.
 - If there is a file name, but the file doesn't exist yet and the extension is .jpg, .png, or .jpeg: The USB cameras are initialized and shown in the tool path display.
4. Select the **Shutter** button to take the picture and create the op1_setup.jpg file.
In future runs of the G-code program, **op1_setup.jpg** will display to the operator for instructional purposes on the workpiece.

For more information, see "Use a USB Camera" (page 177).

7.5.4 Use the Maxvel Override Function

To use the maxvel override function:

7: PATHPILOT TOOLS AND FEATURES

7.5 Control G-Code Programs

- Using the **Maxvel Override** slider, change the maximum velocity by a specified percentage.



Figure 7-88: Maxvel Override slider.

To remove the maxvel override function:

- Select **Maxvel 100%**.

For more information on using the maxvel override function, see "About Maxvel Override" (below).

About Maxvel Override

The maxvel override function affects G00 and G01 commands, and it's useful for:

- **Running a Program for the First Time** Drag the Maxvel Override slider to 0% to verify that all DRO fields look appropriate.
- **Safety** If you're running a spindle-synchronized move, a maxvel override isn't ignored. Verify that the maxvel override value allows the machine to use the programmed feed rate during spindle-synchronized moves. If it can't, the spindle-synchronized move won't produce the results you want.

To indicate lack of motion or unusual levels, the slider turns yellow when it's either at 0% or above 100%.

7.5.5 Use Single Block Mode

- Select **Single Block**.

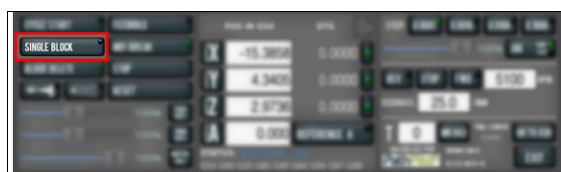


Figure 7-89: Single Block button.

For more information on using single block mode, see "About Single Block" (below).

About Single Block

While single block mode is active, the Single Block button's light is on.

Single block mode runs one line of G-code at a time. After each line, motion is paused, and the Cycle Start button flashes.

For information, see "About Cycle Start" (page 190).

You can turn single block mode on or off either before starting a program or while a program is running. For information, see "Use Single Block Mode" (above).



Note: Single block mode ignores non-motion lines, like comment lines or blank lines.

7.5.6 Use the Spindle Override Function

To use the spindle override function:

- Using the **Spindle Override** slider, change the programmed spindle speed by a specified percentage.

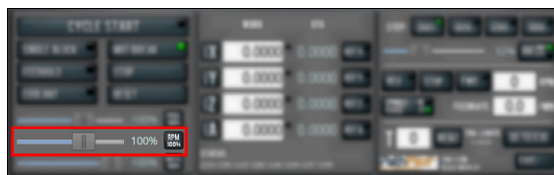


Figure 7-90: Spindle Override slider.



Note: Percentages range from 1-200%.

To remove the spindle override function:

- Select **RPM 100%**.
The spindle speed returns to 100% of its programmed value (it's no longer overridden).

For more information on using the spindle override function, see "About Spindle Override" (below).

About Spindle Override

The spindle override function won't command the spindle to move past the maximum allowable speed. If the spindle isn't moving, the spindle override function is delayed until the next time spindle starts. The override doesn't drive the spindle past its maximum speed. It does affect the speed of a spindle command limited by a D word.

You can use the spindle override function while you're doing any of the following activities:

- Running a program
- Using manual data input (MDI) commands

The spindle override function is ignored in the following situations:

- If the program is running a spindle-synchronized move
- If an M48 (disable feed and speed overrides) command is used

To indicate lack of motion or unusual levels, the slider turns yellow when it's either at 0% or above 100%.

7.5.7 Change the Feed Rate

- In the **Feed Rate** DRO field, type in a feed rate. Then select the **Enter** key.

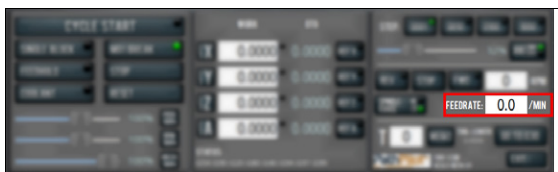


Figure 7-91: Feed Rate DRO field.

For information, see "About Feed Rates" (below).

About Feed Rates

A feed rate is the velocity at which the workpiece can be fed against the tool in the machine's spindle.

Motion	Feed Rate
Coordinated linear motion of one or more axis (X-axis, Y-axis, or Z-axis)	Inches per minute (G20) or millimeters per minute (G21)
Rotational axis motion of one axis (A-axis)	Degrees per minute
Coordinated linear motion of one or more axis (X-axis, Y-axis, or Z-axis) with simultaneous rotational axis motion (A-axis)	Usually programmed in inverse time feed rate mode (G93)

7.5.8 Change the Spindle Speed

- In the **Spindle RPM** DRO field, type in a spindle speed. Then select the **Enter** key.

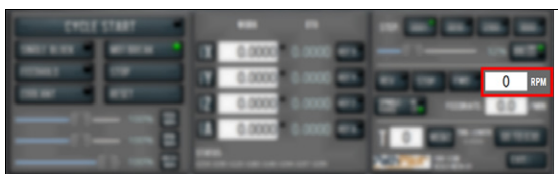


Figure 7-92: Spindle RPM DRO field.

For information, see "About Spindle Controls" (below).

About Spindle Controls

A spindle speed is the rate at which the spindle rotates. Use the FWD, REV, and Stop buttons to manually control the spindle.

Button	G-Code	Use to...
FWD	M03	Start the spindle clockwise at the RPM specified in the Spindle RPM DRO field.
REV	M04	Start the spindle counterclockwise at the RPM specified in the Spindle RPM DRO field.
Stop	M05	Stop the spindle.

The FWD and REV buttons and the Spindle RPM DRO field don't operate if selected when:

- A G-code program is running.
- Using manual data input (MDI) commands.

7.5.9 Change the Tool Number

The Tool DRO field shows the tool number currently active.



Figure 7-93: Tool DRO field.

To change the tool number (and apply its tool length offset):

1. In the **Tool** DRO field, type a number (the valid range is from 0-1000). Then select the **Enter** key.



Note: You can also select **M6 G43**. For information, see "About M6 G43" (below).

About M6 G43

The M6 G43 button is a shortcut used to do the following:

- Change the number of the currently-loaded tool in the spindle to the number typed in the Tool DRO field. This is the equivalent of an M06 command.
- Apply the tool length offset for that tool typed in the Tool DRO field. For more information on tool length offsets, see "Set Tool Length Offsets" (page 213). This is the equivalent of a G43 command.

7.5.10 Use a G30 Position

The Go to G30 button moves the machine to a predefined G30 position. For information, see "About G30" (on the next page). To set a G30 position:

7: PATHPILOT TOOLS AND FEATURES

7.5 Control G-Code Programs

1. Jog the machine to the desired G30 position.
2. From the **Offsets** tab, select **Set G30**.

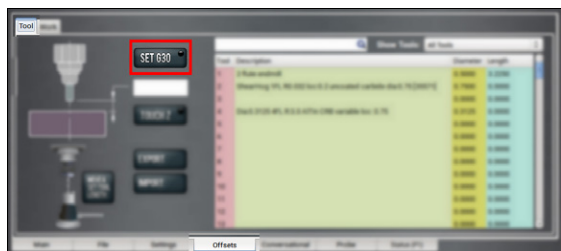


Figure 7-94: Set G30 button.

To go to a set G30 position:

- Use a G30 command in a G-code program.
- Select **Go To G30**.



Figure 7-95: Go to G30 button.



Note: The G30 position defaults to only moving the Z-axis.

About G30

A G30 command in a G-code program moves the machine to a preset position. For more information on setting a G30 position, see "Use a G30 Position" (on the previous page). Use a G30 move to start a coordinated movement of the axes. You can limit the movement to only the Z-axis. For information, see "Limit G30 Moves" (page 176).



Tip! It's useful to program a G30 move right before a tool change so that the machine can jog to a safe tool change position.

7.5.11 View the Tool Length

- Identify the **Tool Length** read-only DRO field.

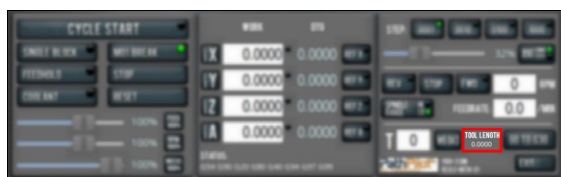


Figure 7-96: Tool Length DRO field.

If the tool offset matches the number of the tool in the **Tool DRO** field, the text is light blue on a gray background.

If the tool offset doesn't match the number of the tool in the **Tool DRO** field, the text is orange on a red background.

7.5.12 Manually Enter Commands

You can send G-code commands directly to the machine by using the MDI Line DRO field. For information, see "About the MDI Line DRO Field" (below).

To manually enter commands:

1. Select the **MDI Line DRO** field.

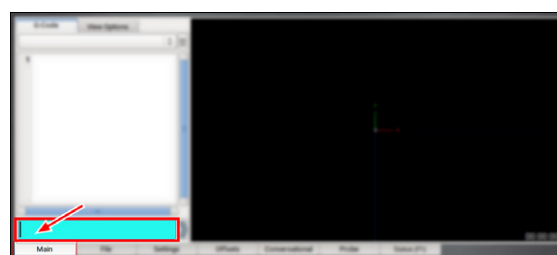


Figure 7-97: MDI Line DRO field.

The DRO field highlights.

2. Type the command.



Note: You can use the **Backspace**, **Delete**, **Left Arrow**, and **Right Arrow** keys to correct typing errors.

3. You must press the **Enter** key to execute the command. To abandon the command, press **Esc**.

About the MDI Line DRO Field

The MDI Line DRO field allows you to send commands (or, manual data input) directly to PathPilot. For information, see "Manually Enter Commands" (above).

The MDI Line DRO field saves up to 100 of your most recent commands, which are saved after a power cycle.

When you select the MDI Line DRO field, all keystrokes are used within the field — so, you can't jog the machine.

Admin Commands Reference

Use the following commands in PathPilot:

Admin Command	Use to...
ADMIN AUDIO	Customize the controller's audio device settings.
ADMIN CALC	Open the calculator.
ADMIN CLEAR	Clear the message history on the Status tab.
ADMIN CONFIG	Change the configuration of the PathPilot interface.
ADMIN CYCLECOUNTER	Control the cycle counters in the Tool Path display.
ADMIN DATE	Customize the controller's date and time.
ADMIN DISPLAY	Customize the controller's screen display.
ADMIN DROPBOX	Connect your controller to a Dropbox account for cloud file syncing.
ADMIN HELP	Review a list of available Admin commands.
ADMIN KEYBOARD	Customize the controller's keyboard layout.
ADMIN LOGDATA	Write the latest machine log data to a USB drive for technical support assistance.
ADMIN MEMORY	Determine how much total RAM is on your controller.
ADMIN MOUSE	Change the mouse preferences, like pointer speed and right- or left-hand button mapping
ADMIN NETWORK	Configure a Wi-Fi network.
ADMIN OPENDOORMAXRPM	Change the maximum spindle speed with the spindle cabinet door open, when using the optional Enclosure Door Switch Kit.
ADMIN RESET_SOFT_LIMITS	Reset axis soft limits to machine defaults.
ADMIN SET_X_LIMIT	Set the X-axis soft limit.

Admin Command	Use to...
ADMIN SET_Y_LIMIT	Set the Y-axis soft limit.
ADMIN SET_Z_LIMIT	Set the Z-axis soft limit.
ADMIN SETTINGS BACKUP	Create a backup of tool offset and fixture information to store externally.
ADMIN SETTINGS RESTORE	Restore tool offset and fixture information backup from an external location.
ADMIN SHOW_SOFT_LIMITS	Display the current axis soft limits on the Status tab.
ADMIN TOOLTIP DELAYMS	Set the milliseconds prior to displaying the tooltip (and then again for the expanded tooltip). The default is 1200 milliseconds.
ADMIN TOOLTIP MAXDISPLAYSEC	Limit the amount of time the expanded tooltip displays. The default is 15 seconds.
ADMIN TOUCHSCREEN	Adjust the touch screen calibration.
ADMIN VERSION	Display detailed version information on the Status tab.

7.5.13 Copy Recently Entered Commands

- From the **MDI Line** DRO field, press either the **Up Arrow** key or the **Down Arrow** key.
The previously entered command displays.
- You must press the **Enter** key to execute the command.
To abandon the command, press **Esc**.

For information, see "Manually Enter Commands" (on the previous page).

7.5.14 Use Feeds and Speeds Suggestions

Note: Calculating feeds and speeds requires that PathPilot has relevant details about the tooling. If you haven't yet done so, go to "Create Tool Descriptions" (page 199).



7: PATHPILOT TOOLS AND FEATURES
7.5 Control G-Code Programs

You can use PathPilot to automatically calculate feeds and speeds: from the Conversational tab, in the Conversational DROs group, select a material, a sub-type, and a tool.

- 1. If you haven't yet done so, enable the conversational feeds and speeds setting. From the Settings tab, select Conversational Feeds and Speeds.

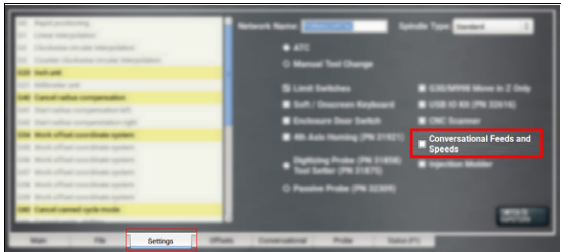


Figure 7-98: Settings tab.

- 2. From the Conversational tab, locate the Material dropdowns in the Conversational DROs group.



Figure 7-99: Feeds and speeds suggestions on the Conversational tab.

- 3. From the Material dropdown, select your material (like Aluminum or Plastic).
- 4. If required, from the Sub-Type dropdown, select the material sub-type (like -any- or 6061).
- 5. In the Tool DRO field, type the assigned tool number.
- 6. Select Refresh (to the right of the Sub-Type dropdown). The following machining-related DRO fields are calculated:

- Spindle RPM
- Feedrate
- Z Feedrate
- Depth of Cut
- Stepover
- Peck (if drilling)



Note: After PathPilot calculates values for the machining-related DRO fields, the background turns green.

- 7. (Optional) You can adjust the values in the calculated DRO fields. Adjusting the value in one of these DRO field doesn't change the value in the other machining-related DRO fields.



Note: Once you adjust the value in the DRO field, the background switches from green back to white. This helps you identify which DRO fields have suggested values (those with a green background), and which DRO fields have values you've supplied (white background).

Refresh DRO Field Values

The suggested values are no longer valid if:

- You select different material or sub-type values, or if you type a new value in to the Tool DRO field. The suggested feeds and speeds are made by taking into account all of these values. Changing any value requires you to refresh.
- You select a different Conversational tab. The suggested feeds and speeds are made by taking into account the current, specific conversational operation. Changing your conversational operation requires you to refresh the feeds and speeds values.

When the feeds and speeds are no longer valid, the Refresh button turns green, and the machining-related DRO field backgrounds switch from green to white, as shown in the following image.

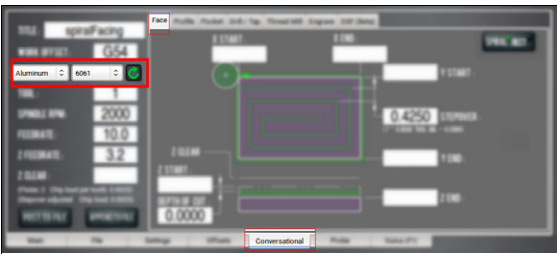


Figure 7-100: Refresh button on the Conversational tab.

Use Additional Provided Information

The following tips are displayed based on the calculations that PathPilot is performing:

- Chip Load Information Chip load — the amount of material removed per tooth — is based on the number of flutes, RPM, and feed rate.

Chip thinning takes the stepover (the horizontal depth of cut into the workpiece) into account, and provides the actual chip load.

As the stepover value decreases, the actual chip load decreases. If the stepover is too small, the cutter may not have enough contact with the material to cut — effectively resulting in premature tool wear.

- **Cutting Speed Information** Cutting speed is the speed that a given tooth (flute) on the cutter will be moving when it cuts through the material. All materials have a documented cutting speed.

In imperial units, cutting speed is measured as surface feet per minute (SFM).

In metric units, cutting speed is measured as surface meters per minute (SMM).

- **Material Removal Information** The material removal rate (MRR) indicates how much material is removed by the tool per minute while cutting.
In imperial units, cutting speed is measured as cubic inches per minute.
In metric units, cutting speed is measured as cubic centimeters per minute.

Create Tool Descriptions

If desired, you can create tool descriptions in PathPilot. Detailed tool descriptions allow you to receive feeds and speeds suggestions in conversational programming. For information, see "Use Feeds and Speeds Suggestions" (page 197).

Manually Enter Tool Descriptions

PathPilot uses keywords and patterns in the tool description to recognize tooling features. For information, see "Tool Keywords Reference" (on the next page).

To manually enter tool descriptions:

1. From the PathPilot interface, on the **Offsets** tab, identify the **Tool Table** window.
2. Select a blank line.
3. Type a description for the tool. Descriptions are not case sensitive.
If a pattern or word in the description is recognized, PathPilot uses syntax highlighting to indicate a valid description.

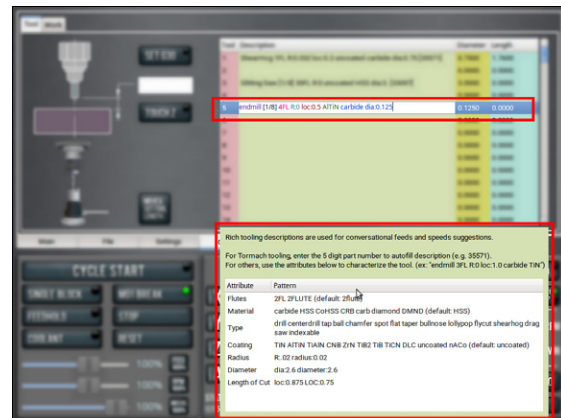


Figure 7-101: A manually-entered tool description.

Examples

To get accurate machining information, all tooling must be described with detail: the more detail, the better the results.



EXAMPLE

Dia.:.3125 4FL R:.03 AlTiN CRB variable loc.:.75

This description provides the following to PathPilot to calculate machining information:

- 0.3125 tool diameter
- Four flutes
- 0.03 radius, or "bullnose"
- Aluminum-titanium nitride coating
- Carbide
- Variable helix
- 0.75 length of cut (loc)

Using a personal description likely won't contain meaningful information for PathPilot.



EXAMPLE

Gold colored end mill from middle drawer

This description provides very little information, and PathPilot defaults to basic cutter features:

- Two flutes
- Uncoated, high-speed steel end mill
- Length of cut based on the diameter

Automatically Generate Tool Descriptions

If you're using a Tormach tool, you can enter the part number to automatically generate tool descriptions in the Tool Table window.

7: PATHPILOT TOOLS AND FEATURES

7.5 Control G-Code Programs



Note: If you don't know the part number, you can search for the tool at tormach.com.

1. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, select a blank line.
2. Type the part number for the tool, like **35571**.
The full description and tool diameter for a ShearHog (PN 35571) displays.

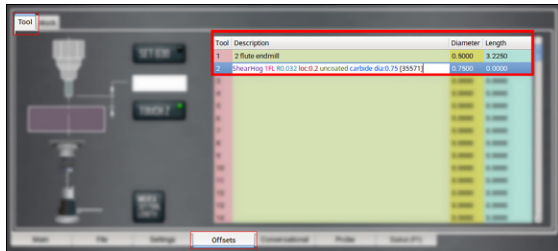


Figure 7-102: An automatically-generated tool description for a Tormach tool.

3. You must enter the value for the **Length**.

Tool Keywords Reference

PathPilot uses keywords and patterns in the tool description to recognize tooling features.

Item	Pattern	Example	Notes
type	drill, centerdrill, tap, ball, chamfer, spot, flat, taper, bullnose, lollipop, flycut, shearhog, drag, saw, indexable	DRILL, BALL, FLY CUT, DRAG	“Drag” indicates that the tool is a drag tool, and has no (0) RPM associated with it.
flutes	A number followed by “FL” or “FLUTE”	4FL, 12FL, 2FLUTE	No flutes is specified the same as two flutes.

Item	Pattern	Example	Notes
length of cut (or flute length)	“loc” followed by a colon, followed by a decimal number	LOC:0.875	If no length of cut is specified, a length is assumed based on cutter diameter.
tool coating	TiN, AlTiN, TiAlN, CNB, ZrN, TiB2, TiB, TiCN, DLC, uncoated, nACo	TiN, ZrN, TiB2	No coating is specified same as “uncoated.”
tool diameter	“diameter” or “dia” followed by a colon, followed by a decimal number	DIAMETER: .0341 , DIA: .750	—
tool material	carbide, HSS, CoHSS, CRB, carb, diamond, DMND	HSS, COHSS, CRB	No tool material is specified the same as HSS (high-speed steel).
tool radius	“R” or “radius” followed by a colon, followed by a decimal number	R: .02, RADIUS:0.02	No radius is specified the same as a zero radius.

7.5.15 Use Cycle Counters (M30 and M99)

On the Main tab, the Tool Path display shows M30 and M99 cycle counters. They're useful to count parts completed during

unattended operation. For each M-code, there's an A and B counter. This provides more flexibility, because you can reset them to 0 independently.

For example, you could use M30 A to count parts each shift, and M30 B to count parts each week. The cycle counters persist across the controller's power cycles.

Monitor Cycle Counters

- In the **MDI Line DRO** field, type `ADMIN CYCLECOUNTER` to show or hide the counters and to reset them to 0.

Change Cycle Counter Values

The cycle counters are implemented as read-only persistent G-code numbered parameters, as detailed in the following table.

If needed, the cycle counter value can be read in G-code.

Cycle Counter	Parameter
M30 A	#5650
M30 B	#5651
M99 A	#5652
M99 B	#5653

To change a counter value explicitly, use a G10 command: `G10`

`L99 P~ Q~`

- `P~` selects the cycle counter to change. Use any of the values detailed in the following table.

Cycle Counter	P~
M30 A	0
M30 B	1
M99 A	2
M99 B	3

- `Q~` specifies the value to set the cycle counter. If `Q~` is omitted, the cycle counter is incremented by 1.
For example, if you program `G10 L99 P2`, the M99 A cycle counter increments by 1.

7: PATHPILOT TOOLS AND FEATURES
7.6 System File Management

7.6 SYSTEM FILE MANAGEMENT

To keep the files on your system backed up and organized, use the following controls:

7.6.1 Manage System Files.....202
7.6.2 Create Backup Files..... 202
7.6.3 Restore Backup Files..... 203
7.6.4 Import and Export the Tool Table..... 204

7.6.1 Manage System Files

Use the File tab to manage system files on the PathPilot controller. For information, see "Transfer Files to and From the Controller" (page 156).

To manage system files:

- From the PathPilot interface, on the File tab, do any of the following from the Controller Files window:
- Select a file, and then select New Folder, Rename, or Delete.
- Select a file, and go to the Options menu. Then, select Copy, Cut, or Paste.

To navigate through the system files:

- Select Back or Home.

7.6.2 Create Backup Files

1. Insert a blank, formatted USB drive into the PathPilot controller.

Note: To prevent errors when backing up and restoring files, only use a blank, formatted USB drive.

2. From the PathPilot interface, on the Main tab, in the MDI Line DRO field, type ADMIN SETTINGS BACKUP. Then select the Enter key. PathPilot generates a backup .zip file, and the Admin Settings Backup dialog box displays.

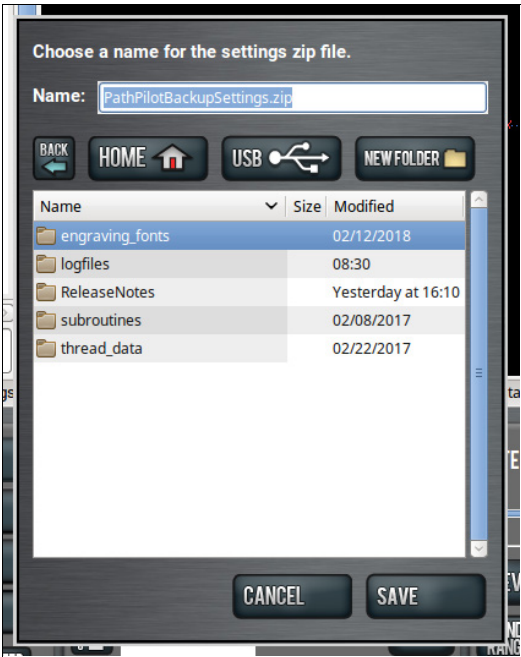


Figure 7-103: Admin Settings Backup dialog box.

3. From the Admin Settings Backup dialog box, specify where (on the PathPilot controller or on a USB drive) to save the backup .zip file.
4. Select Save. The backup .zip file is saved in the location you specified in Step 3.
5. If you saved the backup .zip file on the PathPilot controller, you must manually transfer it — along with other files you want to back up (like G-code programs) — to a USB drive. From the PathPilot interface, on the File tab, in the Controller Files window, select the backup .zip file and any other files you want to back up.

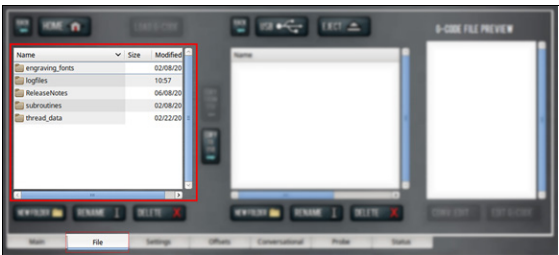


Figure 7-104: Controller Files window on the File tab.

Note: Files must have unique names. If they don't, PathPilot prompts you to overwrite or rename files, or cancel the file transfer.

6. To prevent errors, make sure you don't include the following folders:
 - **logfiles**
 - **media**
 - **ReleaseNotes**
 - **subroutines**
 - **USB**
7. Select **Copy to USB**.
The files are copied and display in the **USB Files** window.
8. Eject the USB drive from the PathPilot controller.
9. From the PathPilot interface, select **Exit**.
10. Verify that all files are properly saved: insert the USB drive on a device other than the PathPilot controller, and review the list of files on the USB drive.
11. (Optional) As an extra precaution, copy all the files onto the device.

About Backup Files

Make a regular backup of all tool offset and fixture information and machine settings stored on your PathPilot controller. Store the file externally to use if you replace your controller or restore it to factory settings.

7.6.3 Restore Backup Files

1. Insert the USB drive with your backup files into the PathPilot controller.
2. From the PathPilot interface, on the **Main** tab, in the **MDI Line DRO** field, type `ADMIN SETTINGS RESTORE`. Then select the **Enter** key.
The **Admin Settings Restore** dialog box displays.

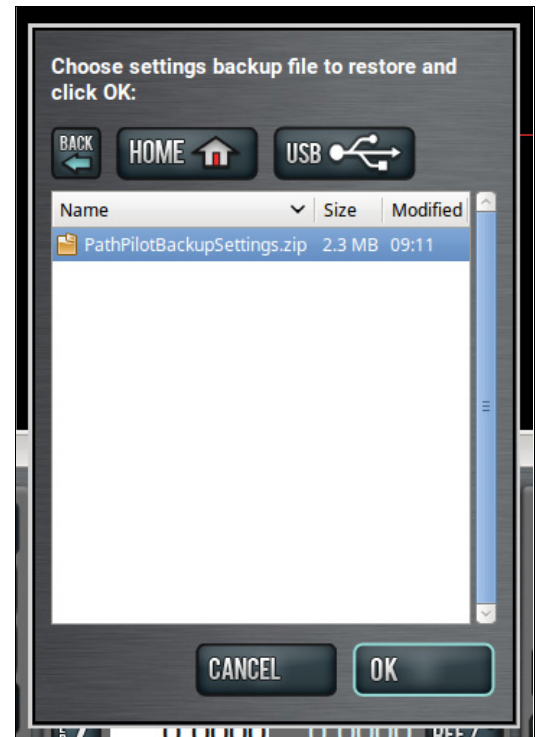


Figure 7-105: Admin Settings Restore dialog box.

3. From the **Admin Settings Restore** dialog box, navigate to the backup .zip file on the USB drive, and then select **OK**. The PathPilot operating system restores the backup, then restarts.
4. If you backed up any other files onto the USB drive, you must manually transfer the files to the PathPilot controller. From the PathPilot interface, on the **File** tab, in the **USB Files** window, select the files you want to transfer.

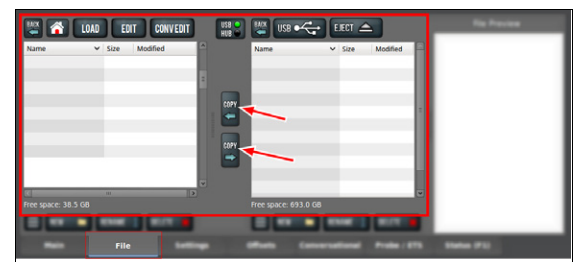


Figure 7-106: USB Files window on the File tab.



Note: To navigate backward, select **Back**. To navigate to the top level, select **USB**.

5. From the **Controller Files** window, select the folder into which you want to copy the files.

7: PATHPILOT TOOLS AND FEATURES

7.6 System File Management

6. Select **Copy From USB**.

The files display in the **Controller Files** window.



Note: Files must have unique names. If they don't, PathPilot prompts you to overwrite or rename files, or cancel the file transfer.

7.6.4 Import and Export the Tool Table

You can manage the tool table using an external .csv file.

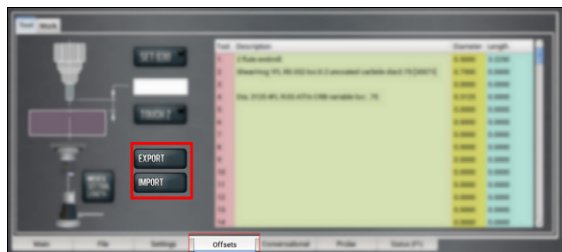


Figure 7-107: Export and Import buttons on the Offsets tab.

Import a .csv File

1. Transfer the .csv file to a USB drive.
2. Insert the USB drive into the PathPilot controller.
3. Confirm that the PathPilot controller is on.
4. From the **Offsets** tab, select **Import**.

The **Import** dialog box displays.

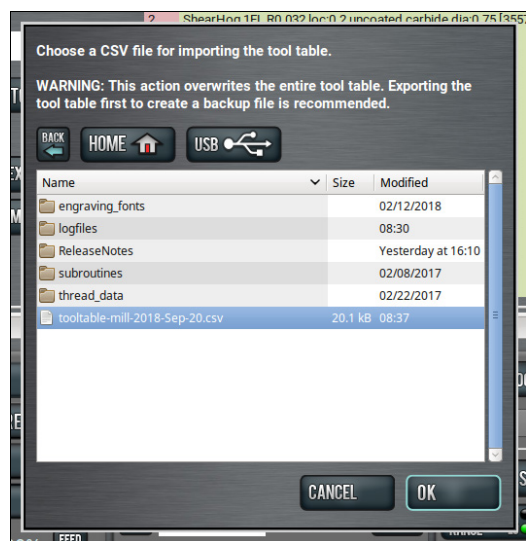


Figure 7-108: Import dialog box.

5. Navigate to the .csv file on the USB drive. Then, select **OK**.

The .csv file updates the tool table.

Export the Tool Table as a .csv File

1. From the **Offsets** tab, select **Export**.

PathPilot generates the .csv file, and the **Export** dialog box displays.

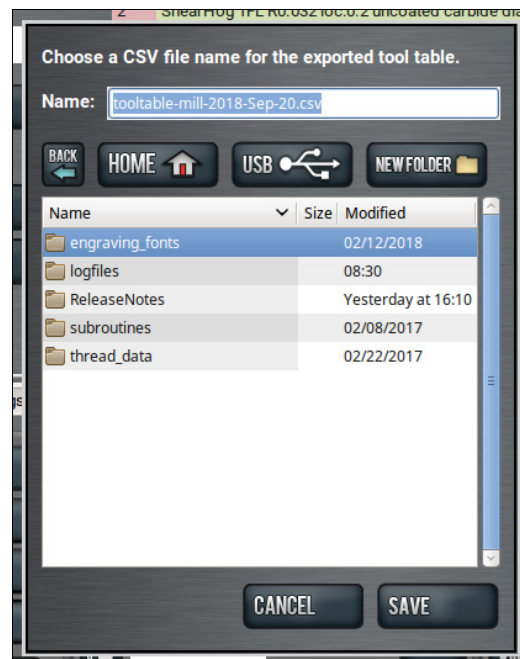


Figure 7-109: Export dialog box.

2. In the **Name** DRO field, type the name for the .csv file.
3. Select **Save**.
The .csv file is saved in the **File** tab.
4. From the **File** tab, select the newly created .csv file, and then select **Copy to USB**.
5. Select **Eject**.
It's safe to remove the USB drive from the controller.

BASIC OPERATIONS

IN THIS SECTION, YOU'LL LEARN:

- About the basic operations required for most projects, organized as a suggested project workflow.

CONTENTS

8.1 Start the Machine.....	206
8.2 Reference the Machine.....	207
8.3 Jog the Machine.....	208
8.4 Manually Control the Spindle.....	210
8.5 Load G-Code.....	211
8.6 Set Up Tooling.....	212
8.7 Set Tool Length Offsets.....	213
8.8 Set Work Offsets.....	217
8.9 Operate the Coolant Pump.....	218

8: BASIC OPERATIONS

8.1 Start the Machine

8.1 START THE MACHINE

Power on the machine and the PathPilot controller.

1. Turn the Main Disconnect switch to **ON** on the side of the electrical cabinet.
2. Twist out the machine's red Emergency Stop button, which enables movement to the machine axes and the spindle.
3. Press the machine's Reset button (next to the Emergency Stop button).

8.2 REFERENCE THE MACHINE



Note: The machine automatically references when it's powered on.

1. Verify that the machine can freely move to its reference position (at the ends of travel).
2. To verify that the tooling is clear of any possible obstructions, reference the Z-axis before referencing the other axes: from the PathPilot interface, select **Ref Z**.



Figure 8-1: Reference buttons.

3. Once the spindle is clear of any possible obstructions, continue referencing all axes.



Note: You can select the buttons one after another. Once the machine references one axis, it'll move on to the next.

After each axis is referenced, its button light comes on. For more information on referencing the machine, see About Referencing.

8.2.1 About Referencing

The axes are referenced during assembly and, aside from the A-axis, do not need re-referencing after powering on or once the Emergency Stop button is released. You must reference the X-, Y-, or Z-axis or the ATC at the following times:

- After replacement of a linear motion component such as linear rails, ballscrew, or servo motor
- Disconnection of an encoder battery and powering off of the machine
- Disconnection of the encoder cable from the servo motor

When referencing the X-, Y-, and Z-axis, the machine moves to the end of travel, presses against the bumper on the ballscrew until torque increases, and then backs off to the index pulse of the encoder.

You must reference the A-axis only if the rotary table is removed from the machine.

When referencing the A-axis, the machine lines up the index marks on the body and face plate, then backs off to the index pulse of the encoder.

To reference the ATC, select the **Align Tool Tray** button on the **ATC** tab. When referencing, an ATC pocket is aligned to the flange of a tool holder in the spindle until both parts of the ATC fork open evenly when engaging the flange of the tool holder.



Figure 8-2: Align Tool Tray button on the ATC tab.

8: BASIC OPERATIONS

8.3 Jog the Machine

8.3 JOG THE MACHINE

To switch between jogging modes:

- From the **Manual Control** area, in the **Jog** group, select **Jog**.
PathPilot toggles between continuous velocity mode and step mode.



Figure 8-3: Jog button.

When the **Cont** green light is on, continuous velocity mode is selected.

When the **Step** green light is on, step mode is selected.

To use continuous velocity mode:

- Set the velocity: drag the **Jog Speed** slider.

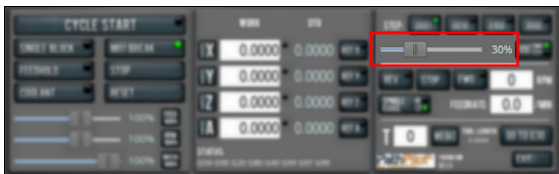


Figure 8-4: Jog Speed slider.

For more information on continuous velocity mode, see "About Continuous Velocity Jogging" (below).

To use step mode, select the step size. Do one of the following, depending on your accessories:

- In the **Manual Control Area**, in the **Jog** group, select the step size.
The **Step** button's light comes on, indicating which step size is active.



Figure 8-5: Step buttons (in G20 mode).

- On the (optional) Jog Shuttle, press the Step button to toggle the currently selected step size.
In the PathPilot interface, the **Step** button's light comes on, indicating which step size is active.

For more information on step mode, see "About Step Jogging" (below).

8.3.1 About Jogging

Jogging is the operation of manually moving an axis in various directions (like to set up and indicate fixtures or workpieces). You can't manually jog the machine while it's performing automatic operations (like running a G-code program or an MDI command).

Jog the machine using the keyboard, Jog Shuttle, or Operator Console pendant. Whichever device you're jogging with, you can either:

- Jog the machine at a consistent velocity (for information, see "About Continuous Velocity Jogging" (below)).
- Jog the machine in steps (for information, see "About Step Jogging" (below)).

For more information, see "Jog Controls Reference" (on the next page).

About Continuous Velocity Jogging

While jogging in continuous velocity mode, the machine moves at a constant speed for as long as:

- A keyboard key is pressed
- The Jog Shuttle outer ring is twisted away from the neutral position
- The Operator Console's pendant wheel is turned in the desired direction

This is useful when you're doing things like:

- Roughly positioning the machine (for example, to move the spindle head away from the workpiece).
- Moving the machine a certain distance at a constant speed (for example, to align a vise).

About Step Jogging

While jogging in step mode, the machine moves one step at a time. The jog step sizes range depending on the programming mode you are using:

- **Imperial (G20) Mode** 0.0001 in. to 0.1000 in.
- **Metric (G21) Mode** 0.01 mm to 10 mm

Step jogging mode is useful to finely move the machine, like when you're indicating a workpiece or manually setting tool lengths.

The jog keys on the keyboard only move the machine in steps when step mode is indicated in PathPilot. The inner wheel on the jog shuttle always moves the machine in steps, regardless of which mode is indicated in PathPilot. The Operator

Console's pendant moves the machine in the step size that's selected with the three-position switch.

8.3.2 Jog Controls Reference

The machine's jogging functions are controlled by the following:

- The Jog group of the Manual Control area in the PathPilot interface
- The keyboard
- The (optional) Jog Shuttle or Operator Console pendant

Axis	Direction	Keyboard Key	Jog Shuttle
X-Axis	Positive	Right Arrow	Clockwise
	Negative	Left Arrow	Counterclockwise
Y-Axis	Positive	Up Arrow	Clockwise
	Negative	Down Arrow	Counterclockwise
Z-Axis	Positive	Page Up	Clockwise
	Negative	Page Down	Counterclockwise
A-Axis	Positive	Period	Clockwise
	Negative	Comma	Counterclockwise

Jogging in PathPilot

From the PathPilot interface, in the Manual Control area, the Jog group has the following functions:

- The Jog button, which toggles between continuous velocity mode and step mode.
- The Jog Speed slider, which controls the machine's jog rate (whether in continuous velocity mode or in step mode).

The jog rate is measured as a percentage of the machine's maximum jog rate.

Jogging with the Keyboard

Pressing the keys results in the following actions:

- **[KEY]** jogs the axis at the current jog rate.
- **[KEY]+Shift** jogs the axis at the maximum jog rate.

Jogging with the Operator Console Pendant

- **Axis Movement** Provides variable-speed jogging based on rotation, similar to the shuttle's outer ring.



Note: Rotating clockwise jogs the axis in the positive direction. Rotating counterclockwise jogs the axis in the negative direction.

- **Axis Selection** A four-position switch selects the active axis.



Note: The currently selected axis displays in PathPilot: in the Position Status group, there's a green light to the left of the Axis DRO field. When it's on, it indicates the active axis.

- **Step Size Selection** A three-position switch selects the jog step size.

8: BASIC OPERATIONS

8.4 Manually Control the Spindle

8.4 MANUALLY CONTROL THE SPINDLE

- 1. Verify that the machine is powered on and out of reset.
- 2. From the PathPilot interface, in the **Manual Control** area, locate the **Spindle** group.



Figure 8-6: Spindle group.

- 3. In the **RPM DRO** field, type the desired RPM speed. Then select the **Enter** key.



Figure 8-7: RPM DRO field.

- 4. Select **FWD** to start the spindle in the forward direction, or **REV** to start the spindle in the reverse direction.
- 5. Select **Stop** to stop the spindle.

8.4.1 About the Spindle

The machine spindle gives power to the cutting tool, which allows it to remove material from the workpiece. The spindle motor drives the spindle through a 5 mm pitch HTD timing belt.

The machine uses a single-contact BT30 spindle taper. The tool holder contacts only the spindle taper, which keeps it in position. Because of this, there's a gap (2 mm) between the tool holder's flange and the end surface of the spindle nose. Operate the spindle either manually or by G-code commands (entered in the MDI Line DRO field or programmed into a G-code program). Manually controlling the spindle is useful when you're setting work offsets for tools that require the spindle to be running (like “wiggler”-style edgefinders or coaxial indicators).

The machine's spindle rotates either clockwise (forward) or counterclockwise (reverse) at a specified spindle speed.

8.5 LOAD G-CODE

To run a G-code program on a PathPilot controller, you must first verify that the file is on the controller. For more information on transferring and moving files, see "Transfer Files to and From the Controller" (page 156).

To load G-code:

1. From the **File** tab, in the **Controller Files** window, select the desired .nc file.
2. Select **Load**.

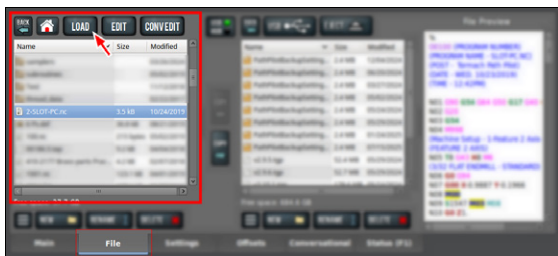


Figure 8-8: Controller Files window on the File tab.



Note: This function is only available for files stored on the PathPilot controller.

PathPilot loads the G-code file and opens the **Main** tab.

8: BASIC OPERATIONS

8.6 Set Up Tooling

8.6 SET UP TOOLING

Before you begin machining, you must put your cutting tools in tool holders and measure the tool length offsets for each tool.

8.6.1 Install a Tool in a Set Screw Tool Holder

1. Clean the shank of the tool holder with a clean rag. Verify that the shank is free of any grease or oil.
2. Remove the set screw from the tool holder with a hex wrench.
3. Put the desired cutting tool into the tool holder.
4. Replace the set screw in the tool holder, and then completely tighten it with a hex wrench.

8.6.2 Install a Tool in an ER Collet Tool Holder

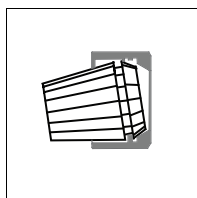
The ER20 collet is self-extracting: the collet must be mounted in the nut before the nut and collet assembly are put into the collet holder.

If you look closely, you'll notice that the collet nut isn't symmetrical — an area of the retaining ring is cut away. When the collet is correctly mounted in the nut, the collet is pushed forward and out of the collet holder taper while the nut is slightly loosened (which results in self-extraction).

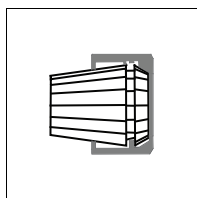
NOTICE! If you don't install the collet in the order specified, there's a risk that the collet and/or nut could be damaged, and the collet's holding capacity could be reduced.

To install a tool in an ER collet tool holder:

1. Hold the collet at an angle, and then insert it into the collet nut as shown in the following image.



2. Tilt up the collet to snap it into place.



3. Loosely thread the nut on the tool holder, insert the tool, and then tighten the collet.

8.6.3 Install a Drill Chuck in a Jacobs Taper Arbor

1. Assemble the drill chuck on to the Jacobs taper arbor:
 - a. Use a clean rag and acetone to clean the taper and socket. Verify that the taper and socket are both free of any grease or oil.
 - b. Retract the jaws: fully open the drill chuck.
 - c. Use a dead-blow hammer (or similar) to seat the drill chuck on the Jacobs taper arbor.
2. Put the drill into the drill chuck.
3. Depending on the type of drill chuck, do one of the following:
 - **Keyless Drill Chuck** Tighten the drill chuck by hand.
 - **Keyed Drill Chuck** Use a chuck key to tighten the drill chuck until it is finger tight.

8.7 SET TOOL LENGTH OFFSETS

Before running a G-code program, PathPilot must know the length of the tools that are required for the program. For more information on using tool length offsets, see "About Tool Offsets" (below).



Note: You can import a .csv file with tool length offset data. For information, see "Import and Export the Tool Table" (page 204).

To set tool length offsets:

1. Verify that the machine is powered on and out of reset.
2. Put a tool into a tool holder, and set it aside to measure. For information, see "Set Up Tooling" (on the previous page).
3. From the PathPilot interface, on the **Offsets** tab, verify that the **Tool** tab is selected.
4. Find the **Tool Table** window.

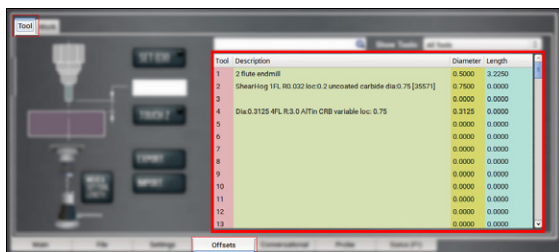


Figure 8-9: Tool Table window on the Offsets tab.

5. Depending on your workflow, you can measure your tools using any of the following methods:
 - **Use a Tool Height Setter** For information, see "Use a Tool Height Setter to Measure Tools" (page 215).
 - **Use an Electronic Tool Setter** For information, see "Use an Electronic Tool Setter (ETS) to Measure Tools" (page 215).
 - **Touch Off of a Known Reference Height** For information, see "Touch Off the Tool Length Offsets" (below).

8.7.1 About Tool Offsets

Tool offsets allow you to use various tools while still programming with respect to the workpiece. Tools can have different lengths (and, while using cutter radius compensation, different diameters).

The most common tool offset is the tool length offset: when you change tools, PathPilot must account for the difference in tool length. In CNC machines, the tool length offset is applied using a G43 command.

The tool length offset is the distance from the cutting edge of the tool to the shoulder of the tool holder.

Before you begin a G-code program, you must verify the lengths of the tools in the program, and make sure that the lengths agree with the tool length offsets set in PathPilot:

- Each time you change tools, you must apply a new tool length offset in PathPilot.
- Each time you replace a tool, you must remeasure its length, and apply a new tool length offset in PathPilot.

NOTICE! You must always verify that the physical length of a tool agrees with the tool length offset value set in PathPilot. If you don't, there's a risk that the tool length offset misrepresents the currently active tool in the spindle, which may result in a machine crash or damaged tooling, workpieces, or fixtures.

8.7.2 Touch Off the Tool Length Offsets

Touch off the tool length offsets by using a reference surface with a known height, which gives you a basis to measure any other tool lengths. Use any surface that is parallel (within 0.02 mm) to the machine table. For example:

- A 1-2-3 Block Set (PN 31950)
- Box parallel

There are two steps to touch off the tool offsets. Complete the following steps in the order listed:

- Set a Known Reference Height 213
- Measure Tools Using a Known Reference Height 214

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

1. Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.
2. Verify that the drive dogs won't contact the reference surface before the end face of the spindle.

8: BASIC OPERATIONS

8.7 Set Tool Length Offsets

3. Set a new, unused work offset (like G55). From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type a work offset. Then select the **Enter** key. For information, see "Set Work Offsets" (page 217).
4. If there's already a tool in the spindle, remove it.
5. From the PathPilot interface, in the **Tool** DRO field, type 0. Then select the **Enter** key.
6. Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.
7. Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
8. While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.



Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 208).

9. From the PathPilot interface, in the **Z-axis** work offset DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

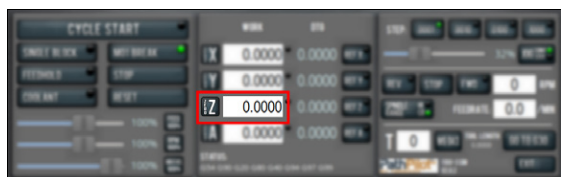


Figure 8-10: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

10. To set the tool length offset, go to Measure Tools Using a Known Reference Height.

Measure Tools Using a Known Reference Height

This procedure sets the tool length offset using a known reference height. If you have not yet done so, you must first set the Z zero position; go to Set a Known Reference Height. To measure tools using a known reference height:

1. Verify that the reference surface is still on the machine table with the piece of paper.

2. From the PathPilot interface, on the **Offsets** tab, find an unused tool number in the **Tool Table** window. Then, type a description for the tool you're measuring.
3. Put the tool holder into the spindle.
4. From the PathPilot interface, in the **Tool** DRO field, type the number of the tool. Then select the **Enter** key.

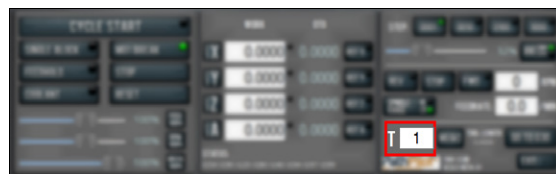


Figure 8-11: Tool DRO field.

5. Slowly jog the Z-axis down (-Z) until it is 0.04 in. (1 mm) from the reference surface.
6. Continue to slowly jog the Z-axis while slowly moving the piece of paper back-and-forth on the reference surface.
7. Stop jogging the Z-axis when you feel a light pull on the piece of paper, which indicates that it is in contact with the tool.
8. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table**, select the tool for which you previously wrote a description.
9. In the **Touch Z** DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

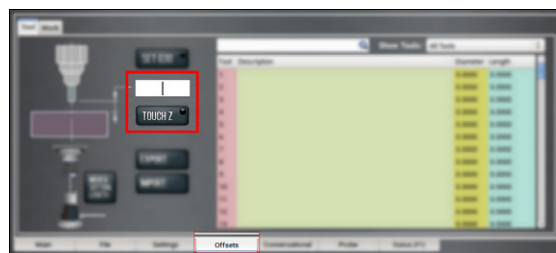


Figure 8-12: Touch Z DRO field and button.

10. Select **Touch Z**.
The length of the tool is stored in the **Tool Table** window.
11. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.
12. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.

13. Jog the Z-axis up (+Z).

You've completed the procedure to measure a tool offset. Repeat this procedure for any remaining tooling you have. Once you're done adding tool length offsets, switch back to your work coordinate system.

8.7.3 Use an Electronic Tool Setter (ETS) to Measure Tools

An ETS is a device used to measure the length of a cutting tool. To use an ETS to measure tools:

1. Put the ETS on the known reference surface below the spindle.
2. From the PathPilot interface, on the **Offsets** tab, in the **Tool Table** window, in the **Description** column, type a description for the tool.
3. In the **Diameter** column, type the diameter of the tool. Then select the **Enter** key.
4. Put a tool holder into the spindle.
5. From the PathPilot interface, type the tool number in the **Tool DRO** field. Then select the **Enter** key.



Figure 8-13: Tool DRO field.

6. Jog the Z-axis down (-Z) until it is above the ETS.
7. From the **Offsets** tab, on the **Tool** tab, select **Move and Set Tool Length**.

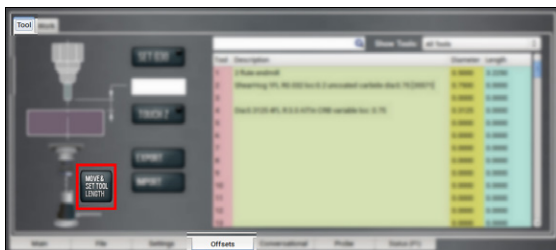


Figure 8-14: Tool tab on the Offsets tab.



Note: Regardless of the initial feed rate, the final touch off feed rate while using an ETS is 2-1/2 in. per minute (IPM).

8. From the **Tool Table** window, in the **Length** column, verify that the length of the tool is correct.

8.7.4 Use a Tool Height Setter to Measure Tools

This procedure sets the tool length offset using a known reference height and a Tool Height Setter (PN 39682).

Complete the following steps in the order listed:

- Set a Known Reference Height 215
- Verify the Calibration of the Tool Height Setter. 216

Set a Known Reference Height

This procedure sets a new Z zero position for the currently selected work offset.

To set a known reference height:

1. Identify a precision surface to use as a reference surface (like a 1-2-3 Block Set), and put it below the spindle on the machine table. Verify that there's a clear path from the spindle to the machine table.
2. Set a new, unused work offset (like G55). From the PathPilot interface, on the **Main** tab, in the **MDI Line** DRO field, type a work offset. Then select the **Enter** key. For information, see "Set Work Offsets" (page 217).
3. If there's already a tool in the spindle, remove it.
4. From the PathPilot interface, in the **Tool DRO** field, type 0. Then select the **Enter** key.
5. Slowly jog the Z-axis down (-Z) until it's 0.04 in. (1 mm) from the reference surface.
6. Measure the thickness of a piece of paper, and put the paper on the reference surface. Note the thickness of the paper for later.
7. While moving the paper back-and-forth across the reference surface, slowly step the Z-axis down (-Z) until you feel a light pull on the piece of paper. This indicates that the paper is contacting the end face of the spindle.



Note: It's easier to use step jogging for this task. For information on step jogging, see "About Step Jogging" (page 208).

8: BASIC OPERATIONS

8.7 Set Tool Length Offsets

8. From the PathPilot interface, in the **Z-axis** work offset DRO field, type the thickness of the piece of paper. Then select the **Enter** key.

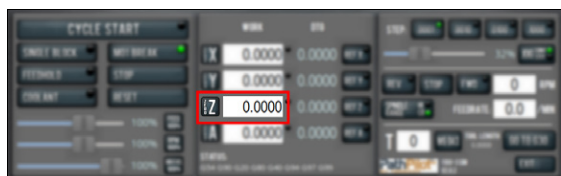


Figure 8-15: Z-axis work offset DRO field.

The reference surface is now set as the Z zero position in the current coordinate system.

Verify the Calibration of the Tool Height Setter

The higher side of the Tool Height Setter is precision ground.

You can use it as a reference surface to calibrate the tool.



Figure 8-16: Tool Height Setter.

1. Use the provided dowel pin to compress the setting face of the Tool Height Setter to the level of the ground reference surface.
2. Adjust the indicator dial's bezel to read zero. Make note of how many times the indicator rotates around the dial.
3. Measure the height of the ground reference surface from the bottom surface of the Tool Height Setter with a calipers. Note the measured height for later.
4. Carefully, without moving the bezel, put the Tool Height Setter on the reference surface that's on the machine table.
5. Measure the tools using a known reference height.

8.8 SET WORK OFFSETS

To set the current axis location to zero in the active work coordinate system:

- Select **Zero [Axis]**.

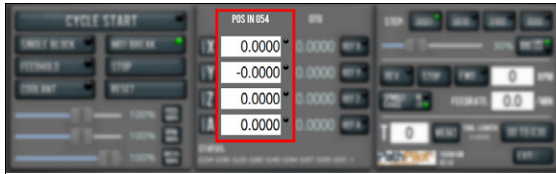


Figure 8-17: Work Offset DRO fields.

To change work offsets:

1. On the **Main** tab, in the **MDI Line** DRO field, type the new work offset to activate (for example, G55). Then select the **Enter** key.
2. The new work offset displays in the following locations in the PathPilot interface:
 - The **Status** read-only DRO field.
 - Above the **Work Offset** DRO fields.



Figure 8-18: Work offset indicated in the PathPilot interface.



Note: The values in the **Work Offset** DRO fields update to indicate the new location of each axis in the new work offset.

For more information on using work offsets, see "About Work Offsets" (below).

8.8.1 About Work Offsets

Work offsets allow you to think in terms of X, Y, and Z coordinates with respect to the part, rather than thinking of them with respect to the machine position. This means that you can jog the machine to an arbitrary location (like the end of a workpiece) and call that location zero.

You can save up to 500 work offsets in PathPilot. The naming structure varies based on the offset number, as detailed in the following table.

Work Offset Naming		
Offsets 1-9 (Use either name)		
Offset	Extended Name	Name
1	G54.1 P1	G54
2	G54.1 P2	G55
3	G54.1 P3	G56
4	G54.1 P4	G57
5	G54.1 P5	G58
6	G54.1 P6	G59
7	G54.1 P7	G59.1
8	G54.1 P8	G59.2
9	G54.1 P9	G59.3
Offsets 10-500 (Use extended name)		
Offset	Extended Name	Name
10	G54.1 P10	Not used
11	G54.1 P11	Not used
...		
499	G54.1 P499	Not used
500	G54.1 P500	Not used

8: BASIC OPERATIONS

8.9 Operate the Coolant Pump

8.9 OPERATE THE COOLANT PUMP

To turn coolant on or off:

- Select **Coolant**.

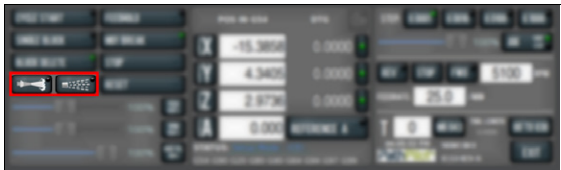


Figure 8-19: Coolant button.

For more information on turning on and off coolant, see "About Coolant" (below).

8.9.1 About Coolant

In the PathPilot interface, the Coolant button controls the machine's coolant pump power outlet. The Coolant button's light shows the current state of the outlet: the light is on when the outlet has power; the light is off when the outlet does not have power.

Note: The Coolant button is equivalent to using an M08 (coolant on) or M09 (coolant off) command in the G-code program.

Use the Coolant button before or after a program is running, while a program is running, or while you are using manual data input (MDI) commands.

PROGRAMMING

IN THIS SECTION, YOU'LL LEARN:

- About the languages that are understood and interpreted by PathPilot.

CONTENTS

9.1 Programming Overview	220
9.2 Programming G-Code	226
9.3 Programming Canned Cycles	238
9.4 Programming M-Code	243
9.5 Programming Input Codes	247
9.6 Advanced Programming	248

9: PROGRAMMING
9.1 Programming Overview

9.1 PROGRAMMING OVERVIEW

Read the following sections for a G-code overview:

9.1.1 Before You Begin 220
9.1.2 About G-Code Programming Language 220
9.1.3 G-Code Formatting Reference 220
9.1.4 Supported G-Codes Reference 224

9.1.1 Before You Begin

- Referring to This Section Use this section only for reference. To learn about the principles of the control language (so that you can write programs by hand from first principles, for example), we recommend that you consult an introductory textbook on G-code programming.
- Creating and Editing G-Code Files We recommend using a text editor like Gedit or Notepad++. Don't use a word processor to create or edit G-code files — it'll leave unseen codes that could cause problems or prevent a G-code file from working.

9.1.2 About G-Code Programming Language

A G-code program is made up of one or more lines of code. Each line of code is called a block, and can include commands to the machine. Blocks are collected into a file, which makes a program. A block is normally made up of an optional line number at the beginning, followed by one or more words, which groups the elements together into a single statement. A word is a letter followed by a number (or, something that evaluates to a number). A word can either give a command or provide an argument to a command. A program is one or more blocks, each separated by a line break. Blocks in a program are executed either:

- Sequentially (from the top of the program to the bottom)
- Until an end command (M02 or M30) is encountered

EXAMPLE :

G01 X3 is a valid line of code with two words:

- G01 is a command: the machine should move in a straight line at the programmed feed rate.
- X3 provides an argument value: the value of X should be 3 at the end of the move.

Most commands start with either G (general) or M (miscellaneous) — G-codes and M-codes. There are two commands (M02 and M30) that end a program. A program can end before the end of a file. If there are lines in a file after the end of a program, they're not meant to be executed in the normal flow (they're generally parts of subroutines).

9.1.3 G-Code Formatting Reference

A permissible block of input code is made up of the following programming elements, in order, with the restriction that there is a maximum of 256 characters allowed on a line:

- (Optional) Block delete character (/)
- (Optional) Line number
- Any number of words, parameter settings, and comments
- End of line marker (carriage return or line break)

Spaces and tabs are allowed anywhere on a line of code and do not change the meaning of the line, except inside comments. Blank lines are allowed in the input, but they're ignored. Input is not case sensitive (except in comments), so any letter outside a comment may be in uppercase or lowercase without changing the meaning of a line.

EXAMPLE

G00 x +0. 12 34y 7 is equal to G00 x+0.1234 y7

- A line may have:
- Any number of G words, but two G words from the same modal group may not appear on the same line.
 - Zero to four M words, but two M words from the same modal group may not appear on the same line.
 - For all other legal letters, a line may have only one word beginning with that letter.

Any input not explicitly allowed is illegal, and causes the interpreter to either signal an error or ignore the line. PathPilot omits blocks of code that are prefixed with a block delete character (/). PathPilot sometimes ignores things it doesn't understand. If a command doesn't work as expected, or does nothing, make sure that it's correctly typed. PathPilot doesn't check for excessively high machining feeds or speeds, and it doesn't detect situations where a legal command will do something unfortunate (like machining a fixture).

Line Numbers

A line number is indicated by the following, in the order listed:

1. The letter N
2. An integer (with no sign) between 0 and 99,999,999 (which must be written without commas)

Line numbers may be repeated, or used out of order, but that's rare in normal practice. A line number isn't required, and is often omitted.

Words

A word is indicated by the following, in the order listed:

1. A letter other than N or O
2. A real value

Letters

Words may begin with any of the following letters, except N or O:



Note: Several letters (I, J, K, L, P and R) may have different meanings in different contexts.

Letter	Description
A	A-axis
B	B-axis
C	C-axis
D	Tool radius compensation number
F	Feed rate
G	General function
H	Tool length offset index
I	X-axis offset for arcs
J	Y-axis offset for arcs
K	Z-axis offset for arcs
L	Number of repetitions in canned cycles and subroutines, or key used with G10
M	Miscellaneous function
N	Line number
O	Subroutine label number

Letter	Description
P	Dwell time in canned cycles, dwell time with G04, key used with G10, or tapping depth in M871 through M874
Q	Feed increment in a G83 canned cycle, or repetitions of subroutine call
R	Arc radius, or canned cycle retract level
S	Spindle speed
T	Tool selection
U	Synonymous with A
V	Synonymous with B
W	Synonymous with C
X	X-axis
Y	Y-axis
Z	Z-axis

Values

A real value is one of the following:

- An explicit number (like 341, or -0.8807)
- An expression (like [2+2.4])
- A parameter value (like #88)
- A unary operation value (like acos[0])



Note: In the command examples that we use, the tilde symbol (~) stands for a real value. If $L\sim$ is written in an example, the $\sim$ is often referred to as the L number. Similarly the $\sim$ in $H\sim$ may be called the H number, and so on for any other letter.

A number is a subset of a real value. Processing a real value to come up with a number is called evaluating. An explicit number evaluates to itself.

Explicit numbers have the following rules (in this case, a digit is a single character, 0 through 9):

- A number must consist of the following, in the order listed:
 1. An optional plus or minus sign
 2. Zero to many digits

9: PROGRAMMING

9.1 Programming Overview

3. (Optional) One decimal point
 4. Zero to many digits
- There must be at least one digit somewhere in the number.
 - It must be either an integer (no decimal point) or a decimals (decimal point).
 - It may have any number of digits (subject to line length limitations).



Note: PathPilot only keeps 17 significant figures, which is enough for all known applications.

- A non-zero number with no sign as the first character is assumed to be positive.

Initial zeros (a zero before the decimal point and the first non-zero digit) and trailing zeros (a zero after the decimal point and the last non-zero digit) are allowed, but not required. A number written with initial or trailing zeros has the same value when it is read as if the extra zeros were not there. Numbers used for specific purposes by PathPilot are often restricted to some finite set of values, or to some range of values. In many uses, decimal numbers must be close enough to an integer to be accepted as a valid input. A decimal number which is supposed to be close to an integer is considered close enough if it is within 0.0001 of an integer.

Order of Execution

If a parameter setting of the same parameter is repeated on a line (like #3=15 #3=6), only the last setting takes effect. It's illogical, but not illegal, to set the same parameter twice on the same line.

The order of items on a line doesn't determine the order of execution on the commands.

Three types of items' order may vary on a line (as given earlier in this section):

- **Word** May be reordered in any way without changing the meaning of the line.
- **Parameter Setting** If it's reordered, there is no change in the meaning of the line unless the same parameter is set more than once. In this case, only the last setting of the parameter takes effect.



EXAMPLE

When the line #3=15 #3=6 is interpreted, the value of parameter 3 is 6. If the order is reversed to #3=6 #3=15 and the line is interpreted, the value of parameter 3 is 15.

- **Comment** If it contains more than one comment and is reordered, only the last comment is used. If each group is kept in order or reordered without changing the meaning of the line, then the three groups may be interleaved in any way without changing the meaning of the line.



EXAMPLE

G40 G01 #3=15 (f00) #4=-7.0 has five items and means exactly the same thing in any of the 120 possible orders, like #4=-7.0 G01 #3=15 G40 (f00), for the five items.

The order of execution of items on a line is critical to safe and effective machine operation. If items occur on the same line, they are executed in a particular order. To impose a different order (like to turn coolant off before the spindle is stopped), code the commands on separate blocks.

The order of execution is as follows:

1. Comment (including message)
2. Set feed rate mode (G93, G94, G95)
3. Set feed rate (F)
4. Set spindle speed (S)
5. Special I/O (M62 to M68)



Note: This is not supported.

6. Change tool (T)
7. Spindle on/off (M03, M04, M05)
8. Save State (M70, M73, restore state (M72), invalidate state (M71)
9. Coolant on/off (M07, M08, M09)
10. Enable/disable overrides (M48, M49, M50, M51, M52, M53)
11. Operator defined commands (M101 to M199)
12. Dwell (G04)

13. Set active plane (G17, G18, G19)
14. Set length units (G20, G21)
15. Cutter radius compensation on/off (G40, G41, G42)
16. Tool table offset on/off (G43, G49)
17. Fixture table select (G54 through G58 and G59 P~)
18. Set path control mode (G61, G61.1, G64)
19. Set distance mode (G90, G91)
20. Set canned cycle return level mode (G98, G99)
21. Home, change coordinate system data (G10) or set offsets (G92, G94)
22. Perform motion (G00 to G03, G12, G13, G80 to G89 as modified by G53)
23. Stop (M00, M01, M02, M30, M60)

Modal Groups

G- and M-codes are, generally speaking, modal — they cause the machining system to change from one mode to another. The mode stays active until another command changes it implicitly or explicitly.



EXAMPLE

If coolant is turned on (M07 or M08), it stays on until it is explicitly turned off in the program (M09).

A few G-codes and M-codes are non-modal (like Dwell (G04)). These codes have effect only on the lines on which they occur. Modal commands are arranged in sets, called modal groups. Only one member of a modal group may be in force at any given time. In general, a modal group contains commands for which it is logically impossible for two members to be in effect at the same time (like inch units (G20) vs. millimeter units (G21)).

A machining system may be in many modes at the same time, with one mode from each modal group being in effect. For all G-code modal groups, when a machining system is ready to accept commands, one member of the modal group must be in effect. There are default settings for these modal groups. When the machining system is turned on or re-initialized, default values are automatically in effect. Modal groups for G-codes are detailed in the following table.

Group	Commands	Group Description
Group 1	{G00, G01, G02, G03, G33, G37/G37.1, G38.x, G73, G76, G80, G81, G82, G84, G85, G86, G88, G89}	Motion (one always in effect)
Group 2	{G17, G18, G19, G17.1, G17.2, G17.3}	Plane selection
Group 3	{G90, G91}	Distance mode
Group 4	{G90.1, G91.1}	Arc distance mode
Group 5	{G93, G94}	Feed rate mode
Group 6	{G20, G21}	Length units
Group 7	{G40, G41, G42, G41.1, G42.1}	Cutter compensation
Group 8	{G43, G43.1, G49}	Tool length offset
Group 10	{G98, G99}	Return mode in canned cycles
Group 12	{G54, G55, G56, G57, G58, G59, G59.1, G59.2, G59.3}	Select work offset coordinate system
Group 13	{G61, G61.1, G64}	Path control mode
Group 14	{G96, G97}	Spindle control mode

9: PROGRAMMING

9.1 Programming Overview

Group	Commands	Group Description
Group 15	{G07, G08}	Lathe diameter mode

Modal groups for M-codes are detailed in the following table.

Group	Commands	Group Description
Group 4	{M00, M01, M02, M30, M60}	Program stop and program end
Group 7	{M03, M04, M05}	Spindle control
Group 8	{M07, M08, M09}	Coolant control (special case: M07 and M08 may be active at the same time)
Group 9	{M48, M49}	Override control

Non-modal G-codes are:

- **Group 0** {G04, G10, G28, G30, G53, G92, G92.1, G92.2, G92.3}

Comments

You can add comments to lines of G-code to help clarify the intention of the programmer. To embed a comment in a line, use parentheses. To add a comment to the end of a line, use a semicolon.



Note: The semicolon is not treated as the start of a comment when it's enclosed in parentheses.

Comments can appear between words, but they can't be between words and their corresponding parameter.



EXAMPLE :

S100 (set speed) F200 (feed) is okay, but S (speed) 100F (feed) is not.

9.1.4 Supported G-Codes Reference

G-Code	Description
G00	Rapid linear motion
G01	Linear motion at feed rate

G-Code	Description
G02	Clockwise arc at feed rate
G03	Counterclockwise arc at feed rate
G04	Dwell
G10 L1	Set tool table
G10 L2	Set coordinate system
G10 L10	Set tool table – calculated – workpiece
G10 L11	Set tool table – calculated – fixture
G10 L20	Set coordinate system
G17, G18, G19	Plane selection
G20/G21	Length units
G28	Return to predefined position
G28.1	Return to predefined position
G30	Return to predefined position
G33	Spindle synchronized motion (like threading)
G33.1	Rigid tapping
G37/G37.1	Automatically measure tool lengths with an ETS
G38.x	Straight probe
G40	Cancel cutter compensation
G41/G42	Cutter compensation (left/right)
G41.1, G42.1	Dynamic cutter compensation
G43	Apply tool length offset
G47	Engrave sequential serial number
G49	Cancel tool length compensation
G53	Absolute coordinates
G54-G59.3	Select work offset coordinate system
G61/G61.1	Set exact path control mode
G64	Set blended path control mode

G-Code	Description
<u>G73</u>	High-speed peck drill
G76	Multi-pass threading cycle
<u>G80</u>	Cancel canned cycles
<u>G81</u>	Drilling cycle
<u>G82</u>	Simple drilling cycle
<u>G83</u>	Peck drilling cycle
<u>G84</u>	Tapping cycle
<u>G85</u>	Boring cycle
<u>G86</u>	Boring cycle
<u>G88</u>	Boring cycle
<u>G89</u>	Boring cycle
<u>G90,</u> <u>G90.1</u>	Arc distance mode
G91, G91.1	Incremental distance mode
G92	Offset coordinates and set parameters
G92.x	Cancel G92, etc.
<u>G93, G94,</u> <u>G95</u>	Feed rate mode
<u>G96, G97</u>	Spindle control mode
G98	Initial level return / R-point level after canned cycles

9: PROGRAMMING

9.2 Programming G-Code

9.2 PROGRAMMING G-CODE

Read the following sections as a G-code reference:

9.2.1 About the Examples Used	226
9.2.2 Rapid Linear Motion (G00).....	226
9.2.3 Linear Motion at Feed Rate (G01).....	226
9.2.4 Arc at Feed Rate (G02 and G03).....	227
9.2.5 Dwell (G04).....	229
9.2.6 Set Offsets (G10).....	229
9.2.7 Plane Selection (G17, G18, G19).....	230
9.2.8 Length Units (G20 and G21).....	230
9.2.9 Return to Predefined Position (G28 and G28.1)....	230
9.2.10 Return to Predefined Position (G30 and G30.1)....	231
9.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1).....	231
9.2.12 Straight Probe (G38.x).....	232
9.2.13 Cutter Compensation (G40, G41, G42).....	233
9.2.14 Dynamic Cutter Compensation (G41.1 and G42.1).....	233
9.2.15 Apply Tool Length Offset (G43).....	234
9.2.16 Engrave Sequential Serial Number (G47).....	234
9.2.17 Cancel Tool Length Compensation (G49).....	234
9.2.18 Absolute Coordinates (G53).....	234
9.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500).....	235
9.2.20 Set Exact Path Control Mode (G61).....	235
9.2.21 Set Blended Path Control Mode (G64).....	235
9.2.22 Distance Mode (G90 and G91).....	235
9.2.23 Arc Distance Mode (G90.1 and G91.1).....	235
9.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3).....	235
9.2.25 Feed Rate Mode (G93, G94, and G95).....	236
9.2.26 Spindle Control Mode (G96 and G97).....	236

9.2.1 About the Examples Used

Many commands require axis words ($X\sim$, $Y\sim$, $Z\sim$, or $A\sim$) as an argument. Unless explicitly stated otherwise, you can make the following assumptions:

- Axis words specify a destination point
- Axis words relate to the currently active coordinate system, unless explicitly described as being in the absolute coordinate system
- Where axis words are optional, any omitted axes retain their current value

Any items in the command examples not explicitly described as optional are required.

9.2.2 Rapid Linear Motion (G00)

For rapid linear motion, program: $G00\ X\sim\ Y\sim\ Z\sim\ A\sim$

- $X\sim$ is the X-axis coordinate
- $Y\sim$ is the Y-axis coordinate
- $Z\sim$ is the Z-axis coordinate
- $A\sim$ is the A-axis coordinate

This produces coordinated linear motion to the destination point at the current traverse rate (or slower, if the machine won't go that fast). It's expected that cutting won't take place when a $G00$ command is executing. The $G00$ is optional if the current motion mode is $G00$.

Depending on where the tool is located, follow these two basic rules:

1. If the Z value represents a cutting move in the positive direction (like out of a hole), the X-axis should be moved last.
2. If the Z value represents a move in the negative direction, the X-axis should be moved first.

Conditions

The motion differs if:

- Cutter radius compensation is active
- G53 is programmed on the same line

Troubleshooting

It's an error if:

- All axis words are omitted
The axis words are optional, except that at least one must be used.
- $G10$, $G28$, $G30$ or $G92$ appear in the same block

9.2.3 Linear Motion at Feed Rate (G01)

For linear motion at feed rate (for cutting or not), program:

$G01\ X\sim\ Y\sim\ Z\sim\ A\sim\ F\sim$

- $X\sim$ is the X-axis coordinate
- $Y\sim$ is the Y-axis coordinate
- $Z\sim$ is the Z-axis coordinate
- $A\sim$ is the A-axis coordinate
- $F\sim$ is the feed rate

This produces coordinated linear motion to the destination point at the current feed rate (or slower, if the machine won't go that fast). The $G01$ is optional if the current motion mode is $G01$.

Conditions

The motion differs if:

- Cutter radius compensation is active
- G53 is programmed on the same line

Troubleshooting

It's an error if:

- All axis words are omitted
The axis words are optional, except that at least one must be used.
- G10, G28, G30, or G92 appear in the same block
- No F word is specified

9.2.4 Arc at Feed Rate (G02 and G03)

A circular or helical arc is specified using either G02 (clockwise arc) or G03 (counterclockwise arc). The axis of the circle or helix must be parallel to the X-, Y- or Z-axis of the machine coordinate system. The axis (or equivalently, the plane perpendicular to the axis) is selected with G17 (Z-axis, XY-plane), G18 (Y-axis, XZ-plane) or G19 (X-axis, YZ-plane). If the arc is circular, it lies in a plane parallel to the selected plane. If a line of code makes an arc and includes rotational axis motion, the rotational axes turn at a constant rate so that the rotational motion starts and finishes when the XYZ motion starts and finishes. This is rare.

The motion differs if cutter radius compensation is active.

Two formats are allowed for specifying an arc: the center format and the radius format. In both formats, the G02 or G03 is optional if it's the current motion mode.

Radius Format Arc

For a clockwise arc in radius format, program: G02 X~ Y~ Z~ A~ R~

For a counterclockwise arc in radius format, program: G03 X~ Y~ Z~ A~ R~

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate
- A~ is the A-axis coordinate
- R~ is the radius of the arc

In radius format, the coordinates of the end point of the arc in the selected plane are specified along with the radius of the arc. A positive radius indicates that the arc turns through 180 degrees or less, while a negative radius indicates a turn of 180 degrees to 359.999 degrees.

If the arc is helical, the value of the end point of the arc on the coordinate axis parallel to the axis of the helix is also specified. We don't recommend programming radius format arcs that are:

- Nearly full circles
- Semicircles
- Nearly semicircles

A small change in the location of the end point produces a much larger change in the location of the center of the circle (and the middle of the arc). The magnification effect is large enough that rounding error in a number can produce out-of-tolerance cuts.

You can program arcs that are:

- Up to 165 degrees
- Between 195 degrees to 345 degrees



EXAMPLE

G17 G02 X 1.0 Y 1.5 R 2.0 Z 0.5 is a radius format command to mill an arc, which makes a clockwise (as viewed from the positive Z-axis) circular or helical arc whose axis is parallel to the Z-axis, ending where X = 1.0, Y = 1.5, and Z = 0.5, with a radius of 2.0. If the starting value of Z is 0.5, this is an arc of a circle parallel to the XY-plane; otherwise, it's a helical arc.

Troubleshooting

It's an error if:

- Both of the axis words for the axes of the selected plane are omitted
The axis words are all optional except that at least one of the two words for the axes in the selected plane must be used.
- No R word is given
- The end point of the arc is the same as the current point
- G10, G28, G30, or G92 appear in the same block

Center Format Arc

For a clockwise arc in center format, program: G02 X~ Y~ Z~ I~ J~

For a counterclockwise arc in center format, program: G03 X~ Y~ Z~ I~ J~

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate

9: PROGRAMMING

9.2 Programming G-Code

- **A~** is the A-axis coordinate
- **I~** is the center of arc (X coordinate)
- **J~** is the center of arc (Y coordinate)
- **K~** is the center of arc (Z coordinate)

In the center format, the coordinates of the end point of the arc in the selected plane are specified along with the offsets of the center of the arc from the current location. In this format, it's okay if the end point of the arc is the same as the current point.

The center is specified using the I, J, K words associated with the active plane. These specify the center relative to the current point at the start of the arc, defined in incremental coordinates from the start point.

It's an error if:

- When the arc is projected on the selected plane, the distance from the current point to the center differs from the distance from the end point to the center by more than 0.0002 inches (if you're programming in inches) or 0.002 millimeters (if you're programming in millimeters)
- **G10**, **G28**, **G30**, or **G92** appear in the same block

Arc in XY Plane

When the XY-plane is selected, program: **G02 X~ Y~ Z~ A~ I~ J~** (or, use **G03** instead of **G02**)

I and J are the offsets from the current location or coordinates – depending on arc distance mode (**G90.1/G91.1**) of the center of the circle (X and Y directions, respectively).

It's an error if:

- X and Y are both omitted
The axis words are all optional except that at least one of X and Y must be used.
- I and J are both omitted
I and J are optional except that at least one of the two must be used.

Arc in XZ Plane

When the XZ-plane is selected, program: **G02 X~ Y~ Z~ A~ I~ K~** (or, use **G03** instead of **G02**)

I and K are the offsets from the current location or coordinates – depending on arc distance mode (**G90.1/G91.1**) of the center of the circle (X and Z directions, respectively).

It's an error if:

- X and Z are both omitted
The axis words are all optional except that at least one of X and Z must be used.
- I and K are both omitted
I and K are optional except that at least one of the two must be used.

Arc in YZ Plane

When the YZ-plane is selected, program: **G02 X~ Y~ Z~ A~ J~ K~** (or, use **G03** instead of **G02**)

J and K are the offsets from the current location or coordinates – depending on depending on arc distance mode (**G90.1/G91.1**) of the center of the circle (Y and Z directions, respectively).

It's an error if:

- Y and Z are both omitted
The axis words are all optional except that at least one of Y and Z must be used.
- J and K are both omitted
J and K are optional except that at least one of the two must be used.



EXAMPLE

G17 G02 X1.0 Y1.6 I0.3 J0.4 Z0.9 is a center format command to mill an arc in incremental arc distance mode (**G91.1**) that makes a clockwise (as viewed from the positive Z-axis), circular, or helical arc whose axis is parallel to the Z-axis, ending where X = 1.0, Y = 1.6, and Z = 0.9, with its center offset in the X direction by 0.3 units from the current X location and offset in the Y direction by 0.4 units from the current Y location. If the current location has X = 0.7, Y = 0.7 at the outset, the center is at X = 1.0, Y = 1.1. If the starting value of Z is 0.9, this is a circular arc; otherwise, it's a helical arc. The radius of this arc would be 0.5.

In the center format, the radius of the arc is not specified, but it may be found easily as the distance from the center of the circle to either the current point or the end point of the arc.

```
(Sample Program G02EX3:)  
(Workpiece Size: X4, Y3, Z1)  
(Tool: Tool #2, 1/4" Slot Drill)  
(Tool Start Position: X0, Y0, Z1)  
N2 G90 G80 G40 G54 G20 G17 G94 G64 (SAFETY BLOCK)  
N5 G90 G20
```



```
N10 M06 T2 G43 H2
N15 M03 S1200
N20 G00 X1 Y1
N25 Z0.1
N30 G01 Z-0.1 F5
N35 G02 X2 Y2 I1 J0 F20 (ARC FEED CW, RADIUS I1,J0
AT 20 IPM)
N40 G01 X3.5
N45 G02 X3 Y0.5 R2 (ARC FEED CW, RADIUS 2)
N50 X1 Y1 R2 (ARC FEED CW, RADIUS 2)
N55 G00 Z0.1
N60 X2 Y1.5
N65 G01 Z-0.25
N70 G02 X2 Y1.5 I0.25 J-0.25 (FULL CIRCLE ARC FEED
MOVE CW)
N75 G00 Z1
N80 X0 Y0
N85 M05
N90 M30
```

9.2.5 Dwell (G04)

For a dwell, program: G04 P~

- P~ is the dwell time (measured in seconds)

Dwell keeps the axes unmoving for the period of time in seconds specified by the P number.



EXAMPLE

G04 P4.2 (to wait 4.2 seconds)

Troubleshooting

It's an error if:

- The P number is negative

9.2.6 Set Offsets (G10)

Use the controls on the Offsets tab to set offsets. You can program offsets with the G10 G-code command.

Read the following sections for reference:

Set Tool Table (G10 L1).....	229
Set Coordinate System (G10 L2).....	229
Set Tool Table (G10 L10).....	229
Set Tool Table (G10 L11).....	230
Set Coordinate System (G10 L20).....	230

Set Tool Table (G10 L1)

To define an entry in the tool table, program: G10 L1 P~ R~

- P~ is the tool number
- R~ is the radius of tool

G10 L1 sets the tool table for the P tool number to the values of the words. A valid G10 L1 rewrites and reloads the tool table.

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The P number is unspecified
- The P number is not a valid tool number from the tool table
- The P number is 0

Set Coordinate System (G10 L2)

To define the origin of a work offset coordinate system,

program: G10 L2 P~ <axes R~>

- P~ is the number of coordinate system to use (G54 = 1, G59.3 = 9)
- R~ is the rotation about the rotation about the Z-axis

The G10 L2 P~ command doesn't change from the current coordinate system to the one specified by P. Use G54 through G59.3 to select a coordinate system.

The coordinate system whose origin is set by a G10 command may be active or inactive at the time the G10 is executed. If it's currently active, the new coordinates take effect immediately. For example, if a G92 origin offset was in effect before G10 L2, it continues to be in effect after.

Optionally program R to indicate the rotation of the XY axis around the Z-axis. The direction of rotation is counterclockwise (viewed from the positive end of the Z-axis). When a rotation is in effect, jogging an axis only moves that axis in a positive or a negative direction — not along the rotated axis. To cancel a rotation for the active coordinate, program G10 L2 P0 R0.

Troubleshooting

It's an error if:

- The P number does not evaluate to an integer in the range 0-500
- An axis other than X or Z is programmed

Set Tool Table (G10 L10)

To change the tool table entry for tool P so that if the tool offset is reloaded with the machine in its current position and with the current G5x and G92 offsets active, program: G10 L10 P~ R~

9: PROGRAMMING

9.2 Programming G-Code

- $P\sim$ is the tool number
- $R\sim$ is the radius of tool

The current coordinates for the given axes become the given values. The axes that are not specified in the `G10 L10` command are not changed. This could be useful with a probe move (`G38`).

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The P number is unspecified
- The P number is not a valid tool number from the tool table
- The P number is 0

Set Tool Table (G10 L11)

`G10 L11` is just like `G10 L10`, except that instead of setting the entry according to the current offsets, it's set so that the current coordinates would become the given value if the new tool offset is reloaded and the machine is placed in the `G59.3` coordinate system without any `G92` offset active. This allows you to set the `G59.3` coordinate system according to a fixed point on the machine, and then use that fixture to measure tools without regard to other currently active offsets.

Program: `G10 L11 P~ X~ Y~ Z~ R~`

- $P\sim$ is the tool number
- $R\sim$ is the radius of tool

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The P number is unspecified
- The P number is not a valid tool number from the tool table
- The P number is 0

Set Coordinate System (G10 L20)

`G10 L20` is similar to `G10 L2`, except that instead of setting the offset/entry to the given value, it is set to a calculated value that makes the current coordinates become the given value.

Program: `G10 L20 P~ X~ Y~ Z~ A~`

- $P\sim$ is the number of coordinate system to use (`G54 = 1`, `G59.3 = 9`)
- $X\sim$ is the X-axis coordinate

- $Y\sim$ is the Y-axis coordinate
- $Z\sim$ is the Z-axis coordinate
- $A\sim$ is the A-axis coordinate

Troubleshooting

It's an error if:

- The P number does not evaluate to an integer in the range 0 to 9
- An axis other than X, Y, Z, or A is programmed

9.2.7 Plane Selection (G17, G18, G19)

To select the XY-plane as active, program: `G17`

To select the XZ-plane as active, program: `G18`

To select the YZ-plane as active, program: `G19`

The active plane determines how the tool path of an arc (`G02` or `G03`) or canned cycle (`G73`, `G81` through `G89`) is interpreted.

9.2.8 Length Units (G20 and G21)

To set length units to inches, program: `G20`

To set length units to millimeters, program: `G21`



Tip! Program either `G20` or `G21` near the beginning of a program, before any motion occurs. Avoid using either one anywhere else in the program. It's your responsibility to make sure that all numbers are appropriate for use with the current length units.

9.2.9 Return to Predefined Position (G28 and G28.1)

To make a rapid linear move from the current position to the absolute position of the values in parameters 5161-5166: `G28`

To make a rapid linear move to the `G28.1` position by first going to the intermediate position specified by the $X\sim$, $Y\sim$, and $Z\sim$ words, program: `G28 X~ Y~ Z~`



Note: Any axis not specified won't move.

To store the current location of the tool in the `G28.1` setting, program: `G28.1`

`G28` uses the values stored in parameters 5161, 5162, and 5163 as the X, Y, and Z final points to move to. The parameter values are absolute machine coordinates in the native machine units of inches.

To store the current absolute position into parameters 5161-5163, program: `G28.1`

If no positions are stored with `G28.1`, then all axes will go to the machine origin.

Troubleshooting

It's an error if:

- Cutter Compensation is turned on

9.2.10 Return to Predefined Position (G30 and G30.1)

G30 uses the values stored in parameters 5181 and 5183 as the X and Z final point to move to. The parameter values are absolute machine coordinates in the native machine units of inches.

To make a rapid traverse move from the current position to the absolute position of the values in parameters, program: `G30`

To make a rapid traverse move to the position specified by axes including any offsets, then make a rapid traverse move to the absolute position of the values in parameters 5181 and/or 5183, program: `G30 X~ Z~`



Note: Any axis not specified won't move.

To store the current absolute position into parameters 5181-5183, program: `G30.1`

Troubleshooting

It's an error if:

- Cutter Compensation is turned on

9.2.11 Automatically Measure Tool Lengths with an ETS (G37 and G37.1)

Use G37 and G37.1 with an Electronic Tool Setter (ETS) to enable automatic length measurement. For automated use, add a G37 command after an M6 tool change commands. If you're using the ETS with a mill, the input port varies depending on your machine:

- **M Series Mills** Plug the ETS into the Accessory Input 2 port. You can still use the Accessory Input 1 port for other probes and accessories.
- **Older PCNC Mills** Plug the ETS into the (single) accessory input port.

Move to G37 Position Over ETS (G37.1)

To move to the G37 position (over the ETS), program: `G37.1`

To set the G37 position:

1. Jog the machine over the center of the ETS.
2. From the **Probe** tab, on the **ETS Setup** tab, select **Set G37**

ETS Position.

The read-only DROs in the **ETS G37 Position Setup** group display the new position.

The G37 position is in G53 machine coordinate space. It defaults to (0, 0, 0), or the top left rear of machine travel (the same as the X-, Y-, and Z-axis reference position). G37.1 supports X and Y tool offsets. If there are X or Y tool offsets present in the tool table (manually applied through a G10 L1 command), they offset the spindle position. This enables G37 for tools mounted in an auxiliary spindle installed on the spindle column.



Note: If G10 L1 is used to change the X or Y offset of the currently loaded tool, you must then apply the new offsets with a G43 command.

G37.1 performs as follows:

1. A rapid upward move to the Z clear position (which is always G53 Z = 0.0).
2. A rapid move in X and Y to the X and Y ETS coordinates.
3. A rapid downward move in Z to the Z ETS coordinate.



Note: The Z word saves time by rapidly moving closer to the ETS before the slower probing begins. You must use caution if you set this lower than G53 Z = 0.0. If you don't, there's a risk that a long tool could collide with the ETS and damage it and the tool.

Move and Measure Tool Length (G37)

To move and measure the tool length, program: `G37 H~ P~`

- `H~` saves the measured tool length to the H tool table entry instead of the current tool number's entry. You could use this to track tool wear between the two tool table entries, for example.



Note: The newly measured tool length isn't applied, but it's stored in the tool table entry for tool number H.

9: PROGRAMMING

9.2 Programming G-Code

- $P\sim$ is positive or negative tolerance. It measures the tool length, but, instead of storing it in the tool table, compares it to the length in the tool table. If the difference exceeds the P tolerance, the G-code program stops. You could use this to detect broken or improperly inserted tools that are not fully seated in the spindle, for example.



Note: MX BT30 tool holders are designed to seat in the spindle taper, and should never touch the nose of the spindle.

G37 with no optional words moves to the G37 ETS position (through G37.1), probes the ETS, stores the new tool length in the tool table entry of the current tool, and applies the tool length offset.

G37 fails if the spindle nose hasn't been referenced to the ETS after a Z-axis reference. This sets a G53 coordinate at the ETS trigger point such that the measured tool length is the distance of the spindle nose to ETS reference. For more information, see the **ETS G37 Spindle Nose Reference** group on the **ETS Setup** tab.



Note: On MX mills, use the tip of the BT30 drive dog, not the spindle nose, to reference .

So that tool length measurements have consistent results, G37 uses the fine probe feed rate of 2.5 in./min for the final ETS touch. G37 uses the rough probe feed rate for the first ETS touch.

G37 performs as follows:

1. Issues a G37.1 move to the ETS location.
2. A downward rough probe feed rate move until the tool triggers the ETS.
3. An upward retract move of 0.100 in. to back off the triggered ETS.
4. A downward slow ETS probe feed rate move until the tool triggers the ETS.
5. An upward retract move of 0.100 in. to back off the triggered ETS.
6. An upward rapid move to the G37 ETS Z position.

9.2.12 Straight Probe (G38.x)

G38.2 probes toward the workpiece, stops on contact, and signals error if failure

G38.3 probes toward the workpiece and stops on contact

G38.4 probes away from the workpiece, stops on loss of contact, and signals error if failure

G38.5 probes away from the workpiece and stops on loss of contact

G38.6 moves away from the workpiece and ignores probe input

To perform a straight probe operation program: `G31 X~ Y~ Z~ A~`

Conventionally, the probe is tool #99. The rotational axis words are allowed, but it's better to omit them. If rotational axis words are used, the numbers must be the same as the current position numbers so that the rotational axes do not move. The tool in the spindle must be a probe.

In response to this command, the machine moves the controlled point (which should be at the end of the probe tip) in a straight line at the current feed rate toward the programmed point; if the probe trips, then the probe decelerates.

After successful probing, parameters 5061 to 5064 will be set to the coordinates of the location of the controlled point at the time the probe tripped (not where it stopped), or if it does not trip to the coordinates at the end of the move and a triplet giving X, Y, and Z at the trip is written to the triplet file.

Troubleshooting

It's an error if:

- The current point is less than 0.01 in. (0.254 mm) from the programmed point
- G38 is used in inverse time feed rate mode
- Any rotational axis is commanded to move
- No X-, Y- or Z-axis word is used
The linear axis words are optional, except that at least one of them must be used.
- Feed rate is zero
- The probe is already tripped

Use the Straight Probe Command

When you use the straight probe command, if the probe shank is kept nominally parallel to the Z-axis (i.e., any rotational axes are at zero) and the tool length offset for the probe is used, so

that the controlled point is at the end of the tip of the probe, you may be able to find:

- Without additional knowledge about the probe, the parallelism of a face of a part to the XY-plane
- If the probe tip radius is known approximately, the parallelism of a face of a part to the YZ or XZ-plane
- If the shank of the probe is known to be well-aligned with the Z-axis and the probe tip radius is known approximately, the center of a circular hole

If the shank of the probe is known to be well-aligned with the Z-axis and the probe tip radius is known precisely, you can use the straight probe command for things like finding the diameter of a circular hole.

```
Example code:
o<probe_pocket> sub
(probe to find center of circular or rectangular
pocket)
#<x_start> = #5420 (Current X Location)
#<y_start> = #5421 (Current Y Location)
#<x_max> = 1
#<x_min> = -1
#<y_max> = 1
#<y_min> = -1
#<feed_rate> = 30 (30 IPM)
F #<feed_rate>
G38.3 X #<x_max> (rough probe +X side of hole)
F [#<feed_rate>/30]
G38.5 X #<x_start> (finish probe)
#<x_plus>=#5061 (save results)
G00 X #<x_start> (return to start)
F #<feed_rate>
G38.3 X #<x_min> (probe -X side of hole)
F [#<feed_rate>/30]
G38.5 X #<x_start>
#<x_minus>=#5061 (save results)
G00 X #<x_start>
#<x_center> = [#<x_plus>+#<x_minus>]/2]
G00 X #<x_center> (go to middle)
F #<feed_rate>
G38.3 Y #<y_max> (probe +Y side of hole)
F [#<feed_rate>/30]
G38.5 Y #<y_start>
#<y_plus>=#5062 (save results)
G00 Y #<y_start> (return to start)
F #<feed_rate>
G38.3 Y #<y_min> (probe -Y side of hole)
```

```
F [#<feed_rate>/30]
G38.5 Y #<y_start>
#<y_minus>=#5062 (save results)
G00 Y #<y_start>
#<y_center> = [#<y_plus>+#<y_minus>]/2]
G00 Y #<y_center> (go to middle)
G10 L20 P1 X 0 Y 0 (set current location to zero)
F #<feed_rate> (restore original feed rate)
o<probe_pocket> endsub
M02
```

9.2.13 Cutter Compensation (G40, G41, G42)

To turn Cutter Compensation off, program: G40

It's okay to turn compensation off when it is already off.

It's an error if:

- A G02/G03 arc move is programmed next after a G40
- The linear move after turning compensation off is less than twice the tool tip radius

To program Cutter Compensation to the left of the programmed tool path (as viewed looking down on the machine), program: G41 D~

To program Cutter Compensation to the right of the programmed tool path (as viewed looking down on the machine), program: G42 D~

- D~ is the tool number associated with the diameter offset to be applied

The D word is optional — if there is no D word, the radius of the currently loaded tool is used. If no tool is loaded and no D word is given, a radius of 0 is used. If supplied, the D word is the tool number to use.

The lead in move must be at least as long as the tool radius.

The lead in move can be a rapid move.

It's an error if:

- The D number is not a valid tool number, or it's 0
- Cutter Compensation is commanded to turn on when it is already on

9.2.14 Dynamic Cutter Compensation (G41.1 and G42.1)

To program dynamic Cutter Compensation to the left of the programmed tool path, program: G41.1 D~

To program dynamic Cutter Compensation to the right of the programmed tool path, program: G42.1 D~

- D~ is the tip radius multiplied by two

9: PROGRAMMING

9.2 Programming G-Code

G41.1 and G42.1 function the same as G41 and G42, with the added scope of being able to ignore the tool table and to program the tool diameter.

Troubleshooting

It's an error if:

- Cutter Compensation is commanded to turn on when it is already on

9.2.15 Apply Tool Length Offset (G43)

To apply a tool length offset from a stored value in the tool table, program: G43 H~

- H~ is the tool number associated with the length offset to be applied.



Note: Generally speaking, the value of the H~ word should match the active tool number (T~ word).

It's okay to program using the same offset already in use, or to program without a tool length offset (if none is currently being used).

Troubleshooting

It's an error if:

- The H number is not an integer
- The H number is negative
- The H number is not a valid tool number

9.2.16 Engrave Sequential Serial Number (G47)

To engrave a serial number, either alone or added to the end of any text, program: Z~ R~ X~ Y~ P~ Q~ D~

- Z~ is the depth of cut of the engraving
- R~ is the retract height between character segments in the numbers
- X~ is, if present, the starting X position, or the left side of the serial number
If omitted, the current X position is assumed.
- Y~ is, if present, the starting Y position, or the bottom side of the serial number
If omitted, the current Y position is assumed.
- P~ is, if present, the X extent (width) in current units (inches or millimeters) of the engraved number
- Q~ is, if present, the Y extent (height) in current units (inches or millimeters) of the engraved number

- D~ is, if present, the requested number of decimals of the engraved number
If the requested D value exceeds the number of decimals in the serial number, the serial number will show leading zeros. If the requested D value is less than the number of decimals in the serial number, only the digits of the serial number will show.



EXAMPLE

A serial number of 10, where D = 4, engraves as 0010. A serial number of 9056, where D = 3, engraves as 9056.

Troubleshooting

It's an error if:

- Cutter Compensation is on
- The Z number is unspecified
- The R number is unspecified
- The Z number is greater than the R number
- The P number is too small (determined by the font used)
- The Q number is too small (determined by the font used)

9.2.17 Cancel Tool Length Compensation (G49)

To cancel tool length compensation, program: G49

9.2.18 Absolute Coordinates (G53)

For rapid linear motion to a point expressed in absolute coordinates, program: G01 G53 X~ Y~ Z~ (or use with G00 instead of G01)

All the axis words are optional, except that at least one must be used. The G00 or G01 is optional if it is in the current motion mode. G53 isn't modal, and must be programmed on each line on which it is intended to be active. This produces coordinated linear motion to the programmed point. If G01 is active, the speed of motion is the current feed rate (or slower if the machine won't go that fast). If G00 is active, the speed of motion is the current traverse rate (or slower if the machine won't go that fast).

Troubleshooting

It's an error if:

- G53 is used without G00 or G01 being active
- G53 is used while cutter radius compensation is on

9.2.19 Select Work Offset Coordinate System (G54 to G54.1 P500)

You can save up to 500 work offsets in PathPilot. The naming structure varies based on the offset number.

- To select work offset 1, program: G54 or G54.1 P1
- To select work offset 2, program: G55 or G54.1 P2
- To select work offset 3, program: G56 or G54.1 P3
- To select work offset 4, program: G57 or G54.1 P4
- To select work offset 5, program: G58 or G54.1 P5
- To select work offset 6, program: G59 or G54.1 P6
- To select work offset 7, program: G59.1 or G54.1 P7
- To select work offset 8, program: G59.2 or G54.1 P8
- To select work offset 9, program: G59.3 or G54.1 P9
- To select a work offset beyond the standard 9 (listed above), program: G54.1 P###, where P### is a parameter indicating the index of the work offset you want to use (work offset 10 through work offset 500).

EXAMPLE

To select the 124th work offset, program G54.1 P124.

For information, see "About Work Offsets" (page 217).

Troubleshooting

It's an error if:

- One of these G-codes is used while cutter radius compensation is on
- The X- and Z-axis work offset values are stored in parameters corresponding to the system in use (i.e., System 1 X=5221, Z=5223; System 2 X=5141, Z=5143; up to System 9 X= 5381, Z = 5383).

9.2.20 Set Exact Path Control Mode (G61)

To put the machining system into exact path mode, program: G61

9.2.21 Set Blended Path Control Mode (G64)

To attempt to maintain the defined feed velocity, program: G64 P~ Q~

- P~ is, if present, the maximum acceptable tool path deviation to round corners to maintain speed. If P is omitted then the speed is maintained however far from the programmed path the tool cuts.

- Q~ is, if present, the maximum deviation from collinearity that will collapse a series of linear G01 moves at the same feed rate into a single linear move.

It's okay to program for the mode that is already active.

9.2.22 Distance Mode (G90 and G91)

Interpretation of the operating system code can be in one of two distance modes: absolute or incremental.

To go into absolute distance mode, program: G90.

In absolute distance mode, axis numbers (X, Y, Z, A) usually represent positions in terms of the currently active coordinate system. Any exceptions to that rule are described explicitly in this section.

To go into incremental distance mode, program: G91.

In incremental distance mode, axis numbers (X, Y, Z, A) usually represent increments from the current values of the numbers. I and J numbers always represent increments, regardless of the distance mode setting. K numbers represent increments.

9.2.23 Arc Distance Mode (G90.1 and G91.1)

G90.1 – Absolute distance mode for I and K offsets. When G90.1 is in effect, I and K both must be specified with G02/G03 for the XZ plane or it is an error.

G91.1 – Incremental distance mode for I and K offsets.

G91.1 returns I and K to their default behavior.

9.2.24 Temporary Work Offsets (G92, G92.1, G92.2, and G92.3)

IMPORTANT! This is a legacy feature. Most modern programming methods don't use temporary work offsets.

To apply a temporary work offset, program: G92 X~ Y~ Z~ A~

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate
- A~ is the A-axis coordinate

G92 reassigns the current controlled point to the coordinates specified by the axis words (X~, Y~, Z~, and/or A~). No motion takes place.

The axis words are optional, except that at least one must be used. If an axis word is not used for a given axis, the coordinate on that axis of the current point is not changed.

9: PROGRAMMING

9.2 Programming G-Code

Incremental distance mode (G91) has no effect on the action of G92.

When G92 is executed, it is applied to the origins of all coordinate systems (G54 through G59.3).

EXAMPLE

If the current controlled point is at X = 4, and there is currently no G92 offset active, and then G92 X7 is programmed, this reassigns the current controlled point to X = 7 — effectively moving the origin of the active coordinate system -3 units in X. The origins of all inactive coordinate systems also move -3 units in X. This -3 is saved in parameter 5211.

G92 offsets may be already be in effect when the G92 is called. If this is the case, the offset is replaced with a new offset that makes the current point become the specified value.

It's an error if:

- All axis words are omitted

PathPilot stores the G92 offsets and reuses them on the next run of a program. To prevent this, you can program a G92.1 (to erase them), or program a G92.2 (to stop them being applied — they are still stored).

To reset axis offsets to zero and sets parameters 5211 - 5219 to zero, program: G92.1

To reset axis offsets to zero, program: G92.2

To set the axis offset to the values saved in parameters 5211 to 5219, program: G92.3

9.2.25 Feed Rate Mode (G93, G94, and G95)

To set the active feed rate mode to inverse time, program: G93

Inverse time is used to program simultaneous coordinated linear and coordinated rotary motion. In inverse time feed rate mode, an F word means the move should be completed in **[1/F number]** minutes.

EXAMPLE

If the F number is 2.0, the move should be completed in half a minute.

When the inverse time feed rate mode is active, an F word must appear on every line which has a G01, G02, or G03 motion, and an F word on a line that does not have G01, G02, or G03 is ignored. Being in inverse time feed rate mode does not affect G00 (rapid traverse) motions.

To set the active feed rate mode to units per minute mode, program: G94

In units per minute feed rate mode, an F word is interpreted to mean the controlled point should move at a certain number of inches per minute, or millimeters per minute, depending upon what length units are being used.

To set the active feed rate mode to units per revolution mode, program: G95

In units per revolution mode, an F word is interpreted to mean the controlled point should move a certain number of inches per revolution of the spindle, depending on what length units are being used. G95 is not suitable for threading, for threading use G33 or G76.

Troubleshooting

It's an error if:

- Inverse time feed rate mode is active and a line with G01, G02, or G03 (explicitly or implicitly) does not have an F word
- A new feed rate is not specified after switching to G94 or G95 canned cycle return level — G98 and G99

9.2.26 Spindle Control Mode (G96 and G97)

To set constant surface speed mode, program: G96 D~ S~

- D~ is the maximum spindle RPM.
This word is optional.
- S~ is the surface speed.



Note: If G20 is the active mode, the value is interpreted as feet per minute. If G21 is the active mode, the value is interpreted as meters per minute



EXAMPLE

G96 D2500 S250 (set constant surface speed with a maximum RPM of 2500, and a surface speed of 250).

When using G96 (the most common mode of machine operation), X0 in the current coordinate system (including offsets and tool lengths) must be the spindle axis.

To set RPM mode, program: G97

Troubleshooting

It's an error if:

- S is not specified with G96
- A feed move is specified in G96 mode while the spindle is not turning

9: PROGRAMMING
9.3 Programming Canned Cycles

9.3 PROGRAMMING CANNED CYCLES

Read the following sections for reference:

9.3.1 Canned Cycles Reference... 238
9.3.2 High Speed Peck Drill (G73)... 239
9.3.3 Cancel Canned Cycles (G80)... 239
9.3.4 Drilling Cycle (G81)... 239
9.3.5 Simple Drilling Cycle (G82)... 241
9.3.6 Peck Drilling Cycle (G83)... 241
9.3.7 Tapping Cycle (G84)... 241
9.3.8 Boring Cycle (G85)... 241
9.3.9 Boring Cycle (G86)... 242
9.3.10 Boring Cycle (G88)... 242
9.3.11 Boring Cycle (G89)... 242

9.3.1 Canned Cycles Reference

Supported Canned Cycles

Table with 2 columns: Canned Cycle, Description. Rows include G73 (High speed peck drilling cycle), G80 (Cancel active canned cycle), G81 (Simple drilling cycle), G82 (Simple drilling with dwell cycle), G83 (Peck drilling cycle), G84 (Tapping cycle), G85 (Boring cycle - feedrate out), G86 (Boring cycle - stop, rapid out), G88 (Boring cycle - stop, manual out), G89 (Boring cycle - dwell, feedrate out).

All canned cycles are performed with respect to the active plane. The descriptions we use assume the XY-plane has been selected. The behavior is always analogous if the YZ- or XZ-plane is selected.

- X~ is the X-axis coordinate
- Y~ is the Y-axis coordinate
- Z~ is the Z-axis coordinate
- A~ is the A-axis coordinate
- R~ is the retract position along the axis perpendicular to the currently selected plane (Z-axis for XY-plane, X-axis for YZ-plane, Y-axis for XZ-plane)

- L~ is the L number is optional and represents the number of repeats

All canned cycles use X, Y, Z, and R words. The R word sets the retract position; this is along the axis perpendicular to the currently selected plane (Z-axis for XY-plane, X-axis for YZ-plane, Y-axis for XZ-plane). Some canned cycles use additional arguments.

Rotational axis (A-axis) words are allowed in canned cycles, but it's better to omit them. If rotational axis words are used, the numbers must be the same as the current position numbers so that the rotational axes do not move.

The R number is always sticky — it keeps its value on subsequent blocks if they're not explicitly programmed to be different.

In absolute distance mode (G90), the X, Y, R, and Z numbers are absolute positions in the current coordinate system.

In incremental distance mode (G91), when the XY-plane is selected, X, Y, and R numbers are treated as increments to the current position and Z as an increment from the Z-axis position before the move involving Z takes place; when the YZ- or XZ-plane is selected, treatment of the axis words is analogous. Many canned cycles use the L word. The L word is optional and represents the number of repeats. L0 is not allowed. The L word is not sticky. The interpretation of the L word depends on the active distance mode:

- In incremental distance mode (G91), L > 1 in incremental mode means (with the XY-plane selected), that the X and Y positions are determined by adding the given X and Y numbers either to the current X and Y positions (on the first iteration) or to the X and Y positions at the end of the previous go-around (on the subsequent repetitions). The R and Z positions do not change during the repeats
- In absolute distance mode (G90), L > 1 means do the same cycle in the same place several times. Omitting the L word is equivalent to specifying L=1

The height of the retract move at the end of each repeat — called clear Z — is determined by the setting of the retract mode: either to the original Z position (if that is above the R position and the retract mode is G98) or otherwise to the R position.

Troubleshooting

It's an error if:

- X, Y, and Z words are all missing during a canned cycle
- A P number is required and a negative P number is used
- An L number is used that does not evaluate to a positive integer
- Rotational axis motion is used during a canned cycle
- Inverse time feed rate is active during a canned cycle
- Cutter radius compensation is active during a canned cycle

When the XY plane is active, the Z number is sticky and it's an error if:

- The Z number is missing and the same canned cycle was not already active
- The R number is less than the Z number

When the XZ plane is active, the Y number is sticky and it's an error if:

- The Y number is missing and the same canned cycle was not already active
- The R number is less than the Y number

When the YZ plane is active, the X number is sticky and it's an error if:

- The X number is missing and the same canned cycle was not already active
- The R number is less than the X number

At the very beginning of the execution of any of the canned cycles (with the XY-plane selected), if the current Z position is below the R position, the Z-axis will move in rapid motion to the R position. This happens only once, regardless of the value of L. In addition, at the beginning of the first cycle and each repeat, the following one or two moves are made:

- A straight traverse parallel to the XY-plane to the given XY-position
- A straight traverse of the Z-axis only to the R position, if it is not already at the R position

If the XZ- or YZ-plane is active, the preliminary and in-between motions are analogous.

9.3.2 High Speed Peck Drill (G73)

The G73 cycle is intended for deep drilling with chip breaking. The retracts in this cycle break the chip but do not totally retract the drill from the hole. It's suitable for tools with long flutes which clear the broken chips from the hole.

Program: G73 X~ Z~ R~ L~ Q~

- Q~ is the delta increment along the Z-axis

The G73 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate downward by delta or to the Z position (whichever is less deep).
- × **Step 3:** Rapid back incrementally in Z 0.010 in.
- × **Step 4:** Repeat Step 1 through 3 until the Z position is reached at Step 1.
- × **Step 5:** Rapid back down to the current hole bottom, backed off a bit.
- × **Step 6:** Retract the Z-axis at traverse rate to clear Z.

Troubleshooting

It's an error if:

- The Q number is negative or zero
- The R number is not specified

9.3.3 Cancel Canned Cycles (G80)

To cancels all canned cycles, program: G80

It's okay to program G80 if no canned cycles are in effect.

After a G80, the motion mode must be set with G00 (or any other motion mode G word). If motion mode is not set after G80, this error message appears: **"Cannot use axis values without a g code that uses them."**

9.3.4 Drilling Cycle (G81)

The G81 cycle is intended for drilling.

Program: G81 X~ Y~ Z~ A~ R~ L~

The G81 Cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Retract the Z-axis at traverse rate to clear Z.

Examples

These examples demonstrate how the G81 canned cycle works in detail. Other canned cycles work in a similar manner.

9: PROGRAMMING

9.3 Programming Canned Cycles



EXAMPLE

The current position is (1, 2, 3), the XY-plane has been selected, and the following line of code is interpreted:

```
G90 G81 G98 X4 Y5 Z1.5 R2.8
```

This means that it's in absolute distance mode (G90), old Z retract mode (G98) and the G81 drilling cycle is performed once. The X number and X position are 4. The Y number and Y position are 5. The Z number and Z position are 1.5. The R number and clear Z are 2.8. The following moves take place:

1. G00 motion parallel to the XY-plane to (4,5,3)
2. G00 motion parallel to the Z-axis to (4,5,2.8)
3. G01 motion parallel to the Z-axis to (4,5,1.5)
4. G00 motion parallel to the Z-axis to (4,5,3)



EXAMPLE

The current position is (1, 2, 3), the XY-plane has been selected, the following line of code is interpreted: **G91**

```
G81 G98 X4 Y5 Z-0.6 R1.8 L3
```

This means that it's in incremental distance mode (G91), old Z retract mode, and the G81 drilling cycle is repeated three times. The X number is 4, the Y number is 5, the Z number is -0.6 and the R number is 1.8. The initial X position is 5 (=1+4), the initial Y position is 7 (=2+5), the clear Z position is 4.8 (=1.8+3) and the Z position is 4.2 (=4.8-0.6). Old Z is 3.0.

The first move is a traverse along the Z-axis to (1,2,4.8), since old Z < clear Z.

The first repeat consists of three moves:

1. G00 motion parallel to the XY-plane to (5,7,4.8)
2. G01 motion parallel to the Z-axis to (5,7, 4.2)
3. G00 motion parallel to the Z-axis to (5,7,4.8)

The second repeat consists of three moves. The X position is reset to 9 (=5+4) and the Y position to 12 (=7+5):

1. G00 motion parallel to the XY-plane to (9,12,4.8)
2. G01 motion parallel to the Z-axis to (9,12, 4.2)
3. G00 motion parallel to the Z-axis to (9,12,4.8)

The third repeat consists of three moves. The X position is reset to 13 (=9+4) and the Y position to 17 (=12+5):

1. G00 motion parallel to the XY-plane to (13,17,4.8)
2. G01 motion parallel to the Z-axis to (13,17, 4.2)
3. G00 motion parallel to the Z-axis to (13,17,4.8)

Example code using G81 cycle:

```
(Sample Program G81EX18:)  
(Workpiece Size: X4, Y3, Z1)  
(Tool: Tool #6, 3/4" HSS DRILL)  
(Tool Start Position: X0, Y0, Z1)  
N2 G90 G80 G40 G54 G20 G17 G94 G64 (Safety Block)  
N5 G90 G80 G20  
N10 M06 T6 G43 H6  
N15 M03 S1300  
N20 G00 X1 Y1  
N25 Z0.5  
N30 G81 Z-0.25 R0.125 F5 (Drill Cycle Invoked)  
N35 X2  
N40 X3  
N45 Y2
```



```
N50 X2
N55 X1
N60 G80 G00 Z1 (Cancel Canned Cycles)
N65 X0 Y0
N70 M05
N75 M30
```

9.3.5 Simple Drilling Cycle (G82)

The G82 cycle is intended for drilling.

Program: G82 X~ Y~ Z~ A~ R~ L~ P~

The G82 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Dwell for the P number of seconds.

9.3.6 Peck Drilling Cycle (G83)

The G83 cycle (often called peck drilling) is intended for deep drilling or milling with chip breaking. The retracts in this cycle clear the hole of chips and cut off any long stringers (which are common when drilling in aluminum).

Program: G83 X~ Y~ Z~ A~ R~ L~ Q~

- Q~ is a delta increment along the Z-axis

The G83 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate downward by delta or to the Z position, whichever is less deep.
- × **Step 3:** Rapid back out to the clear Z.
- × **Step 4:** Repeat Steps 1 through 3 until the Z position is reached at Step 1.
- × **Step 5:** Rapid back down to the current hole bottom, backed off a bit.
- × **Step 6:** Retract the Z-axis at traverse rate to clear Z.

Troubleshooting

It's an error if:

- The Q number is negative or zero

9.3.7 Tapping Cycle (G84)

The G84 cycle is intended for tapping. This cycle rotates the spindle clockwise to tap a pre-drilled hole; when the bottom of the hole is reached, the spindle rotates in the reverse direction and exits the hole.

Program: G84 X~ Y~ Z~ R~ P~ F~

- X~ is the position of the hole on the X-axis
- Y~ is the position of the hole on the Y-axis
- Z~ is the depth, tapping from the R-plane to the Z-depth
- R~ is the position of the retract plane (R-plane)
- P~ is the number of seconds to dwell
- F~ is the feed rate

The G84 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Start the spindle forward.
- × **Step 3:** Move the Z-axis at the programmed feed rate (F~) to the Z-depth.
- × **Step 4:** Reverse the spindle.
- × **Step 5:** Dwell for the P number of seconds.
- × **Step 6:** Retract the Z-axis at the programmed feed rate (F~) to the R-plane.

This cycle uses a P word, where P specifies the number of seconds to dwell. The P word is optional – if it is not included, PathPilot calculates a dwell for you (half of a second per 1000 RPM).

Spindle speed must be commanded before calling a G84 cycle. Feed rate override is ignored during a tapping cycle. Feedhold is ignored until the return operation is executed. After the tapping operation is completed, either a G98 or G99 command controls the return height — G99 returns the tool to the R-plane; G98 returns the tool to the initial height.



EXAMPLE

```
N40 T51 G43 H51 M6
N45 S400 M3
N50 G54
N55 M8
N65 G0 X0.5 Y-0.75
N70 G43 Z0.6 H51
N80 G0 Z0.2
N85 S400
N90 G98 G84 X0.5 Y-0.75 Z-0.605 R0.2 F20.
N95 X1.0 Y -1.25
N100 G80
N105 G0 Z0.6
```

9.3.8 Boring Cycle (G85)

The G85 cycle is intended for boring or reaming, but could be used for drilling or milling.

9: PROGRAMMING

9.3 Programming Canned Cycles

Program: G85 X~ Y~ Z~ A~ R~ L~

The G85 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Retract the Z-axis at the current feed rate to clear Z.

9.3.9 Boring Cycle (G86)

The G86 cycle is intended for boring. This cycle uses a P number for the number of seconds to dwell.

Program: G86 X~ Y~ Z~ A~ R~ L~ P~

The G86 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Stop the spindle turning.
- × **Step 5:** Retract the Z-axis at traverse rate to clear Z.
- × **Step 6:** Restart the spindle in the direction it was going.
- × **Step 7:** Move the Z-axis only at the current feed rate to the Z position.

Troubleshooting

It's an error if:

- The spindle is not turning before this cycle is executed

9.3.10 Boring Cycle (G88)

The G88 cycle is intended for boring and uses a P word, where P specifies the number of seconds to dwell.

Program: G88 X~ Y~ Z~ A~ R~ L~ P~

The G88 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Stop the spindle turning.
- × **Step 5:** Stop the program so the operator can retract the spindle manually.
- × **Step 6:** Restart the spindle in the direction it was going.

9.3.11 Boring Cycle (G89)

The G89 cycle is intended for boring. This cycle uses a P number, where P specifies the number of seconds to dwell.

Program: G89 X~ Y~ Z~ A~ R~ L~ P~

The G89 cycle is as follows:

- × **Step 1:** Preliminary canned cycle motion.
- × **Step 2:** Move the Z-axis only at the current feed rate to the Z position.
- × **Step 3:** Dwell for the P number of seconds.
- × **Step 4:** Retract the Z-axis at the current feed rate to clear Z.

9.4 PROGRAMMING M-CODE

Read the following sections for reference:

9.4.1 Supported M-Codes Reference.....	243
9.4.2 Program Stop and Program End (M00, M01, M02, and M30).....	243
9.4.3 Spindle Control (M03, M04, and M05).....	244
9.4.4 Tool Change (M06).....	244
9.4.5 Coolant Control (M07, M08, and M09).....	245
9.4.6 Override Control (M48 and M49).....	245
9.4.7 Feed Override Control (M50).....	245
9.4.8 Spindle Speed Override Control (M51).....	245
9.4.9 Set Current Tool Number (M61).....	245
9.4.10 Set Output State (M64 and M65).....	245
9.4.11 Wait on Input (M66).....	246
9.4.12 Chip Conveyor Control (M231 and M233).....	246
9.4.13 USB Camera Control (M301, M302, M303).....	246

9.4.1 Supported M-Codes Reference

M-Code	Description
<u>M00</u>	Program stop
<u>M01</u>	Optional program stop
<u>M02</u>	Program end
<u>M03</u> , <u>M04</u>	Rotate spindle clockwise/counterclockwise
<u>M05</u>	Stop spindle rotation
<u>M07</u> , <u>M08</u>	Coolant on
<u>M09</u>	All coolant off
<u>M30</u>	Program end and rewind
<u>M48</u>	Enable speed and feed override
<u>M49</u>	Disable speed and feed override
<u>M64</u>	Activate output relays
<u>M65</u>	Deactivate output relays

M-Code	Description
<u>M66</u>	Wait on an input Note: <u>M64</u> through <u>M66</u> is only useful with a <u>USB M-Code I/O Interface Kit (PN 32616)</u> .
<u>M98</u>	Call subroutine
<u>M99</u>	Return from subroutine/repeat
<u>M301</u> , <u>M302</u> , <u>M303</u>	USB camera control
<u>M231</u> and <u>M233</u>	Chip conveyor control

9.4.2 Program Stop and Program End (M00, M01, M02, and M30)

To stop a running program temporarily, regardless of the optional stop switch setting, program: M00

To stop a running program temporarily, but only if the optional stop switch is on, program: M01

It's okay to program M00 and M01 in MDI mode, but the effect probably won't be noticeable because normal behavior in MDI mode is to stop after each line of input.

If a program is stopped by an M00, M01, selecting Cycle Start restarts the program at the following line of the G-code program.

To end a program, program: M02 or M30.

M02 leaves the next line to be executed as the M02 line. M30 rewinds the G-code file. These commands can have the following effects:

- Axis offsets are set to zero (like G92 . 2) and origin offsets are set to the default (like G54)
- Selected plane is set to XY (like G17)
- Distance mode is set to absolute (like G90)
- Feed rate mode is set to units per minute mode (like G94)
- Feed and speed overrides are set to on (like M48)
- Cutter Compensation is turned off (like G40)
- The spindle is stopped (like M05)

9: PROGRAMMING

9.4 Programming M-Code

- The current motion mode is set to G01 (like G01)
- Coolant is turned off (like M09)

No more lines of code in the file are executed after the M02 or M30 command is executed. Selecting Cycle Start starts the program back at the beginning of the file.

Display Information and Capture Images During an M00 or M01 Break

Display Information with Images

If the comment occurs on a line with M00 or M01, and contains a file name with a .jpg or .png extension, PathPilot displays the image in the Tool Path display when the program reaches the M00 or M01 break.

To display an image during an M00 or M01 break:

1. Move an image file with a .jpg or .png extension to the PathPilot controller in one of the following locations:
 - In the same folder as the G-code program
 - In an images folder within the G-code program's folder
 - In an images folder within the home directory
2. Program an M00 or M01 break, and, using parentheses, type the full file name of the image (including its extension).



EXAMPLE

M01 (Op1_Setup.jpg) displays the image file on the Tool Path display.

3. The image file displays on the Tool Path display.

Display Information with Text

To display a message on the Tool Path display:

1. Program an M00 or M01 break, and, using parentheses, type a message that you'd like to display on the screen.



EXAMPLE

M01 (Check coolant nozzles are pointed correctly) displays *Check coolant nozzles are pointed correctly* across the bottom of the Tool Path display.

2. The message displays on the Tool Path display.

Capture Images with a USB Camera

In addition to displaying information like pictures or messages during an M01 break, you can also use a USB camera (if installed) to take a picture.

To use M01 to take pictures:

1. Add M01 (op1_setup.jpg) into your G-code program.
2. Run the G-code program.
3. When PathPilot executes the M01 it looks to see if the comment contains a file name.
 - If there isn't a file name: The comment is shown as instructional text across the tool path.
 - If there is a file name, but the file doesn't exist yet and the extension is .jpg, .png, or .jpeg: The USB cameras are initialized and shown in the tool path display.
4. Select the **Shutter** button to take the picture and create the op1_setup.jpg file.
In future runs of the G-code program, **op1_setup.jpg** will display to the operator for instructional purposes on the workpiece.

For more information, see "Use a USB Camera" (page 177).

9.4.3 Spindle Control (M03, M04, and M05)

To start the spindle turning clockwise at the currently programmed speed, program: M03

To start the spindle turning counterclockwise at the currently programmed speed, program: M04

The speed is programmed by the S word.

To stop the spindle from turning, program: M05

It's okay to use M03 or M04 if the spindle speed is set to 0; if this is done, the spindle won't start turning. If later the spindle speed is set above 0, the spindle starts turning. It is permitted to use M03 or M04 when the spindle is already turning, or to use M05 when the spindle is already stopped.

9.4.4 Tool Change (M06)

To execute a tool change sequence, program: M06

M06 behaves differently depending on whether or not the machine is equipped with an Automatic Tool Changer (ATC):

- If you have an ATC:
 - If the requested tool (T number) is assigned to the carousel, M06 initiates an automatic tool change.

- If the tool is not assigned to the carousel, you're prompted to manually change the tool and select Cycle Start to confirm the tool change. This resumes the program.
- If you don't have an ATC:
 - M06 commands the machine, stops the spindle, pauses program execution, and prompts operator to change tools by flashing Tool Change LED.
 - The program resumes after you select Cycle Start to confirm that the tool has been changed.

We recommend putting the T~, the M06, and the G43 H~ on one line (block) of code.

 **EXAMPLE**
N191 M06 T3 G43 H3

9.4.5 Coolant Control (M07, M08, and M09)

To turn coolant on, program: M07

To turn flood coolant on, program: M08

To turn all coolant off, program: M09

It's always okay to use any of these commands, regardless of what coolant is on or off.

9.4.6 Override Control (M48 and M49)

To enable the speed and feed override, program: M48

To disable both overrides, program: M49

It's okay to enable or disable the switches when they are already enabled or disabled.

9.4.7 Feed Override Control (M50)

To enable the feed rate override control, program: M50 P1

The P1 is optional.

To disable the feed rate control, program: M50 P0

When feed rate override control is disabled, the feed rate override slider has no influence, and all motion is executed at programmed feed rate (unless there is an adaptive feed rate override active).

9.4.8 Spindle Speed Override Control (M51)

To enable the spindle speed override control, program: M51

P1

The P1 is optional.

To disable the spindle speed override control, program: M51

P0

When spindle speed override control is disabled, the spindle speed override slider has no influence, and the spindle speed is equal to the value of the S word.

9.4.9 Set Current Tool Number (M61)

To change the current tool number while in MDI or manual mode, program: M61 Q~

- Q~ is the tool number

Troubleshooting

It's an error if:

- Q~ is not 0 or greater

9.4.10 Set Output State (M64 and M65)

 **Note:** These commands are only useful when the machine is equipped with the USB M-Code I/O Interface Kit.

There are four output relays available on the USB I/O module.

To activate output relays (contact close), program: M64

To deactivate output relays (contact open), program: M65

There are four contacts, numbered from 0 to 3. The contact is specified by the P word.

 **EXAMPLE**

- Activating the first relay: M64 P0
- Activating the second relay: M64 P1

The outputs are deactivated using M65 with the P word specifying the relay.

 **EXAMPLE**

- Deactivating the second relay: M65 P1
- Deactivating the fourth relay: M65 P3

There is only one P word and one relay per line. Each relay command must be done on an individual line.

The following is legal:

```
M64 P0
M64 P2
M64 P3
```

The following is not legal:

```
M64 P023
M64 P0 P2 P3
```

9: PROGRAMMING

9.4 Programming M-Code

9.4.11 Wait on Input (M66)



Note: This command is only useful when the machine is equipped with the USB M-Code I/O Interface Kit.

There are four digital inputs available on the USB I/O module.

M66 P- | E- <L->

- P- is the digital input number from 0 to 3.
- L- is the wait mode type:
 - Mode 0: IMMEDIATE – no waiting, returns immediately. The value of the input at that time is stored in parameter #5399.
 - Mode 1: RISE – waits for the selected input to perform a rise event.
 - Mode 2: FALL – waits for the selected input to perform a fall event.
 - Mode 3: HIGH – waits for the selected input to go to the HIGH state.
 - Mode 4: LOW – waits for the selected input to go to the LOW state.
- Q- is the timeout in seconds for waiting

The Q value is ignored if the L word is zero (IMMEDIATE). A Q value of zero is an error if the L word is non-zero.

9.4.12 Chip Conveyor Control (M231 and M233)

To turn the chip conveyor on, program: M231 P~ Q~

- P~ is the number of seconds to run.
- Q~ is the number of seconds to idle.
- If P~ and Q~ are omitted, the chip conveyor runs continuously.

To turn the chip conveyor off, program: M233

9.4.13 USB Camera Control (M301, M302, M303)

PathPilot supports three new M-codes to control cameras within G-code programs: M301, M302, and M303. Example use cases:

- Record only across each M01 stop where the operator needs to flip a workpiece or change a tool.
- Create short videos that focus on unique aspects of the program to reduce later video editing.
- Record USB IO integration operations with robots or other devices (pneumatic vises, etc.).

- Monitor progress on a workpiece by including M303 throughout the program.

To begin a video recording by an attached camera,

program: M301

To stop a video recording by an attached camera, program:

M302

To take a picture with an attached camera, program: M303

For more information, see "Use a USB Camera" (page 177).

9.5 PROGRAMMING INPUT CODES

Read the following sections for reference:

9.5.1 Feed Rate (F).....	247
9.5.2 Spindle Speed (S).....	247
9.5.3 Change Tool Number (T).....	247

9.5.1 Feed Rate (F)

To set the feed rate, program: `F~`

Depending on the setting of the feed mode toggle, the rate may be in units-per-minute or units-per-rev of the spindle. The units are those defined by the G20/G21 mode. The feed rate may sometimes be overridden.

9.5.2 Spindle Speed (S)

To set the speed in revolutions per minute (rpm) of the spindle, program: `S~`

The spindle turns at the commanded speed when it has been programmed to start turning. It's okay to program an S word whether the spindle is turning or not. If the speed override switch is enabled and not set at 100 percent, the speed is different from what is programmed. It's okay to program S0, but the spindle does turn if that is done.

Troubleshooting

It's an error if:

- The S number is negative

9.5.3 Change Tool Number (T)

It's your responsibility to make sure that the machine is in a safe place for changing tools (for example, by using G30). This allows optimization of motion which can save time. You can provide a pause for manual intervention with M00 or M01 before the tool change.

Troubleshooting

It's an error if:

- A negative T number is used
- A T number larger than 1000 is used

9: PROGRAMMING
9.6 Advanced Programming

9.6 ADVANCED PROGRAMMING

Parameter and expression programming language features are not used in common G-code application (hand coding), G-code created by PathPilot conversational programming, or the majority of third-party CAM-programming systems. There are significant differences between controls in the way parameters work. Do not assume that code from another control works in the same way with the operating system. We don't recommend writing parametric G-code — it's difficult to debug, and difficult for another operator to understand. Modern CAM virtually eliminates the need for it. Read the following sections for reference:

9.6.1 Parameters 248
9.6.2 Expressions 250
9.6.3 Subroutines 251

9.6.1 Parameters

Read the following sections for reference:

Parameters Reference 248
Numbered Parameters Reference 249
Subroutine Parameters Reference 249
Named Parameters Reference 249

Parameters Reference

The RS274/NGC language supports parameters. Parameters are analogous to variables in other programming languages. PathPilot maintains an array of 10,320 numerical parameters. Many of them have specific uses. The parameters that are associated with fixtures are persistent over time. Other parameters are undefined when the operating system is loaded. The parameters are preserved when the interpreter is reset. Parameters 1 to 1000 can be used by the code of part-programs. There are several types of parameters of different purpose and appearance. The only value type supported by parameters is floating-point; there are no string, Boolean or integer types in G-code like in other programming languages. However, logic expressions can be formulated with Boolean operators (AND, OR, XOR, and the comparison operators EQ, NE, GT, GE ,LT, LE), and the MOD, ROUND, FUP and FIX operators support integer arithmetic.

Parameter Syntax

There are three types of parameters, numbered, named local, and named global. The type of the parameter is defined by its syntax:

- Numbered - #4711
• Named local - #<localvalue>
• Named global - #<_globalvalue>

Parameter Scope

The scope of a parameter is either global or local within a subroutine. The scope of each parameter is inferred from its syntax. Subroutine parameters and named local parameters have local scope. Named global parameters and all numbered parameters starting from #31 are global in scope. RS274/NGC uses lexical scoping. In a subroutine, only the local parameters defined therein and any global parameters are visible. The local parameters of a calling procedure are not visible in a called procedure.

Behavior of Uninitialized Parameters

Uninitialized global parameters and unused subroutine parameters return the value zero when used in an expression. Uninitialized named parameters signal an error when used in an expression.

Parameter Mode

The mode of a parameter can either be read/write or read-only. Read/write parameters may be assigned values within an assignment statement. Read-only parameters cannot be assigned values. They may appear in expressions, but not on the left-hand side of an assignment statement.

Persistence and Volatility

Parameters can either be persistent or volatile. When the operating system is powered off, volatile parameters lose their values and are reset to zero. The values of persistent parameters are saved in a disc file and restored to their previous values when the operating system is powered on again. All parameters except numbered parameters in the current persistent range (5163 to 5390) are volatile.

Intended Use

Numbered parameters in the range #31-#5000, named global, and local parameters are available for general-purpose storage of floating-point values, like intermediate results, flags, etc., throughout program execution. They are read/write (can be

assigned a value). Subroutine parameters, numbered parameters #1-#30, and system parameters are read-only and not available for general use. Subroutine parameters are used to hold the actual parameters passed to a subroutine. Numbered parameters in the range of #1-#30 are used to access offsets of coordinate systems. System parameters are used to determine the current running version and are read-only.

Numbered Parameters Reference

A numbered parameter is recognized by the pound symbol (#) followed by an integer between 1 and 5399. The parameter is referred to by this integer, and its value is whatever number is stored in the parameter. A value is stored in a parameter with the (=) operator.

Example: `#3 = 15` (set parameter 3 to 15)

A parameter setting does not take effect until after all parameter values on the same line have been found. For example, if parameter 3 has been previously set to 15 and the line: `#3=6 G01 X#3` is interpreted, a straight move to a point where X = 15 occurs before the value of parameter 3 is set to 6.

The # symbol takes precedence over other operations. For example, `#1+2` means the number found by adding 2 to the value of parameter 1, not the value found in parameter 3. Of course, `# [1+2]` does mean the value found in parameter 3. The # character may be repeated; for example `##2` means the value of parameter whose index is the (integer) value of parameter 2. PathPilot maintains a number of read-only parameters. Only parameters for the relevant axes are maintained: (X Y Z A) for mill and (X Z) for lathe. The remaining parameters for unused axes are undefined.

Read-Only Parameters

- 1-30: Subroutine local parameters of call arguments. These parameters are local to the subroutine. For further information, see Programming with Subroutines later in this chapter
- 31-5000: G-code operator parameters. These parameters are global in G-code file
- 5061-5070: Result of G38.2 probe (X Y Z A B C U V W)
- 5161-5169: G28 home for (X Y Z A B C U V W)
- 5181-5189: G30 home for (X Y Z A B C U V W)
- 5210: 1 if G92 offsets are active, 0 if not
- 5211-5219: G92 offset (X Y Z A B C U V W)

- 5220: Current coordinate system number 1-9 for G54 - G59.3
- 5221-5230: Coordinate System 1, G54 (X Y Z A B C U V W R) – R denotes XY rotation angle around Z-axis
- 5241-5250: Coordinate System 2, G55 (X Y Z A B C U V W R)
- 5261-5270: Coordinate System 3, G56 (X Y Z A B C U V W R)
- 5281-5290: Coordinate System 4, G57 (X Y Z A B C U V W R)
- 5301-5310: Coordinate System 5, G58 (X Y Z A B C U V W R)
- 5321-5330: Coordinate System 6, G59 (X Y Z A B C U V W R)
- 5341-5350: Coordinate System 7, G59.1 (X Y Z A B C U V W R)
- 5361-5370: Coordinate System 8, G59.2 (X Y Z A B C U V W R)
- 5381-5390: Coordinate System 9, G59.3 (X Y Z A B C U V W R)
- 5399: Result of M66 – check or wait for input
- 5400: Current tool number
- 5401-5409: Tool offset (X Y Z A B C U V W)
- 5410: Current tool diameter
- 5411: Current tool front angle
- 5412: Current tool back angle
- 5420-5428: Current position including offsets in current program units (X Y Z A B C U V W)

Subroutine Parameters Reference

Subroutine parameters are specifically reserved for call arguments. By definition, these are parameters #1-#30 and are local to the subroutine.

Named Parameters Reference

Named parameters work like numbered parameters, but are easier to read and remember. All parameter names are converted to lowercase and have spaces and tabs removed. Named parameters must be enclosed with < > marks. `#<named parameter here>` is a local named parameter. By default, a named parameter is local to the scope in which it is assigned.

You can't access a local parameter outside of its subroutine. This is so two subroutines can use the same parameter names

9: PROGRAMMING
9.6 Advanced Programming

without fear of one subroutine overwriting the values in another.
#<_global named parameter here> (i.e., name starting with an underscore) is a global named parameter.
They are accessible from within called subroutines and may set values within subroutines that are accessible to the caller.
As far as scope is concerned, they act just like regular numeric parameters. They are not made persistent by storage in a file.
The global parameters _a, _b, _c, ... _z are reserved for special use. Do not use these parameters.

EXAMPLES

- #<_endmill_dia> = 0.049 is a declaration of named global variable.
- #<_endmill_rad> = [#<_endmill_dia>/2.0] is a reference to previously declared global variable.
- o100 call [0.0] [0.0] [#<_inside_cutout>-#<_endmill_dia>] [#<_Zcut>] [#<_feedrate>] is mixed literal and named parameters.

9.6.2 Expressions

An expression is a set of characters starting with a left bracket ([) and ending with a right bracket (]). Located between the brackets are numbers, parameter values, binary operators, functions, and other expressions. An expression is evaluated to produce a number. An example of an expression is:
[1 + acos[0] - [#3 ** [4.0/2]]]
All expressions on a line are evaluated when the line is read and before anything on the line is executed.
Read the following sections for reference:

Binary Operators Reference250
Functions Reference..... 250

Binary Operators Reference

Binary operators only appear inside expressions. There are three types of binary operators: mathematical, logical, and relational.

There are four basic mathematical operations: addition (+), subtraction (-), multiplication (*), and division (/). In addition, the modulus operation (MOD) finds the remainder after division of one number by another number. The power operation (**) of raising the number on the left of the operation to the power on the right. There are three logical operations: non-exclusive or (OR), exclusive or (XOR), and logical and (AND).
The relational operators are equality (EQ), inequality (NE), strictly greater than (GT), greater than or equal to (GE), strictly less than (LT), and less than or equal to (LE).

Binary operators are divided into several groups according to their precedence as follows, from highest to lowest:

- 1. **
- 2. * / MOD
- 3. + -
- 4. EQ NE GT GE LT LE
- 5. AND OR XOR

If operations in different precedence groups are strung together, operations with a higher precedence are performed before operations with a lower precedence. If an expression contains more than one operation with the same precedence, the operation on the left is performed first.

EXAMPLE

[2.0 / 3 * 1.5 - 5.5 / 11.0] is equivalent to
[[[2.0 / 3] * 1.5] - [5.5 / 11.0]]
which is equivalent to [1.0 - 0.5]
which is
0.5

The logical operations and modulus are to be performed on any real numbers, not just on integers. The number zero is equivalent to logical false, and any non-zero number is equivalent to logical true.

Functions Reference

- The available functions are:
- ATAN[Y] / [X]: Four quadrant inverse tangent
 - ABS[arg]: Absolute value
 - ACOS[arg]: Inverse cosine
 - ASIN[arg]: Inverse sine
 - COS[arg]: Cosine
 - EXP[arg]: e raised to the given power (ex)

- `FIX[arg]`: Round down to integer
- `FUP[arg]`: Round up to integer
- `ROUND[arg]`: Round to nearest integer
- `LN[arg]`: Base-e logarithm
- `SIN[arg]`: Sine
- `SQRT[arg]`: Square root
- `TAN[arg]`: Tangent
- `EXISTS[arg]`: Check named parameter

9.6.3 Subroutines

Subroutines are subprograms that are called from inside another program.

Read the following sections for reference:

Subroutines Reference	251
Conditional Subroutines Reference	252
Repeating Subroutines Reference	252
Looping Subroutines Reference	252

Subroutines Reference

Subroutines are identified in a program by a unique subroutine label. The subroutine label is the letter `O` followed by an integer (with no sign) between 0 and 99999 written with no more than five digits (000009 is not permitted, for example) or a string of characters surrounded by `<>` symbols.

Examples of valid subroutine labels:

- `O123`
- `O99999`
- `O<my test code>`

Subroutine labels may be used in any order, but they must be unique in a program. Each subroutine label must be followed by a subroutine keyword. The subroutine keyword defines the action associated with the subroutine label.

Valid subroutine keywords and their meanings are:

- `Sub`: Begin subroutine definition
- `Endsub`: End of subroutine definition
- `Call`: Call the subroutine
- `Do/while/endwhile`: Execute the subroutine while a condition is true
- `Repeat/endrepeat`: Execute the subroutine while a condition is true
- `If/elseif/else/endif`: Conditionally execute the subroutine
- `Break`: Break out of a while or if/elseif statement

- `Continue`: Skip remaining code and restart at top of while or repeat loop
- `Return`: Return a value

The `sub` and `endsub` keywords are used to define the beginning and end a subroutine. All lines of code between the `sub` and `endsub` keywords are considered to be part of the subroutine.

Example of `sub`, `endsub`, `call`:

```
O100 sub
G53 G00 X0 Y0 Z0 (rapid move to machine home)
O100 endsub
...
O100 call (call the subroutine here)
M02
```

Subroutines can either be defined in the program file or in a separate file. If the subroutine is defined in the same file as the main program that calls the subroutine, it must be defined before the call statement.

For example, this is valid:

```
O100 sub
G53 G00 X0 Y0 Z0 (rapid move to machine home)
O100 endsub
...
O100 call (call the subroutine here)
M02
```

But this is not:

```
O100 call (call the subroutine here)
M02
O100 sub
G53 G00 X0 Y0 Z0 (rapid move to machine home)
O100 endsub
...
```

A subroutine can be a separate file as long as:

- The file is named the same as your call.
- The file includes a `sub` and `endsub` in the file.
- The file is in the directory `/subroutines`.
- The file name only includes lowercase letters, numbers, dashes, and underscores.
- The file only contains a single subroutine definition.
- The file ends with the extension `.nc`.

9: PROGRAMMING

9.6 Advanced Programming

Note: File names are lowercase letters only.

 `o<MyFile>` is converted to `o<myfile>` by the interpreter.

To execute a subroutine in a program, it must be called. To call a subroutine, program `o~ call` where ~ is the subroutine name. The subroutine name may be either a named file, a numbered file, or an expression that evaluates to a valid subroutine label.

- Expression example: `o[#101+2] call`
- Named file example: `o<myfile> call`
- Numbered file example: `o123 call`

`o~ call` takes up to 30 optional arguments, which are passed to the subroutine as #1, #2, . . . , #N. Unused parameters from #N+1 to #30 have the same value as in the calling context.

Parameters #1-#30 are local to the subroutine. On return from the subroutine, the values of parameters #1 through #30 (regardless of the number of arguments) are restored to the values they had before the call.

The following calls a subroutine with three arguments: `o200 call [1] [2] [3]`

Because 1 2 3 is parsed as the number 123, the parameters must be enclosed in square brackets.

Subroutine bodies may be nested.

- Nested subroutines may only be called after they are defined.
- They may be called from other functions, and may call themselves recursively if it makes sense to do so.
- The maximum subroutine nesting level is 10.

Subroutines do not have return values, but they may change the value of parameters above #30 and those changes are visible to the calling G-code. Subroutines may also change the value of global named parameters.

Conditional Subroutines Reference

Subroutines can be conditionally executed using the if/endif or the if/else/elseif/endif keyword constructs.

if/endif

The if/endif conditional will execute a block of code following the if keyword only when the if argument evaluates to true.

```
If/endif example:
o100 sub
```

```
(notice that the if-endif block uses a different
number)
o110 if [#2 GT 5]
(some code here)
o110 endif
(some more code here)
o100 endsub
```

if/elseif/else/endif

The if/elseif/else/endif conditional will execute the block of code following the if keyword when its argument evaluates to true. If the argument evaluates to false, then the code following each elseif is executed as long as the associated elseif argument evaluates to true. If no elseif keywords are present, or if all elseif arguments evaluate to false, then the code following the else keyword is executed.

```
If/elseif/endif example:
o102 if [#2 GT 5] (if parameter #2 is greater than
5 set F100)
F100
o102 elseif [#2 LT 2] (else if parameter #2 is
less than 2 set F200)
F200
o102 else (else if parameter #2 is 2 through 5 set
F150)
F150
o102 endif
```

Repeating Subroutines Reference

Subroutines can be repeated a finite number of times using the repeat/endrepeat keyword.

```
Repeat example:
(Mill 5 diagonal shapes)
G91 (Incremental mode)
o103 repeat [5]
... (insert milling code here)
G00 X1 Y1 (diagonal move to next position)
o103 endrepeat
G90 (Absolute mode)
```

Looping Subroutines Reference

Subroutines can be looped using the do/while or while/endwhile keyword constructs.

do/while

The do/while loop executes a block of code once and continues to execute the code block until the while argument evaluates to true.

```
Do/while loop example:
#1 = 0 (assign parameter #1 the value of 0)
o100 do
  (debug, parameter 1 = #1)
o110 if [#1 EQ 2]
  #1 = 3 (assign the value of 3 to parameter #1)
  (msg, #1 has been assigned the value of 3)
o100 continue (skip to start of loop)
o110 endif
  (some code here)
#1 = [#1 + 1] (increment the test counter)
o100 while [#1 LT 3]
M02
```

while/endwhile

The while/endwhile repeats a set of statements an indefinite number of times, as long as the while argument evaluates to true.

```
While/endwhile example:
(draw a sawtooth shape)
G00 X1 Y0 (move to start position)
#1 = 1 (assign parameter #1 the value of 0)
F25 (set a feed rate)
o101 while [#1 LT 10]
G01 X0
G01 Y[#1/10] X1
#1 = [#1+1] (increment the test counter)
o101 endwhile
M02 (end program)
```

The following statements cause an error message and abort the interpreter:

- A label on break or continue which does not point to a matching while or do
- A label on endrepeat or endwhile no referring to a corresponding while or repeat
- A return or endsub not within a sub definition
- A label on repeat which is defined elsewhere
- A label on while which is defined elsewhere and not referring to a do
- A label on if defined elsewhere
- A undefined label on else or elseif
- A label on else, elseif or endif not pointing to a matching if



MACHINE MAINTENANCE

IN THIS SECTION, YOU'LL LEARN:

- About the required maintenance procedures that you must do so that this machine operates as designed.



Before operating the machine in any way, you must read and understand this section.

CONTENTS

10.1 Maintenance Safety	256
10.2 Maintenance Schedules	257
10.3 Regular Maintenance	258
10.4 Accessories Maintenance	261

10: MACHINE MAINTENANCE

10.1 Maintenance Safety

10.1 MAINTENANCE SAFETY

Read and understand the following safety messages before beginning any maintenance procedures.

10.1.1 All Maintenance Procedures

- ✓ Understand that the machine is automatically controlled and can start at any time.
- ✓ Power off the machine and disconnect the pneumatic supply before doing any maintenance procedures.
- ✓ When appropriate, lockout/tagout the Main Disconnect switch and the pneumatic supply line before doing any maintenance procedures.
- ✓ Wear safety eye protection rated for ANSI Z87+.

10.1.2 Swarf Maintenance Procedures

- ✓ Wear work gloves.

10.1.3 Coolant Maintenance Procedures

- ✓ Wear rubber gloves.

10.2 MAINTENANCE SCHEDULES

To keep your machine running as smoothly as possible, you must regularly do the following maintenance procedures.



Note: Before you begin any maintenance procedures, read and understand "Maintenance Safety" (on the previous page).

If you disassemble any components, refer to the machine's reference drawings when you've completed the maintenance procedure. For information, see "Diagrams and Parts Lists" (page 285). For any additional support, we can help. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

10.2.1 Daily

- ☐ Clean the way covers of chips.
- ☐ Clean the chip baskets on the coolant tank.
- ☐ Examine the coolant level and condition.
- ☐ Examine the way oil level and refill as necessary.
- ☐ Verify that the regulator has at least 90 psi compressed air (for pneumatic accessories installed, like the Power Drawbar).
- ☐ Verify that the door switches are properly functioning.
- ☐ If you have the flood coolant system installed, examine the filter gauges and replace the filter if necessary.

10.2.2 Weekly

- ☐ Clean all exterior surfaces with a clean rag.
- ☐ Verify that the machine's lubrication points (sliding surfaces and ball screw nuts) are receiving way oil.
- ☐ Examine the enclosure and other guards for damage.
- ☐ Remove vises, fixture plates, rotary tables, and other accessories, and then examine them for rust. If needed, reapply rust inhibitor before reinstalling workholding and accessories.
- ☐ Check coolant concentration.

10.2.3 Monthly

- ☐ Clean the electrical cabinet vents of dust with a clean cloth or compressed air.
- ☐ Clean fine swarf from the coolant tank.

- ☐ Examine all axes' slideway surfaces and ball screws to determine if an oil film is present.
- ☐ Examine the air tool oil level in the FRL Filter-Regulator-Lubricator and refill as necessary.

10.2.4 Semi-Annually



Note: After the first 90 days of operation, complete the items on this list. After that, complete the items every six months.

- ☐ Examine the spindle belt for wear.
- ☐ Examine the way covers for wear.

10.2.5 Annually

- ☐ Remove the way covers and examine them for wear. Clean any chips or oil underneath the way covers.
- ☐ Examine the windows and replace them if necessary.
- ☐ Check the machine's backlash.

10: MACHINE MAINTENANCE

10.3 Regular Maintenance

10.3 REGULAR MAINTENANCE

10.3.1 Clean the Way Covers.....

10.3.2 Clean the Coolant System.....

10.3.3 Examine the Enclosure Windows.....

10.3.4 Lubricate the Machine.....

10.3.5 Examine the Spindle Belt.....

10.3.6 Prevent Rust.....

258

258

259

259

260

260

10.3.1 Clean the Way Covers

To extend the service life of the machine, you must make sure that the way covers are protecting the machine's slideways.

Regularly do the following:

- Examine the way covers for signs of wear or damage. If the way covers are damaged, you must replace them.
 - "Y-Axis Front Way Cover Assembly" (page 335)
 - "Y-Axis Rear Way Cover Assembly" (page 337)
 - "Z-Axis Way Cover Assembly" (page 341)
- Use a chip brush to clean the way covers of chips and other swarf.

10.3.2 Clean the Coolant System

To extend the service life of the coolant and the coolant pump, you must make sure that both are free of contaminants.

Regularly do the following:

- Use a chip brush to clean the machine, chip trays, and enclosure of chips and other swarf.
- Empty the chip strainer on the coolant tank.
- Measure the coolant concentration, pH, and volume, and then compare your findings to the material's safety data sheet (SDS).
 - **Coolant Level Too Low** Fill the coolant tank with fresh coolant, making sure that it is the appropriate concentration.
 - **Coolant pH Outside of Manufacturer's Recommended Coolant Limits** Adjust the pH according to the manufacturer's recommendation.



Note: You must only use coolant that is recommended for machining. See "Cutting Fluid Reference" (below).

- Examine the coolant pump's impeller for blockages.

- To remove tramp way oil from the coolant tank, use one of the following:
 - Oil Skimmer Kit for 1500MX (PN 53859)
 - Floating Tramp Oil Collection Pillow (PN 31925)

Periodically do the following:

- Remove the coolant tank covers and the chip strainer, and then clean the fine swarf from the coolant tank.
- If you're using a filter to prevent small particles from entering the coolant tank, replace it when it's saturated with chips, swarf, or tramp oil.
- Examine the coolant for contamination, and determine if the coolant's oil-water emulsion has broken.
- Drain and thoroughly clean the coolant tank, and then replace with fresh coolant.

NOTICE! Hazardous Waste: Only dispose of coolant as advised by local environmental protection authorities. You must not dispose of coolant in a septic system or a sewer.

About Cutting Fluid

Clean and well maintained coolant has increased performance, prevents rust, and smells better than contaminated coolant.

Coolant becomes contaminated when:

- Swarf accumulates in the chip pans, the chip strainer, or the coolant tank.
- Tramp oil isn't regularly removed from the coolant tank.
- The concentration or pH aren't maintained to the manufacture's specifications.

Cutting Fluid Reference

Using flood coolant provides the following benefits:

- Cools the cutting zone
- Flushes away swarf
- Lubricates the cutting tool
- Provides some degree of rust inhibition

You must only use flood coolant that is recommended for CNC machining applications, like:

- Soluble oils
- Semi-synthetic coolants
- Synthetic coolants

You must never use:

- Coolant without rust inhibitors
- Flammable coolants such as alcohols, diesel fuel, or kerosene

 **WARNING!** Fire Hazard: The machine and its enclosure are not designed to contain fire or explosions. Only use materials and coolants that are intended for the specific machining operation. Never use flammable or explosive items.

- Straight cutting oil
- Water

If you use a coolant concentrate, you must mix it with water to the dilution ratio recommended by the coolant manufacturer. Use an optical refractometer to measure coolant concentration.

10.3.3 Examine the Enclosure Windows

Regularly examine the enclosure windows (if equipped), and all other guarding, for signs of wear or damage.

When required, replace the windows with the following parts:

- Refer to "Enclosure" (page 298) to view the enclosure's diagrams and parts lists.

10.3.4 Lubricate the Machine

To keep the machine operating properly, and to extend the service life of the machine, you must verify that the linear guides and ball screws are receiving lubrication.

Regularly do the following:

- Clean the oil reservoir's cover and all exposed surfaces surrounding the oil reservoir. Swarf or debris that enters the oil reservoir can plug the small, internal passages of the lubrication system.

 **Note:** The strainer at the top of the oil reservoir isn't a filter, and can't remove all types of debris that may cause blockages.

- Examine all axes' linear guides and ball screws to determine if an oil film is present. If there's not an oil film, examine the lubrication system for blockages, broken fittings, or pinched oil lines.

- Examine the amount of available oil and, if necessary, refill with Citgo EP Compound 220 Oil (PN 52499) or equivalent.

About the Automatic Oiler

The automatic oiler is powered whenever the machine is powered on. To prevent the excess use of oil, we recommend powering off the machine at the end of day to prevent the automatic oiler from continuing to pump oil overnight.

The automatic oiler has the following settings:

- 100% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)



Note: Each time the machine is powered on, it pumps oil for the amount of time equal to the actuation time. For this reason, we recommend setting the lubrication interval to 480 minutes (8 hours). This ensures that the machine has enough oil for a full eight-hour shift each time the machine is powered on.

- Actuation time: 7 seconds
- 75% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)
 - Actuation time: 5 seconds
- 50% Duty Cycle
 - Lubrication interval: 480 minutes (8 hours)
 - Actuation time: 4 seconds

About Actuation Time

The lubrication interval and actuation time are set from the factory for a 100% duty cycle. These settings assume the machine is running at maximum velocity 24 hours per day, 7 days per week. As a result, this tends to deliver more oil than is needed for most applications. To prevent excess usage of oil, we recommend that you adjust the actuation time of the automatic oiler to match the duty cycle that best fits your application.

When you estimate the duty cycle that best fits your application, the best indicator is the actual spindle run time for the machine during a standard eight-hour shift. Consider what percentage of that eight-hour shift the machine is running and

10: MACHINE MAINTENANCE

10.3 Regular Maintenance

cutting material versus the time spent for changing parts, setting up fixtures, and idle down time.

Lubrication System Reference

The machine's lubrication system distributes oil to the following 15 points:

- 12 linear guide blocks
 - Four on the X-axis
 - Four on the Y-axis
 - Four on the Z-axis
- Three ball screw nuts

10.3.5 Examine the Spindle Belt

To extend the service life of the spindle belt, you must regularly examine it for signs of damage or wear.

If the spindle belt is damaged, you must replace it with Belt, 1500MX Spindle (PN 51735).

10.3.6 Prevent Rust

Take proper care to protect all exposed iron and steel surfaces on your machine. To reduce the possibility of rust, you must regularly do the following:

- Clean the machine, chip pans, and enclosure of chips and other swarf with a chip brush.
- Clean all exterior surfaces with a mild cleaner.
- Only use flood coolant that is recommended for machining (see "Cutting Fluid Reference" (page 258)).
- Periodically test the coolant concentration, and adjust (if necessary) to meet coolant manufacturer's recommended concentration.
- Put LPS 3® (or similar rust inhibitor) on the machine before installing any workholding or accessories.
- Only operate the machine in a temperature- and humidity-controlled environment. Extreme changes in temperature or humidity can create condensation on the machine.
- Put LPS 3® (or similar rust inhibitor) on all exposed, non-painted metal surfaces before leaving the machine unused.
- Remove all workholding and accessories, and then check for rust.
- If needed, reapply rust inhibitor before reinstalling workholding or accessories.

If you find rust on the machine table, go to "Remove Rust" (below).

Remove Rust

Use a fine machinist's stone to remove light surface rust on the machine table: use light, even pressure, and move the stone in a random motion to avoid changing the flatness of the machine table.

If you find a lot of rust, or if there is rust on the machine's slideways or ball screws, take photos of all rust-covered areas.

Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

10.4 ACCESSORIES MAINTENANCE

10.4.1 Chip Conveyor Maintenance Schedule

Daily

- ☐ Inspect the coolant level in the tank and refill as needed.
The coolant level in the tank should be filled to just below the top of the conveyor belt.
- ☐ Run the chip conveyor for two full revolutions of the conveyor belt to help clear any chips that have collected in the bottom of the conveyor.

Monthly

- ☐ Inspect the conveyor belt for wear or damage. Verify smooth conveyor movement without interruptions.
- ☐ Verify that safety guards and covers are properly secured.
- ☐ Check the conveyor belt tension and adjust as needed.
- ☐ Inspect the coolant tank for fine swarf buildup and clean as needed.



Note: The amount of swarf buildup in the coolant tank depends on several factors, including the material being cut, the tools used, and the toolpaths programmed. The chip conveyor is equipped with stainless steel wire mesh screens designed to prevent most chips from entering the coolant tank. However, fine particles resulting from light cuts, chip recutting, or materials that tend to produce small chips may pass through the screens. Regularly monitor the coolant tank and adjust cleaning frequency based on operating conditions to prevent excessive buildup.

Semi-Annually

- ☐ Grease the drive shaft bearing blocks.



TROUBLESHOOTING

IN THIS SECTION, YOU'LL LEARN:

- About common causes of failure in this machine, and our recommendations for diagnosing and correcting them.



WARNING! Electrocution Hazard - Electrical Cabinet: Do not make or disconnect connections under power.



Before operating the machine in any way, you must read and understand this section.

CONTENTS

11.1 Troubleshooting Safety.....	264
11.2 Getting Help.....	265
11.3 Required Tools.....	266
11.4 Frequently Found Problems.....	267
11.5 Electrical Service.....	268
11.6 Power Distribution Subsystem.....	271
11.7 Control Power Subsystem.....	273
11.8 Servo Drive Subsystem.....	274
11.9 Spindle Drive Subsystem.....	279
11.10 Servo IO Breakout Board Subsystem.....	284



TORMACH®

11: TROUBLESHOOTING

11.1 Troubleshooting Safety

11.1 TROUBLESHOOTING SAFETY

Read and understand the following safety messages before beginning any troubleshooting procedures.

- ✓ Take things slow and be extra cautious. During troubleshooting, you're exposed to more hazards than during normal operation. For example, you may have to do an electrical test on a live circuit, remove guards, or override a safety switch to make an observation.
- ✓ Power off the machine and disconnect the pneumatic supply before doing any troubleshooting procedures.
- ✓ When appropriate, lockout/tagout the Main Disconnect switch and the pneumatic supply line before doing any troubleshooting procedures.

11.2 GETTING HELP

We provide no-cost technical support through multiple channels. The quickest way to get the answers you need is normally in this order:

1. Read this document.
2. Read related documents and watch related videos at tormach.com/support.
3. If you still need answers, gather the following information so that we may help you as quickly as possible:
 - Your phone number, address, and company name (if applicable).
 - Machine model and serial number, which are located on the side of the electrical cabinet, next to the Main Disconnect switch.
 - The version of PathPilot that you're running.
 - Any accessories that you have for your machine.
 - A clear and concise description of the issue.
 - Any supporting media and information that you can share with us. For example, you could:
 - Analyze what might have changed since the machine last worked correctly.
 - Record a short video.
 - Take a picture of a part.
 - For software, share log data .zip files, screen captures, or program files.
For information, see "Share Log Data .zip Files" (below).
 - From the PathPilot interface, on the Status tab, record any available information.
 - Use a digital multimeter for voltage readings.
4. Once you've gathered the information in Step 3, contact us in the following ways:
 - a. Create a support ticket: Go to tormach.com/how-to-submit-a-support-ticket
 - b. Phone: (608) 849-8381 (Monday through Friday, 8 a.m. to 5 p.m. U.S. Central Standard Time)

Share Log Data .zip Files

The controller keeps log data on how the machine has been working, which you can export as a .zip file. This information helps us troubleshoot software situations much faster.

To share log data .zip files:

1. Put a USB drive into the PathPilot controller.
2. From the PathPilot controller, on the **Status** tab, select **Log Data**.
PathPilot creates a file called **logdata_[TODAY'S-DATE].zip**, and saves it on your USB drive.
3. Remove the USB drive from the controller. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

11: TROUBLESHOOTING

11.3 Required Tools

11.3 REQUIRED TOOLS

This procedure requires the following tools. Collect them before you begin.

- #2 Phillips screwdriver
- #3 Phillips screwdriver
- 1/8 in. flat-blade screwdriver
- 3/16 in. flat-blade screwdriver
- Digital multimeter that can test for:
 - Vac volts (up to 300 Vac)
 - Vdc volts (up to 100 Vdc)
 - Resistance (from 0 to 1M ohms)
 - Hz (frequency)
- Electrical safety gloves
- Measuring tools (like a tape measure, calipers, or dial indicator with magnetic base)
- Metric hex wrench set
- Needle nose pliers
- Trouble light, headlamp, or flashlight
- Wire stripper

11.4 FREQUENTLY FOUND PROBLEMS

There are several frequently found problems with all electromechanical machinery. Among the problems that have occurred, we've found that the following are more frequent than others:

- **Loose Wires**



Note: Before you begin the two-finger pull test, we recommend taking photos of the inside of the electrical cabinet to serve as a visual reference while reconnecting any loose wires.

To determine if a wire is loose, use the two-finger pull test:

1. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
2. With your thumb and index finger, hold the wire close to its termination point, and gently tug each wire.
3. If the wire comes loose, re-terminate and reconnect it before moving on to other wires.

- **Poor Cable Connections**

An improperly seated cable may allow some functions to work but cause others not to. We have found that the ribbon cables' plug connections can become loose during the shipping process.

1. Power off the machine and the PathPilot controller.
 - a. Push in the machine's red Emergency Stop button, which removes power to motion control.
 - b. From the PathPilot interface, select **Exit**.
 - c. Turn the Main Disconnect switch to **OFF** on the side of the electrical cabinet.
2. Unplug and firmly reseal connectors.

11: TROUBLESHOOTING

11.5 Electrical Service

11.5 ELECTRICAL SERVICE

11.5.1 LED Identification

 **WARNING!** Electrocution Hazard: When servicing the machine from inside the electrical cabinet, always use caution. Points in the electrical cabinet have high voltages that can electrocute or shock you. Even after you've powered off the machine, electronic devices in the electrical cabinet may retain dangerous electrical voltages. Only qualified electrical machinery technicians should perform maintenance or troubleshooting procedures inside the electrical cabinet while power is still on.

Many electrical problems are self-apparent, and you can trace them by observing LEDs in PathPilot, LEDs in the electrical cabinet, and the machine's actions.

LEDs in PathPilot indicate output or functional status — including the LEDs on the Status tab, which are useful for indicating if any inputs or outputs are operational.

There are various LED indicators in the electrical cabinet. Among these are:

- IO Control Board Indicators**

Category	Function	LED Identifier
General	Control Power	D37
	Output Power	D38
	E-Stop Status	D39
Input Status	Accessory Input 1	D20
	Accessory Input 2	D21
	TSC Input 1	D22
	TSC Input 2	D23
	Probe Trigger	D24
	Probe Battery	D26
	Probe Error	D27
	Enclosure Lock	D28
	Power Drawbar Button	D30
	Spindle Index Sensor	D34

Category	Function	LED Identifier
Output Status	Flood Coolant	D40
	Washdown Coolant	D41
	Accessory Output 1	D52
	Probe Activation	D42
	Toolsetter Activation	D43
	MQL (Mist)	D53
	Enclosure Door Lock LED	D44
	TSC Power	D45
	Z-Axis Brake	D54
	Power Drawbar	D50
	Power Drawbar LED	D51
	Spindle Drive Contactor Start Pulse	D57

- **Axis Indicators on the X-, Y-, Z-, and A-Axis Drivers** Each Driver has a five-digit LED display used to show the servo's status, parameter settings, and error codes.
- **PS1 24 Vdc Power Supply** The power supply has a power on LED.
- **S1 Door Latch Push Button** The push button has an integrated status light that shows the machine is in an operating state where unlatching the door is allowed.
- **S4 Power Drawbar Push Button** The push button has an integrated status light that shows the machine is in an operating state where manually unclamping the power drawbar is allowed to facilitate tool changes.
- **PathPilot Operator Console** Console has an integrated RGB status light that indicates the current machine operating state or fault condition.

11.5.2 Overview

The 1500MX electrical system consists of several interrelated subsystems:

- **230 Vac Power Distribution** Provides 230 Vac mains power to servo drives. Also provides pass-through power for accessory devices (such as flood and washdown coolant pumps, the PathPilot console, Automatic Tool Changer (ATC), and automatic oiler) and auxiliary devices (such as enclosure lights).
- **24 Vdc Safety and Control** Provides 24 Vdc power to the Servo IO breakout board, electrical cabinet and spindle head fans, as well as output devices powered through the Servo IO breakout board via the board's J2 connector.
- **Servo Drives** The four servo drives power and control the machine's spindle motor and three axis motors. Each servo drive includes motor power and encoder connections, a dedicated IO connection, and a Safe Torque Off (STO) connection. The STO functionality allows the drive to be safely disabled in the event of an Emergency Stop or machine fault. Additionally, each servo drive communicates with the PathPilot controller using an EtherCAT® fieldbus connection. Accessories such as the microARC 6 and ATC include additional servo drives that are connected to the EtherCAT fieldbus system. The servo drives are also capable of reporting diagnostic information and error codes through the PathPilot controller via the EtherCAT fieldbus system.

11: TROUBLESHOOTING

11.5 Electrical Service

- **Servo IO Breakout Board** The machine's main control board is the primary interface between the individual servo drives' input and output lines and the sensors and devices connected to them. The Servo Breakout Board connects to the X, Y, Z and Spindle servo drives via the IO-4, IO-5, IO-7, and IO-1 cables respectively. The Servo Breakout Board has additional connectors for the Emergency Stop/Reset push buttons, power drawbar system, and enclosure door latch system as well as connectors for various accessories (including the wireless probe/toolsetter, TSC pump, and MQL system).

11.6 POWER DISTRIBUTION SUBSYSTEM

Electrical power is run through a single power cord to the Main Disconnect switch. This switch controls all power to the machine, major accessories, including the flood and washdown coolant pumps, and the PathPilot controller.

To troubleshoot the power distribution subsystem, read the following:

11.6.1 The Machine Won't Power On	271
11.6.2 The PathPilot Operator Console Won't Power On	271

11.6.1 The Machine Won't Power On

Cause: The machine isn't plugged in to an outlet.

Probability	How-To Steps	Need More?
High	➤ Reseat the NEMA L6-30 plug into an outlet.	If needed, measure for 208 Vac-240 Vac between wires 1001 and 1002/N at the DISC1 Main Disconnect.

Cause: The facility's mains breaker tripped.

Probability	How-To Steps	Need More?
High	➤ Examine power cable for damage or exposed wires, and then reset your facility's circuit breaker serving the machine.	If needed measure for 208 Vac-240 Vac between wires 1001 and 1002/N at the DISC1 Main Disconnect.

Cause: The CB1 circuit breaker tripped.

Probability	How-To Steps	Need More?
High	➤ If the machine, controller, accessories, and enclosure lights don't have power, examine the power cord(s) and wires for damaged or exposed wires, and then reset the CB1 circuit breaker.	If needed measure for 208 Vac-240 Vac between wires 1005 and 1006/N at the CB1 circuit breaker.

Cause: The Main Disconnect switch is in the OFF position.

Probability	How-To Steps	Need More?
High	➤ Switch DISC1 Main Disconnect to the ON position.	If needed, measure for 208 Vac-240 Vac between wires 1003 and 1004/N at the DISC1 Main Disconnect.

11.6.2 The PathPilot Operator Console Won't Power On

Cause: The PathPilot operator console isn't plugged in to an outlet.

Probability	How-To Steps	Need More?
High	➤ Reseat the power cord connection at both the electrical cabinet outlet (XS44) and the controller.	It's possible that the power cord could become loose from movement. If needed, measure for 208 Vac-240 Vac between wires 1062 and 1063/N at the XS44 Controller/Monitor outlet.

11: TROUBLESHOOTING

11.6 Power Distribution Subsystem

Cause: The CB2 circuit breaker tripped.		
Probability	How-To Steps	Need More?
Medium	➤ If the operator console, automatic oiler, flood coolant pump, washdown coolant pump, and automatic tool changer don't have power, examine the power cords and wires for damaged or exposed wires, and then reset the CB2 circuit breaker.	CB2 affects the operator console, automatic oiler, flood coolant pump and washdown coolant pump. If needed, measure for 208 Vac-240 Vac between wires 1013 and 1014/N at the CB2 circuit breaker.
Cause: Missing X1 Terminal Block jumper.		
Probability	How-To Steps	Need More?
Low	➤ If one or more of following don't have power - operator console, automatic oiler, flood coolant pump, and washdown coolant pump – check that the jumper is in position between terminals 9 and 10 on the X1 terminal block	CB2 affects the operator console, automatic oiler, flood coolant pump and washdown coolant pump. If needed, measure for 208 Vac-240 Vac between wires 1013 and 1014/N at the CB2 circuit breaker.

11.7 CONTROL POWER SUBSYSTEM

To troubleshoot the control power subsystem, read the following:

11.7.1 The Machine Won't Power On 273

11.7.1 The Machine Won't Power On

Cause: The Emergency Stop button is pushed in.

Probability	How-To Steps
High	➤ Twist out the Emergency Stop button and press the Reset button.

Cause: The DC power supply PS1 is defective.

Probability	How-To Steps	Need More?
Medium	- Check if Electrical Cabinet Fan (FAN1) and Spindle Motor Fan (FAN2) are running. - Check for DC OK LED on PS1 DC power supply. - Check for Control Power (D37) LED on E1 Servo IO Breakout Board. - Measure for 208 Vac-240 Vac between wires 1032 and 1033/N at the PS1 DC power supply. - Measure for 24 Vdc nominal between wires 4001 and 4002 at the PS1 DC power supply.	Before you replace the DC power supply, power off the machine (see "Power off the Machine" (page 83)).

Cause: The DC power supply PS1 output voltage is too low.

Probability	How-To Steps
Low	- Check if Electrical Cabinet Fan (FAN1) and Spindle Motor Fan (FAN2) are running. - Check for DC OK LED on PS1 DC power supply. - Measure for 208 Vac-240 Vac between wires 1032 and 1033/N at the PS1 DC power supply. - Measure for 24 Vdc nominal between wires 4001 and 4002 at the PS1 DC power supply. - If output voltage is less than 24 Vdc, adjust the output voltage using the +V ADJ trim potentiometer on the front of the PS1 DC power supply.

Cause: The CB1, CB2, or CB4 circuit breaker tripped.

Probability	How-To Steps	Need More?
Low	➤ Examine the power cords and wires for damaged or exposed wires, and then reset the circuit breaker.	If needed, measure for 208 Vac-240 Vac between wires 1005 and 1006/N at the CB1 circuit breaker, between wires 1013 and 1014/N at the CB2 circuit breaker, and between wires 1020 and 1021/N at the CB4 circuit breaker.

11: TROUBLESHOOTING

11.8 Servo Drive Subsystem

11.8 SERVO DRIVE SUBSYSTEM

The servo drives provide power and control to the X-, Y-, Z-, and A-axis motors as well as the spindle motor. The servo drives communicate with PathPilot via the EtherCAT fieldbus connection. Each servo drive also handles a dedicated group of IO connections.

To troubleshoot the axes drive subsystem, read the following:

11.8.1 All Axes Won't Move When Commanded	274
11.8.2 One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move	275
11.8.3 Axis Movement is Noisy	276
11.8.4 Lost Motion on Axis Travel	277

11.8.1 All Axes Won't Move When Commanded

Cause: Control signals aren't reaching the servo motors.

Probability	How-To Steps	Need More?
High	1. Power off the machine (see "Power off the Machine" (page 83)). 2. Examine the EtherCAT® connectors at each servo drive. All servo drives must be connected for the machine to function. Verify that the connectors are firmly seated, and examine the connectors for loose or damaged pins.	Examine the DATA-12, DATA-2, DATA-4, DATA-6, and optional DATA-8 and DATA-10 cables connecting the servo drives. Also examine the Ethernet cable connecting the ETH1 Machine Control Connector to the PathPilot controller.

Cause: PathPilot isn't commanding the move due to a Hold-to-Run condition.

Probability	How-To Steps
High	1. Jog the axes and, from the PathPilot interface, examine the value displayed in their DRO fields. If the position doesn't change while you're jogging, using hold to run is required while the enclosure door is open. 2. Close the enclosure door. 3. From the PathPilot interface, select the Main tab, then press the Esc key on the keyboard. 4. On the keyboard, press and hold one of the Arrow keys to jog an axis and examine the value displayed in its DRO field. 5. Using the jog pendant, select either the X- or Z-axis, then turn the jog wheel, and examine the value displayed in its DRO field. 6. Open the enclosure door. On the keyboard, press and hold an Arrow key to jog an axis. Using the arrow keys jogs the axis and functions as a hold-to-run button. 7. With the enclosure door open, press and hold the Hold-to-Run button on the side of the jog pendant. Then turn the jog wheel and examine the value displayed in the DRO field. 8. If the problem persists, insert the key into the top of the operator console and switch to Setup mode. Then, repeat Steps 1 through 7. 9. If the problem persists, there may be a problem with the controller. Restart the controller. Then, repeat Steps 1 through 8.

Cause: PathPilot isn't commanding the move, or there's a controller problem.

Probability	How-To Steps
Low	1. Jog the axes and, from the PathPilot interface, examine the value displayed in their DRO fields. If the position doesn't change while you're jogging, there's a problem with the controller. 2. Select the Main tab, then, on the keyboard, select the Esc key. 3. Try to jog the axes again, and examine the value displayed in their DRO fields. 4. If the problem persists, restart the controller.

11.8.2 One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move

Cause: The servo drive has an error present.

Probability	How-To Steps
Low	1. Examine the servo drives in the electrical cabinet for an error code. 2. Power the machine on and off, and the trip should reset. 3. If the problem continues, we can help. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.

Cause: There's a loose axis motor coupling.

Probability	How-To Steps
Low	• Jog the axis and listen to determine if you can hear the motor run. • Examine the coupling and make witness marks to determine if the motor's turning but the screw isn't.

Cause: Oil isn't getting to the ways and ball screw.

Probability	How-To Steps
Low	1. Examine the oil level in the oiler. 2. Investigate the oiling system for lack of oil and/or plugged lines.

Cause: There's oil residue from long-term storage.

Probability	How-To Steps
Low	➤ Repeatedly pump oil and slowly jog the axis.

11: TROUBLESHOOTING

11.8 Servo Drive Subsystem

Cause: There's debris on the ball screw.

Probability	How-To Steps	Need More?
Low	➤ Clean the ball screw.	Debris on the ball screws can rapidly accelerate wear and reduce the lifespan of your machine. Evaluate if additional measures are required to protect your machine's ball screws and ways (like supplemental dust collection).

11.8.3 Axis Movement is Noisy

Before You Begin

 **WARNING!** Electrocution Hazard: When servicing the machine from inside the electrical cabinet, always use caution. Points in the electrical cabinet have high voltages that can electrocute or shock you. Even after you've powered off the machine, electronic devices in the electrical cabinet may retain dangerous electrical voltages. Only qualified electrical machinery technicians should perform maintenance or troubleshooting procedures inside the electrical cabinet while power is still on.

Some procedures in this section require servicing the machine from inside the electrical cabinet. Before you begin, you must identify a qualified electrical machinery technician to perform the procedures.

Cause: There's loose sheet metal.

Probability	How-To Steps	Need More?
High	➤ Feel for vibrating sheet metal.	Loose sheet metal is mistakenly diagnosed as a noisy axis motor. On some systems, certain axis motor speeds can cause audible vibration.

Cause: The machine's foot spacer is loose.

Probability	How-To Steps
High	➤ Check that each foot spacer is tight against the base casting's foot plates.

Cause: There's a loose wire connection or failed connector on a driver.

Probability	How-To Steps	Need More?
High / Low	➤ Power off the machine (see "Power off the Machine" (page 83)). Then, check all driver connections.	Examine the green power connector for signs of overheating.

Cause: There's a defective servo motor.

Probability	How-To Steps	Need More?
Medium	➤ See "One Axis Won't Move (or Only Moves in One Direction), and Other Axes Move" (on the previous page).	There have been cases of a noisy axis relating to a defective servo motor. This may be temperature-dependent.

11.8.4 Lost Motion on Axis Travel

Cause: Improper use of tool offset, work offset, or cutter compensation.		
Probability	How-To Steps	Need More?
High	➤ Examine the G-code programs. You must fully understand tool offsets, work offsets, and cutter compensation.	The most common cause of a perceived loss of position is operator error.
Cause: The motor coupling is loose or cracked.		
Probability	How-To Steps	Need More?
Low	➤ Examine the motor coupling.	You may find it useful to carefully run the axis with the cover removed. Make a paint line from the shaft through the coupling to the screw to examine if there's any movement over time.
Cause: The Z-axis brake isn't releasing.		
Probability	How-To Steps	Need More?
Low	➤ Slowly jog the Z-axis: if the brake isn't releasing, the Z-axis will usually move down properly, but won't move up. A faulty Z-axis brake can over-torque and fault the Z-axis motor.	You should be able to hear the motor whenever you command the axis to move. Usually, the brake alone does not have the torque to cause a loss of motion. A condition like poor lubrication in combination with a defective Z brake are required to actually lose position.
Cause: Controller or PathPilot problem.		
Probability	How-To Steps	Need More?
Low	➤ Restart the controller and send the log file (from the logfiles directory) to Tormach Technical Support. Create a support ticket with Tormach Technical Support at tormach.com/how-to-submit-a-support-ticket for guidance on how to proceed.	For information, see "Getting Help" (page 265).

11: TROUBLESHOOTING

11.8 Servo Drive Subsystem

Cause: There's an obstruction or excessive friction, or there's high load in the mechanical system.

Probability	How-To Steps	Need More?
Low	➤ Jog the axis and carefully observe the motion.	Typical mechanical issues include: an increase in friction due to lack of oil at the linear way surfaces or ball screw. They also come from excessive load on the system due to chips or debris a sticking Z-axis brake or an end-of-travel bumper wedged against the motor mount casting. Excessive chip and debris, or a lack of lubrication can also increase the load applied by the way covers. When MQL coolant is used, the way covers' panels should be lubricated with a light oil to reduce friction due to their seals.

11.9 SPINDLE DRIVE SUBSYSTEM

The machine's spindle is driven by a servo motor controlled by the **DR1** servo drive.

The spindle is in a ready-to-run condition when:

1. The control power is on.
2. The machine is reset.
3. The enclosure doors are closed.
4. The spindle brake resistor thermal switch isn't tripped.

To troubleshoot the spindle drive subsystem, read the following:

11.9.1 The Spindle Won't Turn	279
11.9.2 Machining Operations are Loud ("Chatter")	281
11.9.3 Can't Load or Unload a Tool, or the Spindle's Drawbar Drags Against the Power Drawbar Cylinder's Piston	283
11.9.4 Spindle Rotates on Contact, or Spindle Isn't Rigidly Clamped	283
11.9.5 Spindle Doesn't Orient Correctly or Consistently	283

11.9.1 The Spindle Won't Turn

Cause: The motor runs, but the spindle doesn't turn.

Probability	How-To Steps	Need More?
Low	➤ Examine the spindle belt for wear or damage.	If the display on the servo drive is on, the belt may be loose or broken. You'll hear the spindle motor running.

Cause: There's no power to the spindle servo drive.

Probability	How-To Steps	Need More?
—	➤ Examine the servo drive display: it has power if its indicator lights are on.	When power is removed, the servo drive display remains active until the internal capacitors dissipate their energy. That usually takes about five seconds.

11: TROUBLESHOOTING

11.9 Spindle Drive Subsystem

Cause: There's no power to the servo drive output stage.

Probability	How-To Steps
High	There are loose power or control wires in the K1 contactor circuit. 1. Power off the machine (see "Power off the Machine" (page 83)). 2. Examine the circuit for loose wires. 3. Power on the machine (see "Power on the Machine" (page 81)) and reset the machine. Then, test operation. 4. Check for 24 Vdc between wires 4015 and 4105 at the K1 contactor coil.
Probability	How-To Steps
Low	Thermal switch (TS1) tripped, preventing K1 from latching. 1. Power off the machine (see "Power off the Machine" (page 83)). 2. Allow the brake resistor to cool, and reset thermal switch by pressing reset button (between its two terminals). 3. Power on the machine (see "Power on the Machine" (page 81)) and reset the machine. Then, test operation. 4. Check for 24Vdc between wires 4015 and 4105 at the K1 contactor coil.
Probability	How-To Steps
Low	The control board isn't providing a run command or holding the K1 contactor on. 1. Check D57 Spindle Drive Contactor Start Pulse LED on the Servo IO Breakout Board as you command a spindle rotation through PathPilot. 2. Check for 24 Vdc between wires 4088 and 4105 at the J29 connector on the Servo IO Breakout Board.

Cause: The servo drive tripped.

Probability	How-To Steps
Low	➤ If the servo drive tripped, check the error code and troubleshooting steps on the PathPilot Status screen.

Cause: The belt is loose or broken, or sheaves are not fixed to the motor or the spindle.

Probability	How-To Steps
Low	➤ Power off the machine (see "Power off the Machine" (page 83)). Then, examine the mechanical system.

Cause: The motor is defective.

Probability	How-To Steps	Need More?
Low	1. Power off the machine (see "Power off the Machine" (page 83)). 2. Wait 30 seconds and check for voltage, and then remove wires 2001, 2002, and 2003 from the servo drive's power connector. 3. Measure the resistance between: • Wires 2001 and 2002 • Wires 2002 and 2003 • Wires 2003 and 2001 Resistance should be in the range of approximately 2-4 Ω. 4. Reconnect wires to the appropriate servo drive power connector terminals.	• 0 Ω indicates that the winding is shorted. • >1M Ω indicates that the winding is open. Both cases indicate a defective motor or compromised wiring to the motor from the servo drive.

11.9.2 Machining Operations are Loud ("Chatter")

Cause: Inappropriate cutting parameters or CAM settings.

Probability	How-To Steps
High	1. Verify that you're using the correct cutting parameters: use the feed rate and spindle overrides to adjust cutting parameters during operation. 2. Confirm that tool offsets are correct.

Cause: Worn or broken cutting tools.

Probability	How-To Steps
High	➤ Inspect for worn or broken cutting tools, and replace as necessary.

Cause: Swarf in the spindle or on the tool holder's shank.

Probability	How-To Steps
Medium	1. Inspect inside the spindle and on the tool holder's shank for swarf. If necessary, clean the components. 2. Verify that the spindle and tool holder's contact surfaces are clean, dry, and free of grease or oil.

11: TROUBLESHOOTING

11.9 Spindle Drive Subsystem

Cause: Insufficient preload of drawbar springs.

Probability	How-To Steps
Medium	Verify that there's sufficient preload of the drawbar disc springs: 1. Examine the shop air pressure, and verify that there's a minimum of 90 psi compressed air at the machine's FRL Filter-Regulator-Lubricator. If the machine's inlet air pressure is too low, it limits the machine's maximum tool clamping force. 2. Adjust drawbar preload nut to ensure the clamping force is in the range from 300-400 kgf and the spindle smoothly and reliably clamps and unclamps tool holders. 3. Verify that the clamping force is increased as high as possible while still smoothly and reliably clamping and unclamping tool holders.

Cause: Under- or over-tightened pull stud.

Probability	How-To Steps
Medium	➤ Use the following items to tighten the pull studs to 40 Nm (30 ft lb) of torque: ◦ Socket, BT30 Pull Stud (PN 39420) ◦ Tool Tightening Fixture, BT30 (PN 39681) ◦ Torque wrench Under- or over-tightening the pull studs can cause poor contact between the tool holder and the spindle taper.

Cause: Cracked or broken drawbar disc springs.

Probability	How-To Steps
Low	➤ Remove the disc springs from the drawbar assembly and inspect them for damage. If you find any cracked or fractured springs, replace all disc springs in the stack with Disc Spring, 25 mm × 12.2 mm × 1.5 mm (PN 52490). Adjust drawbar preload nut to ensure the clamping force is in the range from 300-400 kgf and the spindle smoothly and reliably clamps and unclamps tool holders.

Cause: Incorrect pull stud used for the machine.

Probability	How-To Steps
Low	➤ Verify that all pull studs used in the machine are of the appropriate type. NOTICE! You must only use BT30-45° (ISO7388-3-JF30-45) type pull studs with this machine (Pull Stud, BT30-45° (PN 37553)). Other pull stud types or angles can cause damage to the pull stud clamping mechanism. If you find incorrect pull studs used in the machine, remove the pull studs from service, and inspect the clamping mechanism for damage. If you find any damage, replace it with Drawbar Assembly Rebuild Kit, 1500MX (PN 52320).

11.9.3 Can't Load or Unload a Tool, or the Spindle's Drawbar Drags Against the Power Drawbar Cylinder's Piston

Cause: Insufficient shop air pressure.

Probability	How-To Steps
High	➤ Examine the shop air pressure, and verify that there's a minimum of 90 psi compressed air at the machine's FRL Filter-Regulator-Lubricator.

Cause: Insufficient or excessive preload of drawbar springs.

Probability	How-To Steps
Medium	Verify that there's sufficient preload of the drawbar disc springs: 1. Examine the shop air pressure and verify that there's a minimum of 90 psi compressed air at the machine's FRL Filter-Regulator-Lubricator. If the machine's inlet air pressure is too low, it limits the machine's ability to unclamp tools. Examine the power drawbar cylinder's hydraulic fluid make up reservoir, excess fluid should be seen in the make up reservoir when the cylinder is in the unclamped position. Top up hydraulic oil if fluid is not seen in reservoir when in the unclamped position. 2. If the spindle drawbar cylinder drags against the top of the spindle, or if excessive tool kickout (>0.6 mm) is noted when unclamping tools adjusting the drawbar's upper nut may be necessary. 3. Verify that the clamping force is 350±50 kgf and the spindle smoothly and reliably clamps and unclamps tool holders.

11.9.4 Spindle Rotates on Contact, or Spindle Isn't Rigidly Clamped

Cause: Excessive torque on spindle.

Probability	How-To Steps
High	➤ Adjust tool paths to reduce forces applied to the braked spindle. The spindle brake is only intended for maintaining orientation during tool changes. Excessive torque imparted on the spindle by punch, shaping, slotting, or similar tooling can cause the spindle to rotate.

11.9.5 Spindle Doesn't Orient Correctly or Consistently

Cause: Worn spindle drive belt.

Probability	How-To Steps
Medium	➤ Examine spindle drive belt for missing or deformed teeth. Replace drive belt if necessary.

Cause: Loose or out of adjustment spindle index sensor.

Probability	How-To Steps
Medium	• Check clearance between spindle index sensor and spindle's index ring. There should be 0.10 mm (0.005 in.) clearance between the sensor face and the index ring when properly adjusted. • Check that the index sensor's mounting nuts are tightened sufficiently to resist vibration.

11: TROUBLESHOOTING

11.10 Servo IO Breakout Board Subsystem

11.10 SERVO IO BREAKOUT BOARD SUBSYSTEM

The machine's E1 Servo IO Breakout Board is the primary interface between the individual servo drives' input and output lines and the sensors and devices connected to them.

To troubleshoot the spindle drive subsystem, read the following:

11.10.1 Groups of Inputs and Outputs Aren't Functioning	284
---	-----

11.10.1 Groups of Inputs and Outputs Aren't Functioning

Cause: Loose IO cable between servo drive and servo IO breakout board.		
Probability	How-To Steps	Need More?
Medium	- Each servo drive is responsible for a group of dedicated inputs and outputs. - Use the "Servo Drive Inputs and Outputs" (below) table to identify which drive is responsible for the non-functional inputs and outputs. - Check the identified IO cable and its connections at the Servo IO Breakout Board and Servo Drive.	

Servo Drive Inputs and Outputs

Identifier	Servo Drive	IO Cable Identifier	Inputs	Outputs
DR1	Spindle	IO-1	Spindle Index Pulse	Power Drawbar Power Drawbar LED Spindle Drive Contactor Start Pulse
DR2	X-Axis	IO-4	Accessory Input 1 Accessory Input 2 TSC Input 1 TSC Input 2	Flood Coolant Washdown Coolant Accessory Output 1
DR3	Y-Axis	IO-5	Probe Trigger Probe Pulse Probe Battery Probe Error	Probe Activation Toolsetter Activation MQL (Mist)
DR4	Z-Axis	IO-6	Enclosure Lock Power Drawbar Button	Enclosure Door Lock TSC Power Z-Axis Brake
DR5	A-AxisTurret	IO-9		

DIAGRAMS AND PARTS LISTS

IN THIS SECTION, YOU'LL LEARN:

- About this machine's components.

NOTICE! Only use Tormach-approved parts when making replacements. If you don't replace parts with those listed in this section, you may void your warranty.

CONTENTS

12.1 Mill Diagrams and Parts Lists	286
12.2 Accessory Diagrams and Parts Lists	343

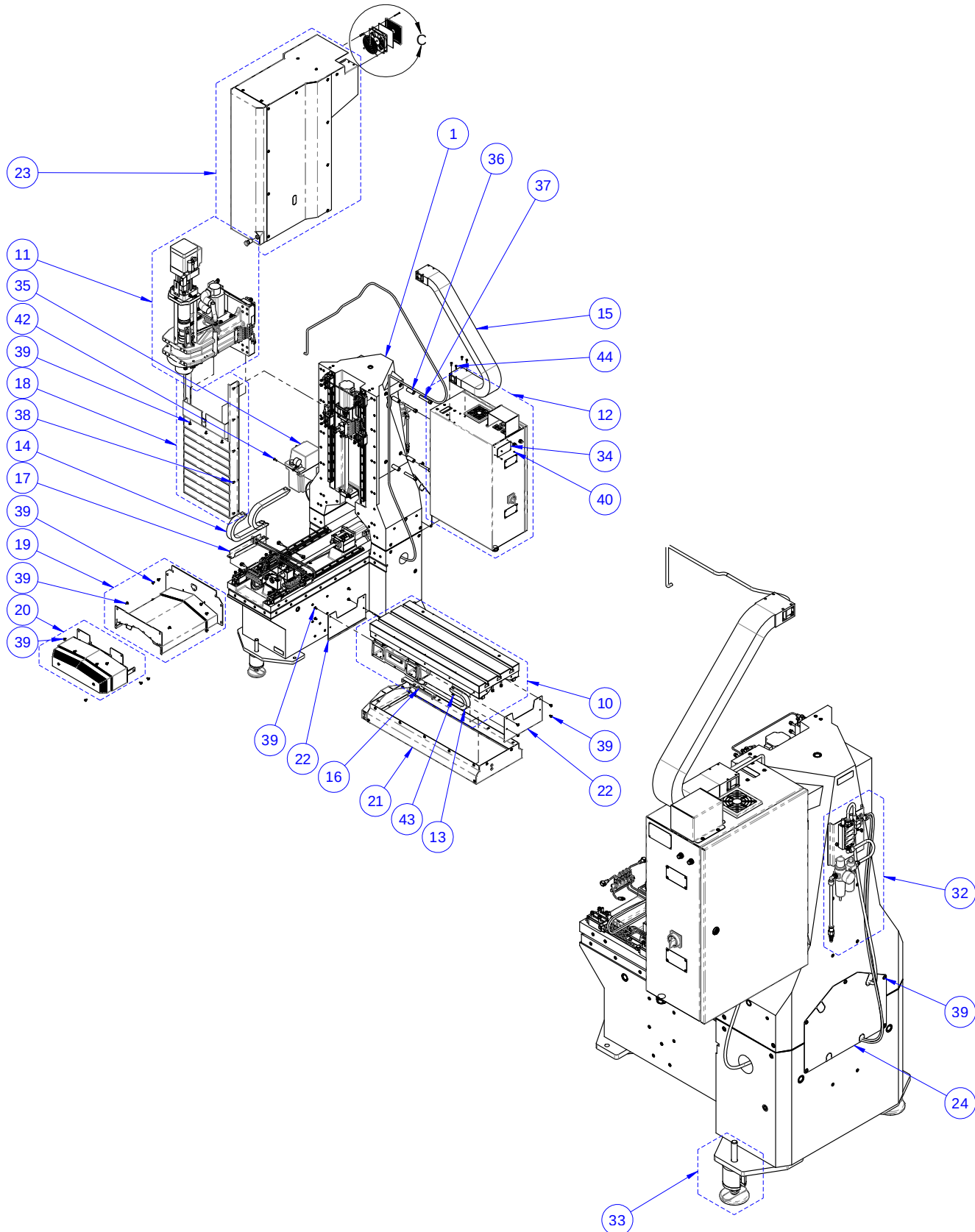
12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

12.1 MILL DIAGRAMS AND PARTS LISTS

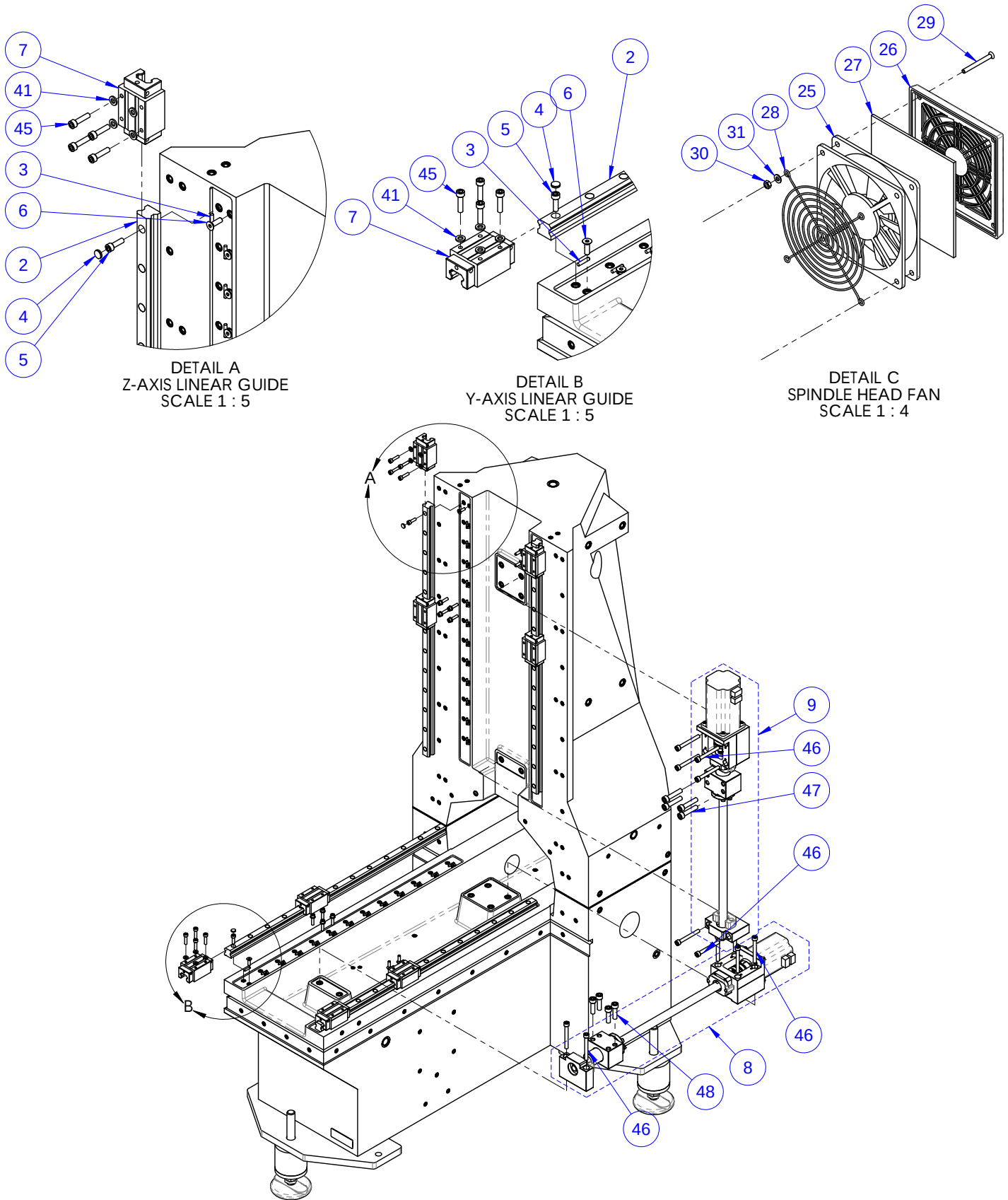
12.1.1 Assembly Overview.....	287
12.1.2 BT30 Power Drawbar Cylinder.....	291
12.1.3 Electrical Cabinet.....	293
12.1.4 Enclosure.....	298
12.1.5 Flood Coolant Kit Assembly.....	303
12.1.6 Linear Actuator Assembly.....	315
12.1.7 Lubrication Assembly.....	317
12.1.8 Pneumatics Assembly.....	319
12.1.9 Spindle Head.....	321
12.1.10 Spindle Head Camera Assembly.....	323
12.1.11 Spindle Head Sheet Metal Cover Assembly.....	325
12.1.12 X-Axis Assembly.....	327
12.1.13 X-Axis Lubrication Assembly.....	329
12.1.14 X-Axis Sheet Metal Cover Assembly.....	331
12.1.15 Y-Axis Lubrication Assembly.....	333
12.1.16 Y-Axis Front Way Cover Assembly.....	335
12.1.17 Y-Axis Rear Way Cover Assembly.....	337
12.1.18 Z-Axis Lubrication Assembly.....	339
12.1.19 Z-Axis Way Cover Assembly.....	341

12.1.1 Assembly Overview



12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists



12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

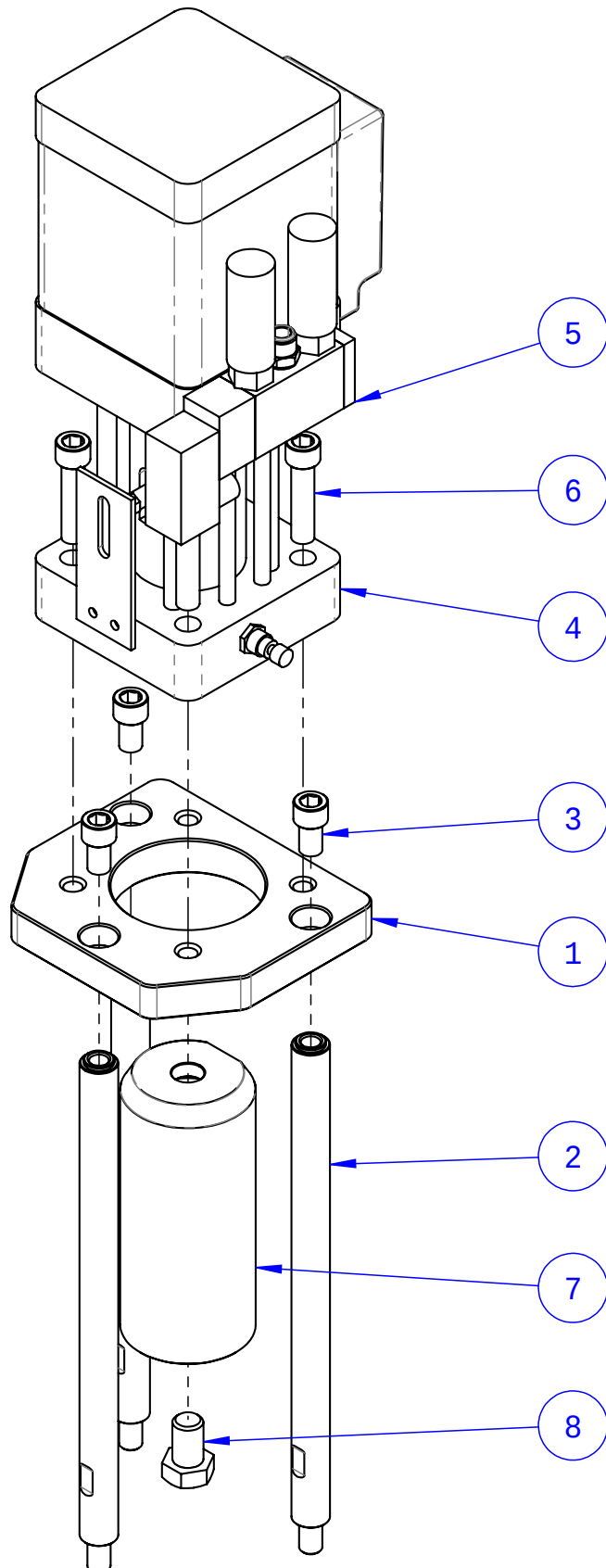
ID	Description	Quantity
1	Base-Column Subassembly, 1500MX (PN 51224)	1
2	Linear Rail, 25 mm, 760 mm Long, Precision H, M6 Top Down Mount (PN 51340)	4
3	Pin, 4 × 20 (PN 51342)	60
4	Linear Guide Rail Bolt Cap, M6, Plastic with O-Ring (PN 51350)	52
5	Screw, Socket Head Cap, M6 × 1 - 20 (PN 30832)	54
6	Screw, Socket Head Countersunk, M6 × 1 - 20 (PN 51321)	60
7	Linear Guide Block, 25 mm, Precision H, ZA Preload, Interchangeable, M6 Top Down Mount (PN 51341)	8
8	Linear Actuator Assembly, 350 mm Travel, 10 mm Lead (PN 51334)	1
9	Linear Actuator Assembly, 356 mm Travel, 5 mm Lead (PN 51335)	1
10	X-Axis Subassembly, 1500MX (PN 51223)	1
11	Spindle Head Assembly, 1500MX (PN 51127)	1
12	Electrical Cabinet Assembly, 1500MX (PN 51228)	1
13	X-Axis Drag Chain, 1500MX (PN 51422)	1
14	Y-Axis Drag Chain, 1500MX (PN 51423)	1
15	Z-Axis Drag Chain, 1500MX (PN 51424)	1
16	X-Axis Drag Chain Guide, 1500MX (PN 51767)	1
17	Y-Axis Drag Chain Guide, 1500MX (PN 51773)	1
18	Z-Axis Way Cover Assembly, 1500MX (PN 51204)	1
19	Y-Axis Rear Way Cover Assembly, 1500MX (PN 51205)	1
20	Y-Axis Front Way Cover Assembly, 1500MX (PN 51206)	1
21	X-Axis Sheet Metal Cover Assembly, 1500MX (PN 51231)	1
22	Saddle Cover Right/Left Panel, 1500MX (PN 51448)	2
23	Spindle Head Sheet Metal Cover Assembly, 1500MX (PN 51398)	1
24	Base-Column Rear Access Panel, 1500MX (PN 51743)	1
25	Fan (24 Vdc, 2.5 A, 120 mm) (PN 37526)	1
26	Electrical Cabinet Exhaust Cover Retainer (PN 37947)	1
27	Electrical Cabinet Exhaust Filter (PN 37948)	1
28	Fan Guard, Wire (PN 30515)	1
29	Screw, Phillips Head Countersunk, M4 × 0.7 - 40, Zinc Plated (PN 51327)	1
30	Nut, Hex, M4, Zinc Plated (PN 38358)	1
31	Washer, Flat, M4 (PN 31087)	1
32	Machine Pneumatics Assembly, 1500MX (PN 51626)	1

12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Quantity
33	Machine Foot Assembly, 1500MX (PN 51309)	3
34	Serial Number Plate, 1500MX (PN 51715)	1
35	Lubrication Assembly, 1500MX (PN 52556)	1
36	Electrical Cabinet Spacer, 1500MX (PN 51479)	4
37	Screw, Socket Head Cap, M12 × 1.75 - 80 (PN 51592)	4
38	Screw, Button Head Cap, M6 × 1 - 12, Stainless Steel (PN 51597)	10
39	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	37
40	Screw Nail, #4 × 0.188 in., Stainless Steel (PN 51517)	4
41	Washer, Flat, M6 (PN 31676)	34
42	Screw, Button Head Cap, M6 × 1 - 20, Stainless Steel (PN 51700)	2
43	Screw, Button Head Cap, M3 × 0.5 - 8, Black Oxide Steel (PN 51326)	4
44	Screw, Socket Head Cap, M5 × 0.8 - 16 (PN 30546)	4
45	Screw, Socket Head Cap, M6 × 1 - 25 (PN 31685)	32
46	Screw, Socket Head Cap, M8 × 1.25 - 70 (PN 51751)	12
47	Screw, Socket Head Cap, M10 × 1.5 × 50 (PN 31597)	4
48	Screw, Socket Head Cap, M10 × 1.5 - 35 (PN 31592)	4
–	Hose, 3/8 in. ID × 1/2 in. OD, PVC (PN 53441)	0.5 m
–	Fitting, Straight Adapter, 3/8 in. NPT (Male) - 3/8 in. Barb (PN 53440)	1

12.1.2 BT30 Power Drawbar Cylinder

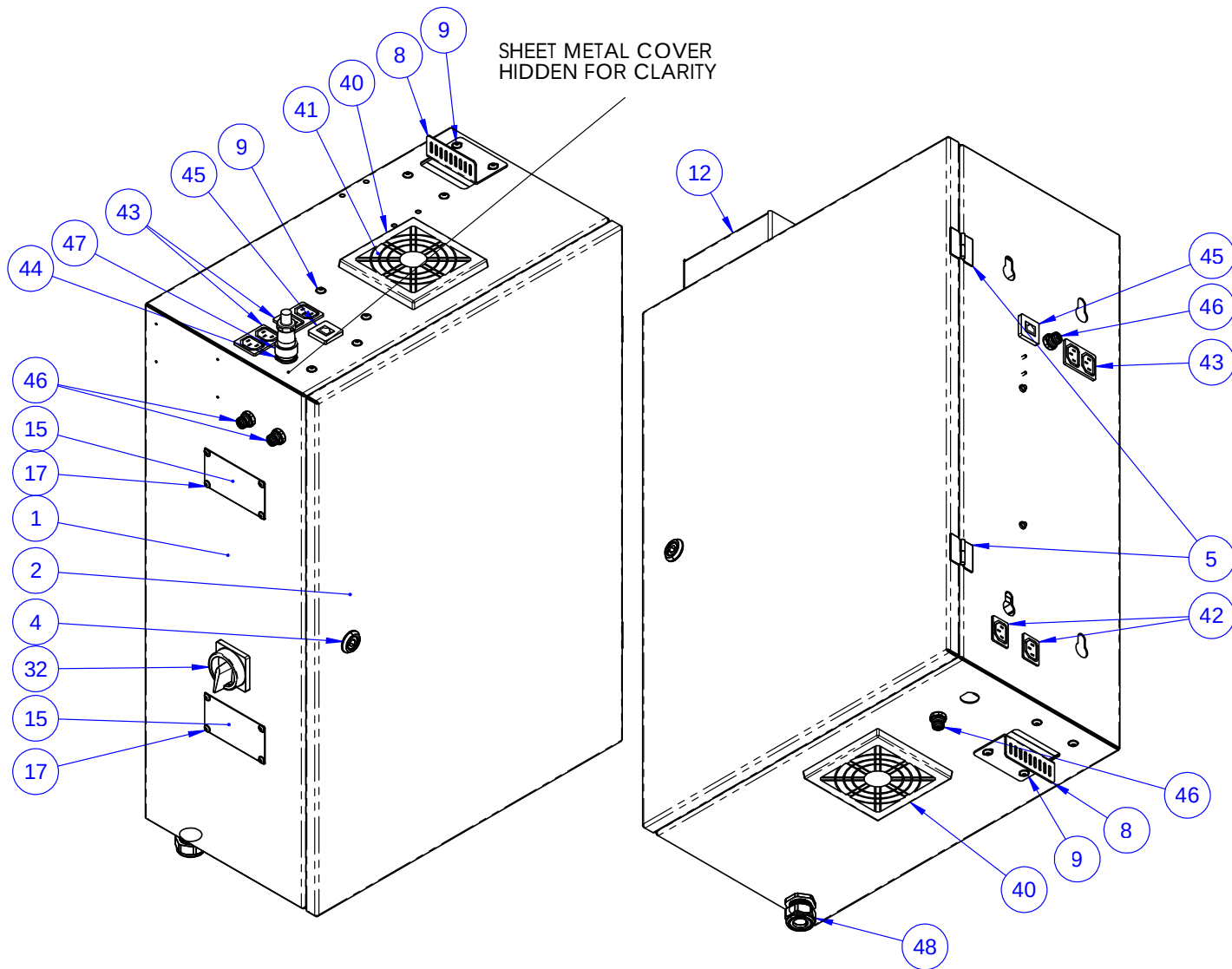


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

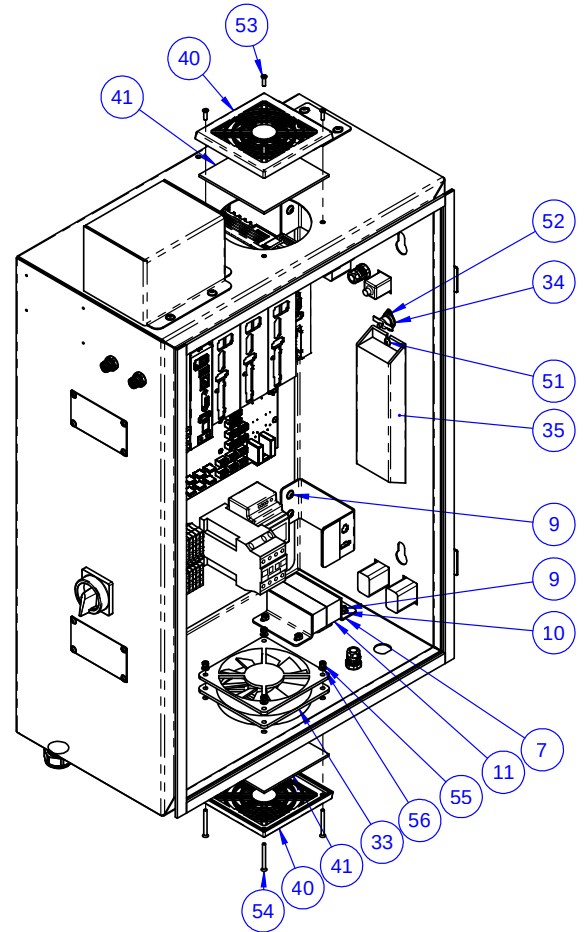
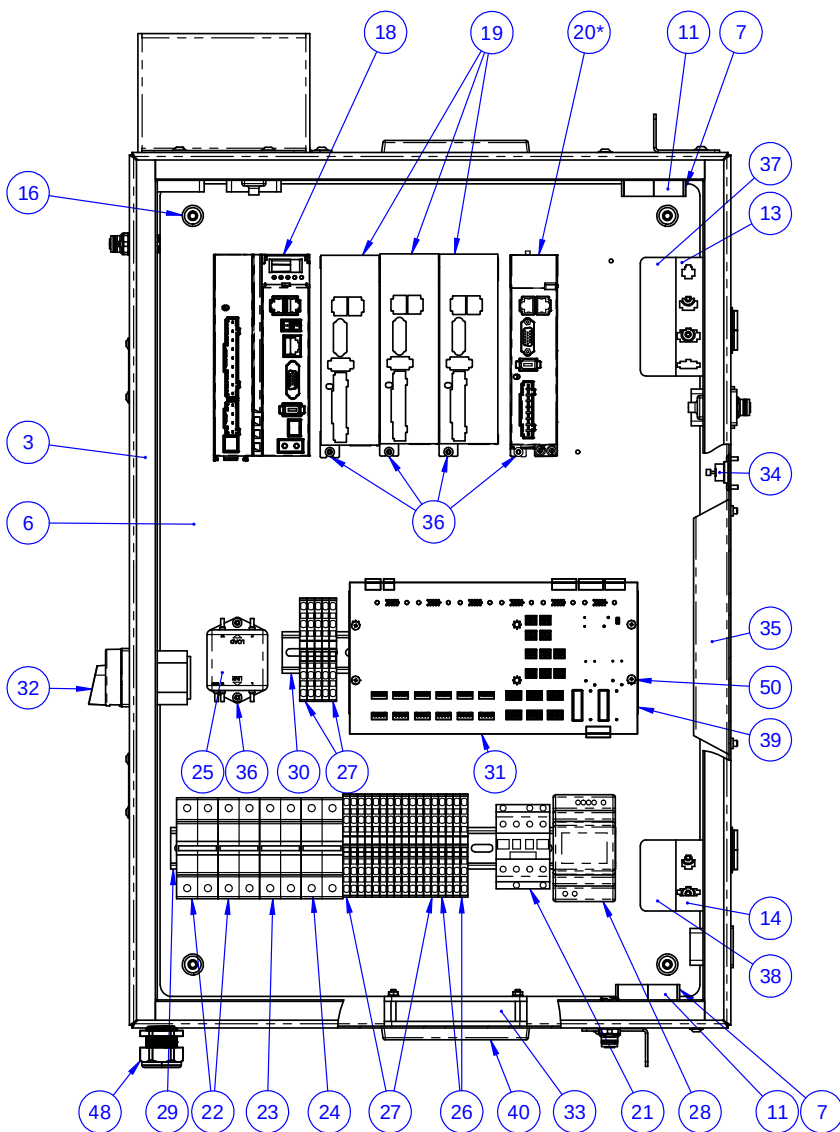
ID	Description	Alternative Part Number	Quantity
1	Power Drawbar Mount Plate, 1500MX (PN 51238)	—	1
2	Standoff, 299.5 mm, M12 × 1.75 - 20 Male, M12 × 1.75 - 15 Female, 45C (PN 51737)	—	3
3	Screw, Socket Head Cap, M12 × 1.75 - 20 (PN 51503)	McMaster-Carr: 91290A612	3
4	Power Drawbar Cylinder, 2.5T × 13 mm (PN 51601)	—	1
5	Drawbar Solenoid Assembly, 1500MX Drawbar (PN 53663)	—	1
6	Screw, Socket Head Cap, M12 × 1.75 - 50 (PN 32476)	McMaster-Carr: 91290A626	4
7	Power Drawbar CTS Extension Sleeve, 1500MX (PN 51605)	—	1
8	Screw, Hex Head Cap, M16 × 1.5 - 25 (PN 31322)	McMaster-Carr: 91180A913	1

12.1.3 Electrical Cabinet



12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists



FAN AND CABLE ENTRY DETAIL

12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Electrical Cabinet, 1500MX (PN 51284)	–	1
2	Electrical Cabinet Door, 1500MX (PN 51285)	–	1
3	Electrical Cabinet Door Gasket, 1500MX (PN 51669)	–	1
4	Cam Lock, Zinc Plated, Hex Drive, Quarter-Turn Counterclockwise to Open (PN 51588)	McMaster-Carr: 2050N12	1
5	Hinge, Surface-Mount, Lift-Off Style, Right Side, 22 mm Hole Spacing (PN 53478)	–	2
6	Electrical Panel Back Plate, 1500MX (PN 51287)	–	1
7	Cable Gland Strain Relief Bracket (PN 51295)	–	4
8	Cable Gland Strain Relief Bracket (PN 51295)	–	2
9	Screw, Button Head Cap (Flanged), M5 × 0.8 - 12 (PN 38890)	McMaster-Carr: 97654A377	16
10	Nut, Hex, M5 × 0.8 (PN 31201)	McMaster-Carr: 90591A260	8
11	Foam Block, 30 mm × 80 mm (PN 51313)	–	4
12	Electrical Cabinet Doghouse, 1500MX (PN 51311)	–	1
13	Connector Bulkhead, Electrical Cabinet, Top Right Exit (PN 51297)	–	1
14	Connector Bulkhead, Electrical Cabinet, Bottom Right Exit (PN 51298)	–	1
15	Electrical Cabinet Accessory Cover Plate (PN 37926)	–	2
16	Screw, Button Head Cap, Flanged M8 × 1.25 - 10, 18-8 Stainless (PN 51324)	McMaster-Carr: 97654A683	4
17	Screw, Button Head Cap, Flanged M4 × 0.7 - 8, 18-8 Stainless (PN 51331)	McMaster-Carr: 97654A372	9
18	Inovance SV660N, AC Servo Drive, Ethercat, 220 Vac, 12 A, STO Function (PN 51195)	–	1
19	AC Servo Drive, SV660N, Size B, EtherCAT, 220 V, 5.5 A, STO Function (PN 51259)	–	3
20*	AC Servo Drive, SV660N, Size A, EtherCAT, 220 V, 2.8 A, STO Function (PN 51194)	–	0
21	Contactor Relay, 3-Position, 220 V, 12 A, 24 Vdc Coil, Screw Terminal (PN 37343)	–	1
22	Circuit Breaker (20 A, 2 Pole) (PN 37345)	–	2
23	Circuit Breaker (10 A, 2 Pole) (PN 37346)	–	1
24	Circuit Breaker (3 A, 2 Pole) (PN 37516)	–	1
25	Filter (110 Vac/250 Vac, 20 A) (PN 37914)	–	1

12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
26	Terminal Block, GND, 4 Position, Spring Type, Internally Jumpered, JUT3-4/2-2PE (PN 51289)	–	4
27	Terminal Block, 4 Position, Spring Type, Internally Jumpered, JUT3-4/2-2 (PN 51290)	–	18
28	Power Supply (24 Vdc, 60 W) (PN 50461)	–	1
29	Din Rail (35 × 7.5), 375 mm Long (PN 51633)	McMaster-Carr: 8961K15	1
30	Din Rail (35 × 7.5), 300 mm Long (PN 51634)	McMaster-Carr: 8961K15	1
31	Servo IO Breakout Board (6 Axis) (PN 51252)	–	1
32	Main Disconnect Switch (PN 30454)	–	1
33	Fan (24 Vdc, 2.5 A, 120 mm) (PN 37526)	McMaster-Carr: 8774N18	1
34	Thermal Switch, Manual Reset, Ceramic, 220 V, 10 A, 85C (PN 37420)	–	1
35	Spindle Brake Resistor (PN 37906)	–	1
36	Screw, Button Head Cap, M4 × 0.7 - 8, Black Oxide Steel (PN 51317)	McMaster-Carr: 91239A140	15
37	Bulkhead Label, Upper Bulkhead, 1500MX Electrical Cabinet (PN 51471)	–	1
38	Bulkhead Label, Upper Bulkhead, 1500MX Electrical Cabinet (PN 51472)	–	1
39	Standoff, 47 mm Hole Spacing, Clip-On Din Rail, Plastic (PN 51473)	–	2
40	Electrical Cabinet Exhaust Cover Retainer (PN 37947)	McMaster-Carr: 19155K23	2
41	Electrical Cabinet Exhaust Filter (PN 37948)	McMaster-Carr: 19155K53	2
42	IEC 320 Socket (Female, Single) (PN 37350)	–	2
43	IEC 320 Socket (Female, Double) (PN 37351)	–	3
44	Connector, 5 Pin, Female (PN 37353)	–	1
45	Connector, RJ45 Socket (PN 37355)	–	2
46	Circular Connector, M12, Rear Panel Mount, Plug, 4 Pin Female (PN 51293)	–	4
47	Circular Connector, Plug, 5 Pin Male, Metal Hose, Solder (PN 39263)	–	1
48	Cable Cord Grip M20 × 1.25 / 25 mm Nut (PN 38758)	–	1
49	Screw, Button Head Cap, M5 × 0.8 - 8 (PN 34636)	McMaster-Carr: 92095A207	4
50	Screw, Pan Head, Thread Forming M4 × 1.79 - 10, Zinc Plated (PN 51323)	McMaster-Carr: 90380A376	4

12: DIAGRAMS AND PARTS LISTS

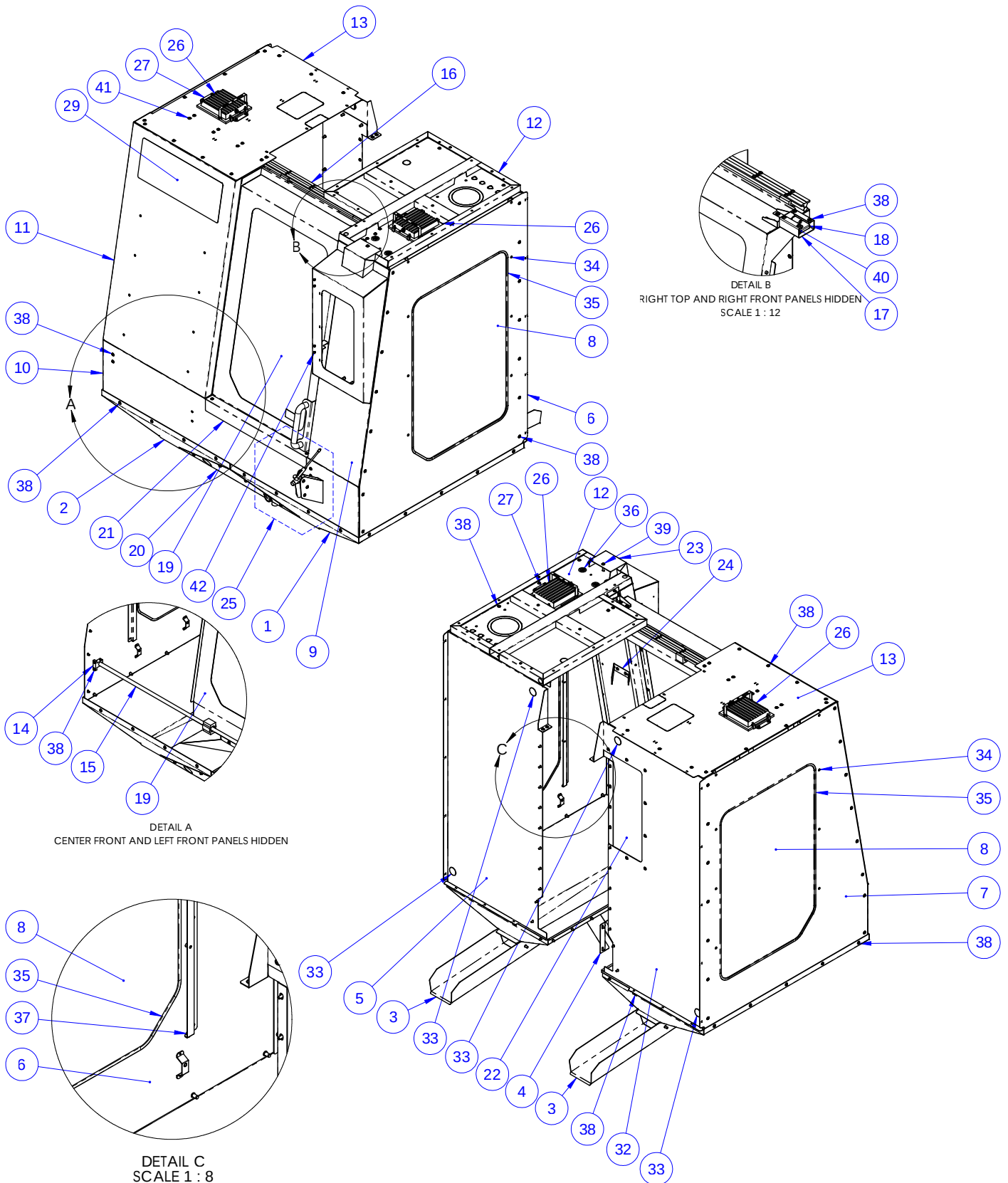
12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
51	Screw, Button Head Cap, M5 × 0.8 - 10 (PN 35774)	McMaster-Carr: 91239A224	3
52	Screw, Button Head Cap, M3 × 0.5 - 8, Black Oxide Steel (PN 51326)	McMaster-Carr: 91239A113	2
53	Screw, Phillips Head Countersunk, M4 × 0.7 - 14, Zinc Plated (PN 51766)	McMaster-Carr: 91420A224	4
54	Screw, Phillips Head Countersunk, M4 × 0.7 - 40, Zinc Plated (PN 51327)	McMaster-Carr: 91420A250	4
55	Nut, Hex, M4, Zinc Plated (PN 38358)	McMaster-Carr: 90591A255	4
56	Washer, Flat, M4 (PN 31087)	McMaster-Carr: 91166A230	4
*Optional accessory not included with the base machine.			

12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

12.1.4 Enclosure



12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Right Chip Tray, 1500MX (PN 51263)	–	1
2	Left Chip Tray, 1500MX (PN 51264)	–	1
3	Coolant Chute, 1500MX (PN 51280)	–	2
4	Chip Tray Support Bracket, 1500MX (PN 52439)	–	2
5	Right Rear Enclosure Panel, 1500MX (PN 51265)	–	1
6	Right Side Enclosure Panel, 1500MX (PN 51267)	–	1
7	Left Side Enclosure Panel, 1500MX (PN 51268)	–	1
8	Side Enclosure Panel Window Cover, 1500MX (PN 51527)	–	2
9	Right Front Enclosure Panel, 1500MX (PN 51269)	–	1
10	Center Front Enclosure Panel, 1500MX (PN 51343)	–	1
11	Left Front Enclosure Panel, 1500MX (PN 51270)	–	1
12	Right Top Enclosure Panel, 1500MX (PN 51271)	–	1
13	Left Top Enclosure Panel, 1500MX (PN 51272)	–	1
14	Linear Rail Support, Round, 16 mm (PN 37622)	–	2
15	Linear Rail, 16 mm Round, 1250 mm (PN 51364)	–	1
16	Linear Rail, Supported 16 mm Round, 1200 mm (PN 51816)	–	1
17	Locking Door Switch Bracket, 1500MX (PN 51369)	–	1
18	Locking Door Switch, 1500MX (PN 51328)	–	1
19	Enclosure Door Assembly, 1500MX (PN 51273)	–	1
20	Chip Tray Center Kick Plate, 1500MX (PN 51374)	–	1
21	Enclosure Scuff Guard, 1500MX (PN 51345)	–	1
22	ATC Mount Cover Panel, 1500MX (PN 52207)	–	1
23	Console Cable Cover, 1500MX (PN 51382)	–	1
24	Enclosure Mount Camera Bracket, 1500MX (PN 51417)	–	1
25	Air Gun Kit (PN 51443)	–	1
26	LED Flood Light (20 W) (PN 51591)	–	2
27	Flood Light and Window Retainer, 1500MX Enclosure (PN 51507)	–	4
28	Cable, IEC 320 Extension (IEC 320 C13 - IEC 320 C14), 2.0 m, 10 A 250 V 18/3 AWG SJT (PN 38389)	–	2
29	Decal, Enclosure, 1500MX, Front Left Panel (PN 51437)	–	1
30	Decal, Enclosure, 1500MX, Rear Right Panel (Interior) (PN 51438)	–	1
31	Label Kit, 1500MX Enclosure (PN 52443)	–	1

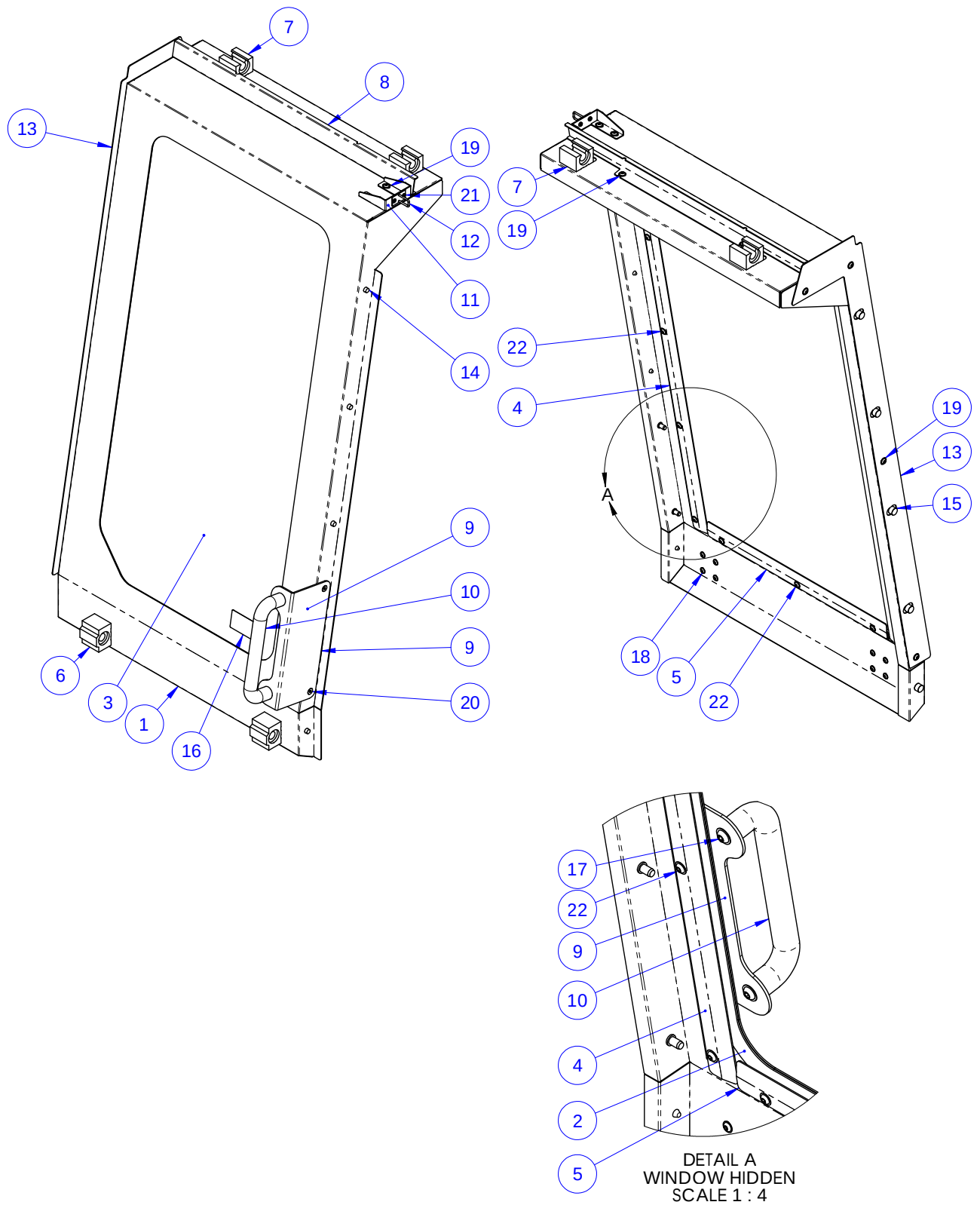
12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
32	Left Rear Enclosure Panel, 1500MX (PN 51266)	–	1
33	Panel Plug, Push-In, 32 mm (PN 51383)	McMaster-Carr: 9600K521	4
34	Panel Plug, Push-In, 6 mm (PN 51530)	McMaster-Carr: 9600K512	16
35	Enclosure Side Panel Trim, 1500MX (PN 51375)	–	2
36	Expandable Locking Grommet, 7/8 in. × 1 1/4 in. × 1/32 in. - 1/8 in., Nylon (PN 51519)	McMaster-Carr: 4946A704	3
37	Push-In Bumper, 0.25 in. Stem, 0.22 in. Height (PN 51367)	McMaster-Carr: 9309K64	4
38	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	175
39	Screw, Button Head Cap, Flanged M6 × 1 - 40, 18-8 Stainless (PN 51544)	McMaster-Carr: 90909A432	1
40	Screw, Button Head Cap, Flanged M4 × 0.7 - 8, 18-8 Stainless (PN 51331)	McMaster-Carr: 97654A372	4
41	Screw, Button Head Cap, Flanged M6 × 1 - 6, 18-8 Stainless (PN 51692)	McMaster-Carr: 97654A682	12
42	Screw, Button Head Cap, M5 × 0.8 - 12, Stainless Steel (PN 37716)	McMaster-Carr: 92095A210	4
43	Cable Tie, 4 in., Nylon, Black (PN 31719)	McMaster-Carr: 7130K52	20

12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

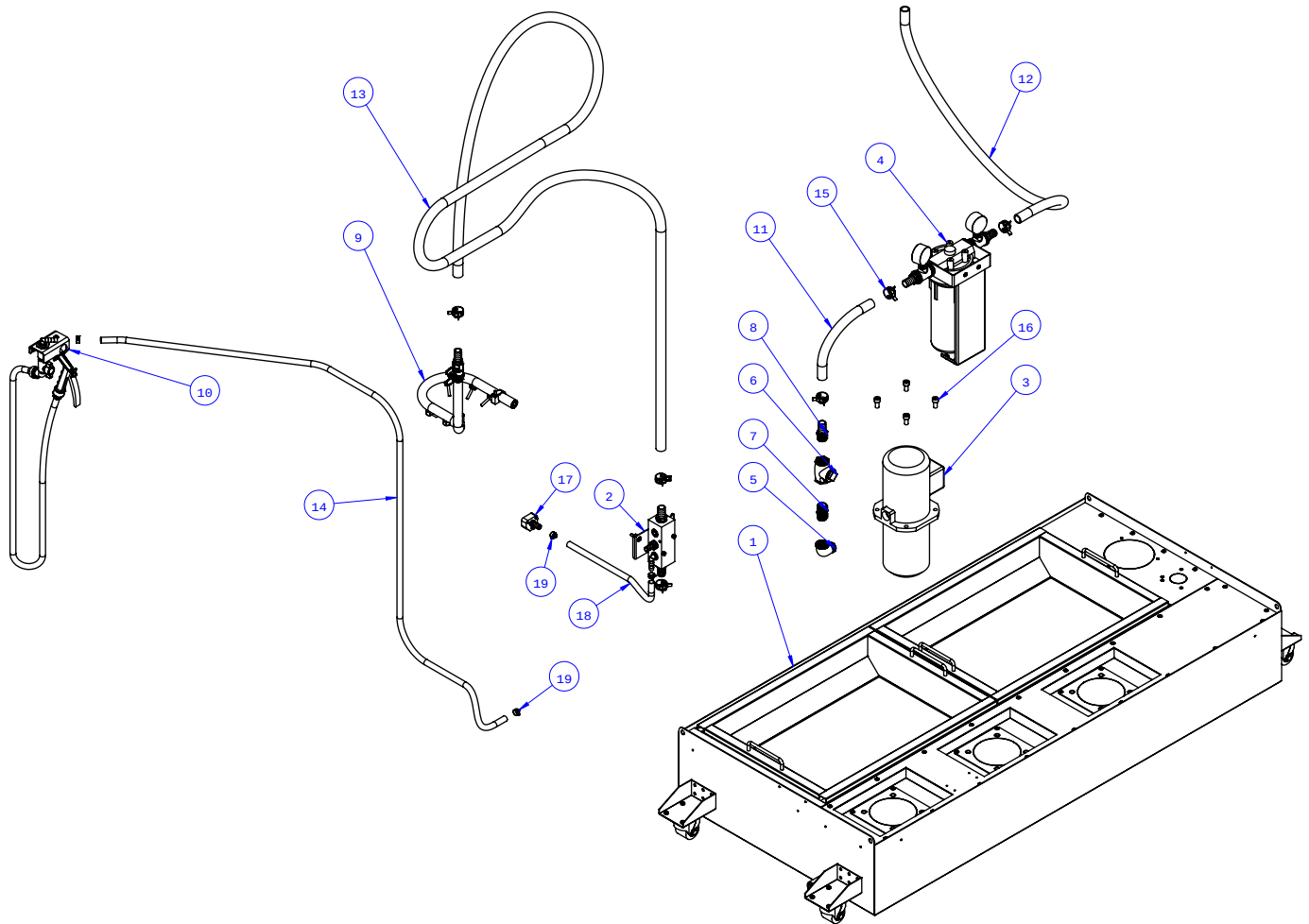


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Enclosure Door Panel, 1500MX (PN 51274)	–	1
2	Sealing Strip (Self-Adhesive), 25 mm × 1.5 mm (PN 51693)	McMaster-Carr: 9023K81	1
3	Enclosure Door Window, 1500MX (PN 51275)	–	1
4	Long Window Clamp, Enclosure Door, 1500MX (PN 51690)	–	2
5	Short Window Clamp, Enclosure Door, 1500MX (PN 51691)	–	2
6	Linear Bearing Block, Round, 16 mm (PN 37610)	–	2
7	Linear Bearing Block, Supported Round, 16 mm (PN 51817)	–	2
8	Enclosure Door Linear Bearing Cover Panel, 1500MX (PN 51886)	–	1
9	Door Handle Bracket, 1500MX (PN 51360)	–	1
10	Door Handle, 1500MX (PN 51361)	–	1
11	Door Lock Latch Plate Bracket, 1500MX (PN 51363)	–	1
12	Locking Door Switch Latch Plate, 1500MX (PN 51329)	–	1
13	Enclosure Door Overlap Extension, 1500MX (PN 51365)	–	1
14	Push-In Bumper, 0.25 in. Stem, 0.22 in. Height (PN 51367)	McMaster-Carr: 9309K64	4
15	Push-In Bumper, 0.25 in. Stem, 0.38 in. Height (PN 52210)	McMaster-Carr: 9309K68	5
16	Decal Kit, Mill Enclosure Safety (PN 38830)	–	1
17	Screw, Button Head Cap, Flanged M8 × 1.25 - 16, 18-8 Stainless (PN 38468)	McMaster-Carr: 90909A479	2
18	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	McMaster-Carr: 97654A376	16
19	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	10
20	Screw, Socket Head Countersunk, M6 × 1 - 12 (PN 51432)	McMaster-Carr: 91294A236	2
21	Screw, Socket Head Countersunk, M4 × 0.7 - 8 (PN 51431)	McMaster-Carr: 91294A188	2
22	Screw, Button Head Cap, Flanged M6 × 1 - 6, 18-8 Stainless (PN 51692)	McMaster-Carr: 97654A682	16

12.1.5 Flood Coolant Kit Assembly

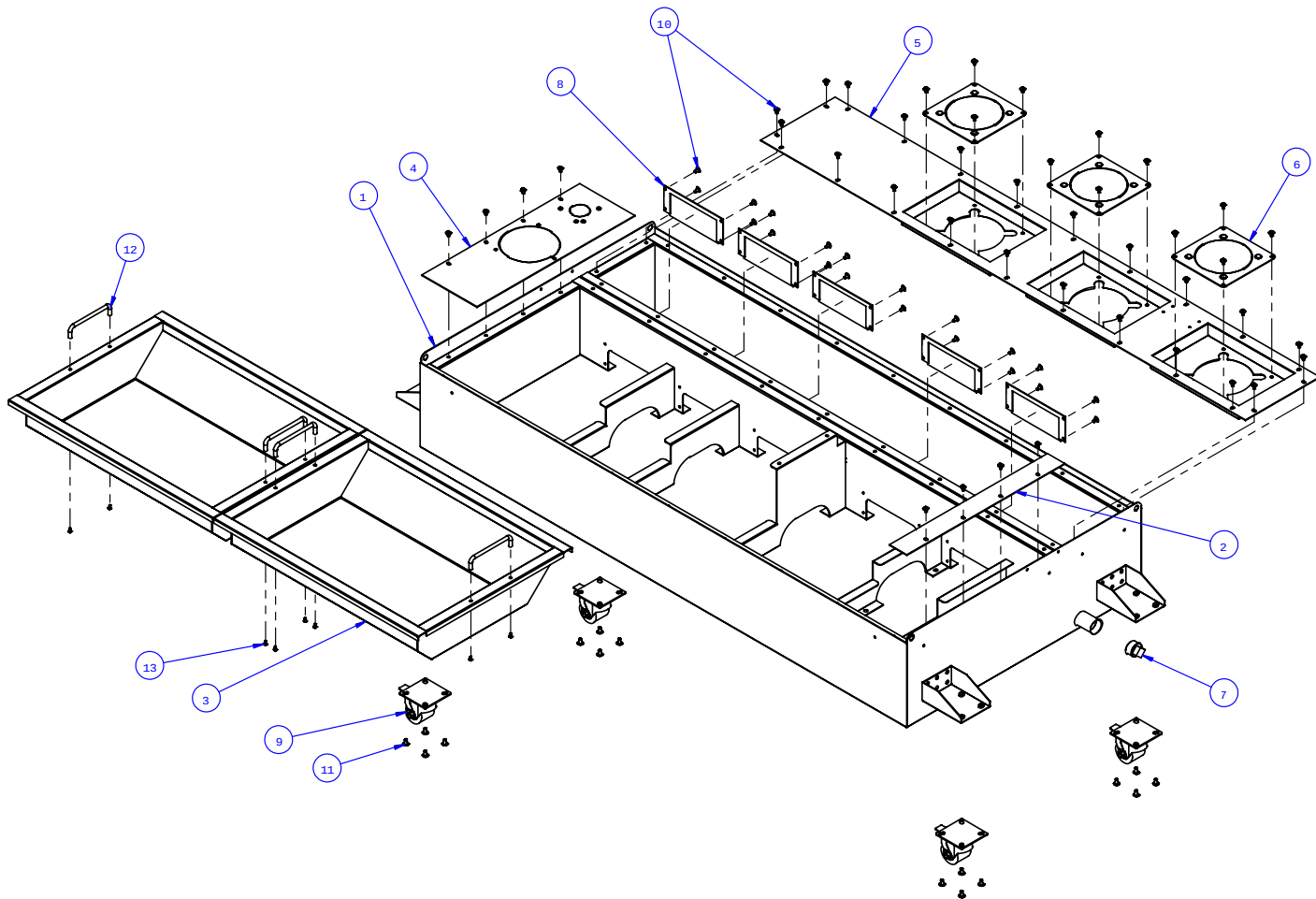


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	1500MX Coolant Tank Assembly with Chip Baskets (PN 51371) For details, go to "Coolant Tank Assembly" (on the next page).	–	1
2	Flood Coolant Manifold Assembly, 1500MX (PN 51565)	–	1
3	Coolant Pump, Dual Voltage (Preset to 240), 1/4 hp, 180 mm Length, 3/4 NPT Outlet, 2 m 14 AWG Cord (with Right-Angle C14 Plug) (PN 51384)	–	1
4	Flood Coolant Filter Assembly, 1500MX (PN 51614)	–	1
5	Fitting, Street Elbow Adapter, 3/4 in. NPT (Male) - 3/4 in. NPT (Female), Brass (PN 51606)	McMaster Carr: 4429K154	1
6	Fitting, Swing Check Valve, 3/4 in. NPT (Female) - 3/4 in. NPT (Female) (PN 51555)	McMaster Carr: 4708K54	1
7	Fitting, Straight Connector, 3/4 in. NPT (Male) - 3/4 in. NPT (Male), Brass (PN 51554)	McMaster Carr: 5485K25	1
8	Fitting, Straight Adapter, 3/4 in. NPT (Male) - 3/4 in. Barb, Brass (PN 51556)	McMaster Carr: 5346K28	1
9	Coolant Ring Assembly, 1500MX (PN 51247)	–	1
10	Washdown Gun Kit (PN 51509)	–	1
11	Hose, 3/4 in. ID × 1 in. OD, PVC, 300 mm Long (PN 51608)	McMaster-Carr: 5233K71	1
12	Hose, 3/4 in. ID × 1 in. OD, PVC, 1300 mm Long (PN 51608)	McMaster-Carr: 5233K71	1
13	Hose, 3/4 in. ID × 1 in. OD, PVC, 3700 mm Long (PN 51608)	McMaster-Carr: 5233K71	1
14	Hose, 1/2 in. ID × 5/8 in. OD, PVC, 2200 mm Long (PN 51516)	McMaster Carr: 9446K71	1
15	Hose Clamp, Spring, for 1 in. OD Hose (PN 51558)	McMaster Carr: 7329K16	6
16	Screw, Socket Head Cap, M10 × 1.5 - 20 (PN 32625)	McMaster Carr: 91290A516	4
17	Y-Axis Washdown Nozzle, 1500MX (PN 51578)	–	1
18	Hose, 1/2 in. ID × 5/8 in. OD, PVC, 500 mm Long (PN 51516)	McMaster Carr: 9446K71	1
19	Hose Clamp, Spring, for 5/8 in. OD Hose (PN 51679)	McMaster Carr: 7329K42	4

Coolant Tank Assembly

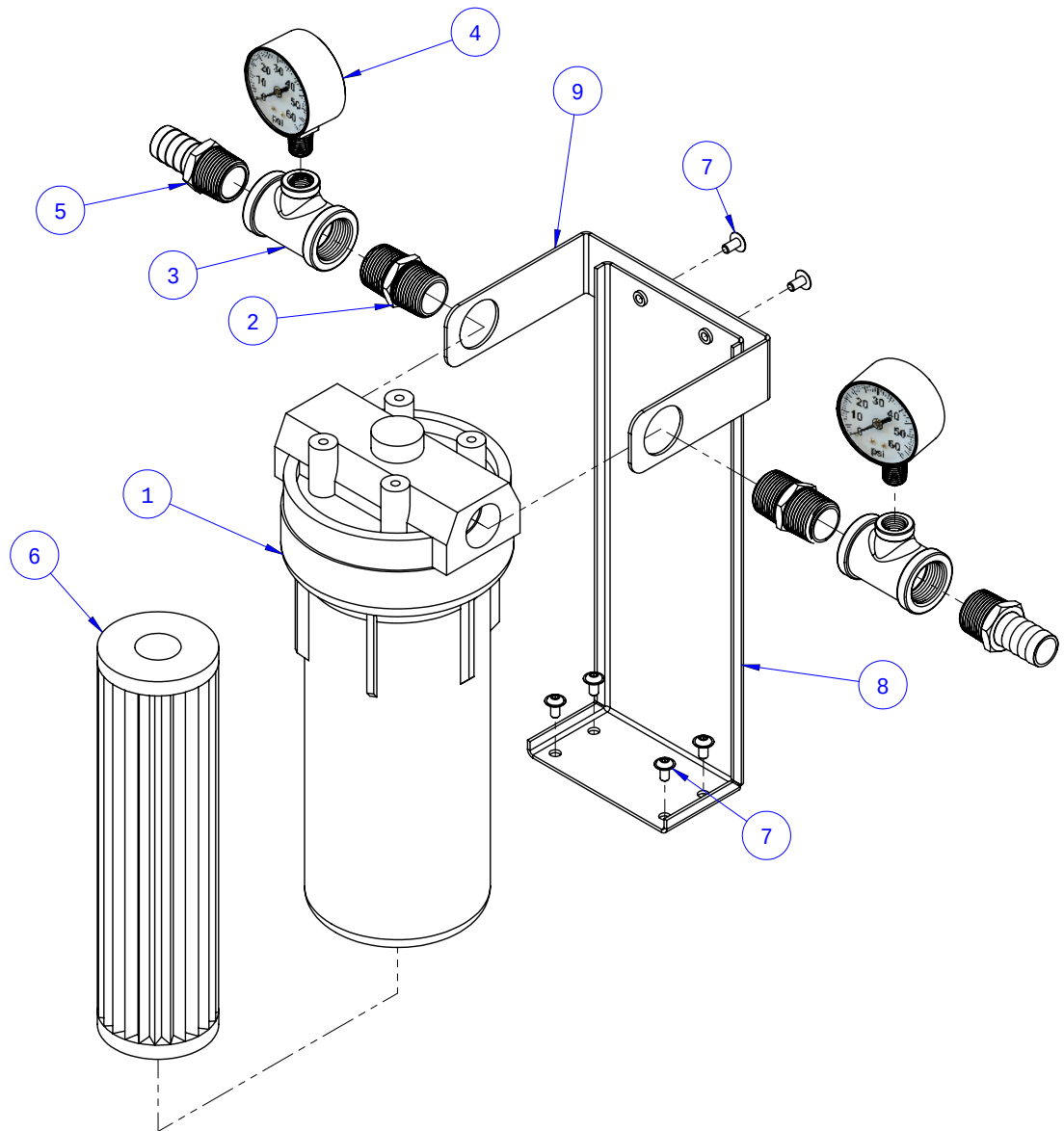


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Coolant Tank, 1500MX (PN 52548)	–	1
2	End Cover Panel, 1500MX Coolant Tank (PN 52549)	–	1
3	Chip Basket, 1500MX Coolant Tank (PN 52550)	–	2
4	Oil Skimmer Cover Panel, 1500MX Coolant Tank (PN 52551)	–	1
5	Coolant Pump Cover Panel, 1500MX Coolant Tank (PN 52552)	–	1
6	Coolant Pump Mounting Plate, 1500MX Coolant Tank, 1/4 hp, Fits ASP-4180 (PN 52553)	–	3
7	Fitting, Plug, 1 in. NPT, External Square Drive (PN 52561)	–	1
8	Removable Chip Screen, 1500MX Coolant Tank (PN 52557)	–	5
9	Locking Swivel Caster, 1500MX Coolant Tank (PN 52554)	–	4
10	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	McMaster-Carr: 97654A376	62
11	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	16
12	Handle, Stainless Steel, 1500MX Coolant Tank Chip Baskets (PN 52562)	–	4
13	Screw, Button Head Cap, M4 × 0.7 - 8, Black Oxide Steel (PN 51317)	McMaster-Carr: 91239A140	8

Flood Coolant Filter Assembly

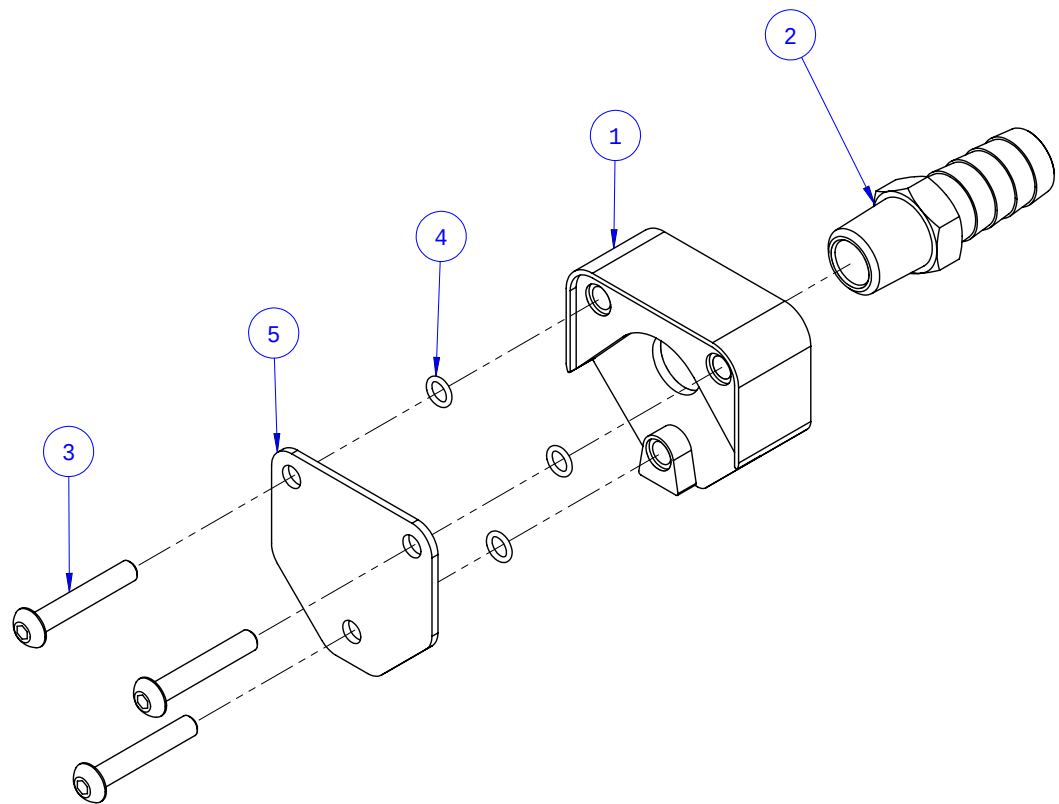


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Flood Coolant Filter Housing, 3/4 in. NPT Inlets (PN 51613)	McMaster-Carr: 4422K3	1
2	Fitting, Straight Connector, 3/4 in. NPT (Male) - 3/4 in. NPT (Male), Brass (PN 51554)	McMaster Carr: 5485K25	2
3	Fitting, Inline Tee Reducer, 2x 3/4 in. NPT (Female) x 1/4 in. NPT (Female), Brass (PN 51610)	McMaster-Carr: 4429K229	2
4	Fitting, Pressure Gauge, 1/4 in. NPT, 0-60 psi, for Water (PN 51611)	McMaster-Carr: 4089K61	2
5	Fitting, Straight Adapter, 3/4 in. NPT (Male) - 3/4 in. Barb, Brass (PN 51556)	McMaster Carr: 5346K28	2
6	Replacement Filter Cartridge, For Flood Coolant Filter (PN 51615)	McMaster-Carr: 7191K11	1
7	Screw, Button Head Cap (Flanged), M5 × 0.8 - 10, Stainless Steel (PN 38205)	McMaster-Carr: 90909A722	6
8	Bracket, Flood Coolant Filter, 1500MX (PN 51612)	—	1
9	Upper Bracket, Flood Coolant Filter (PN 52615)	—	1

Y-Axis Washdown Nozzle

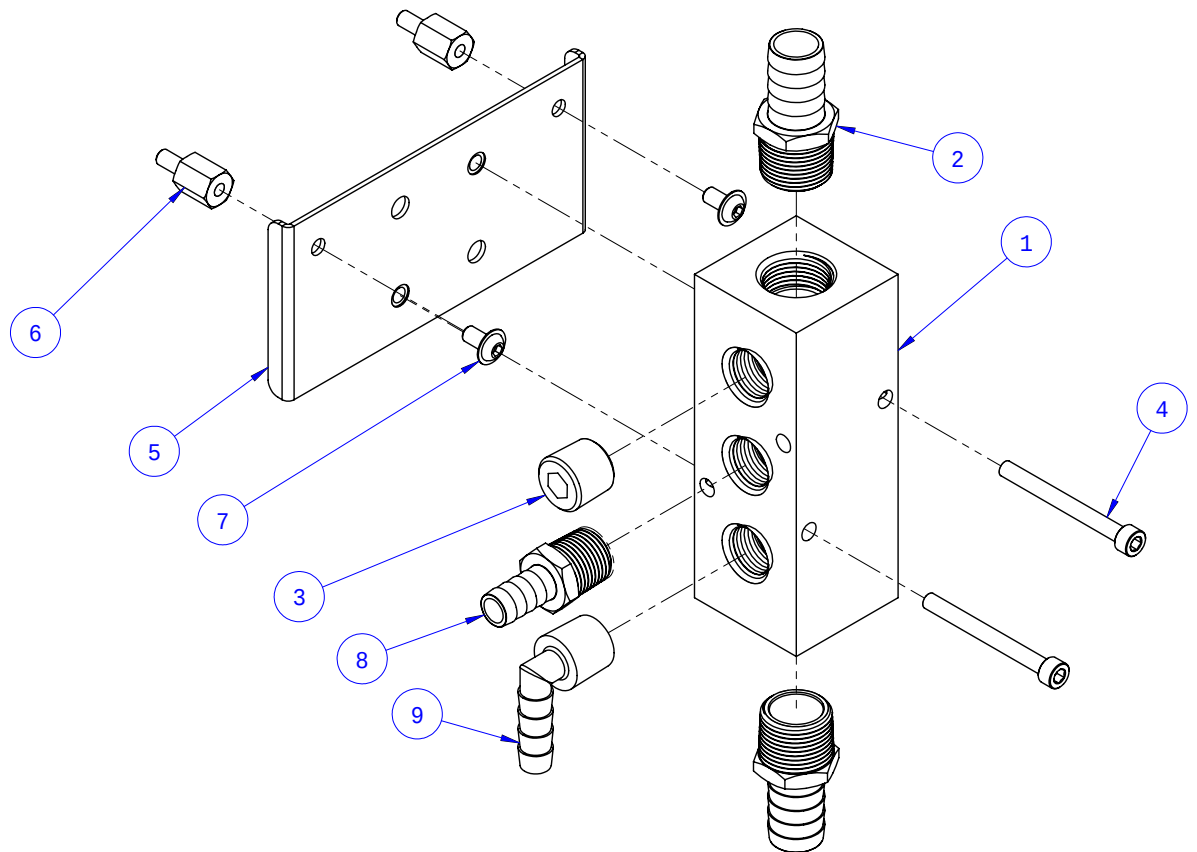


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Y-Axis Washdown Block, 1500MX (PN 51674)	—	1
2	Fitting, Straight Adapter, 1/4 in. NPT (Male) - 1/2 in. Barb, Brass (PN 51676)	McMaster-Carr: 2838N24	1
3	Screw, Button Head Cap, M4 × 0.7 - 25, Stainless Steel (PN 51689)	McMaster-Carr: 92095A197	3
4	O-Ring, 4 mm ID × 6 mm OD × Thickness, Buna-N, 70A (PN 51677)	McMaster-Carr: 9262K102	3
5	Washdown Cover Plate, Y-Axis Rear Way Cover, 1500MX (PN 51675)	—	1

Flood Coolant Manifold Assembly

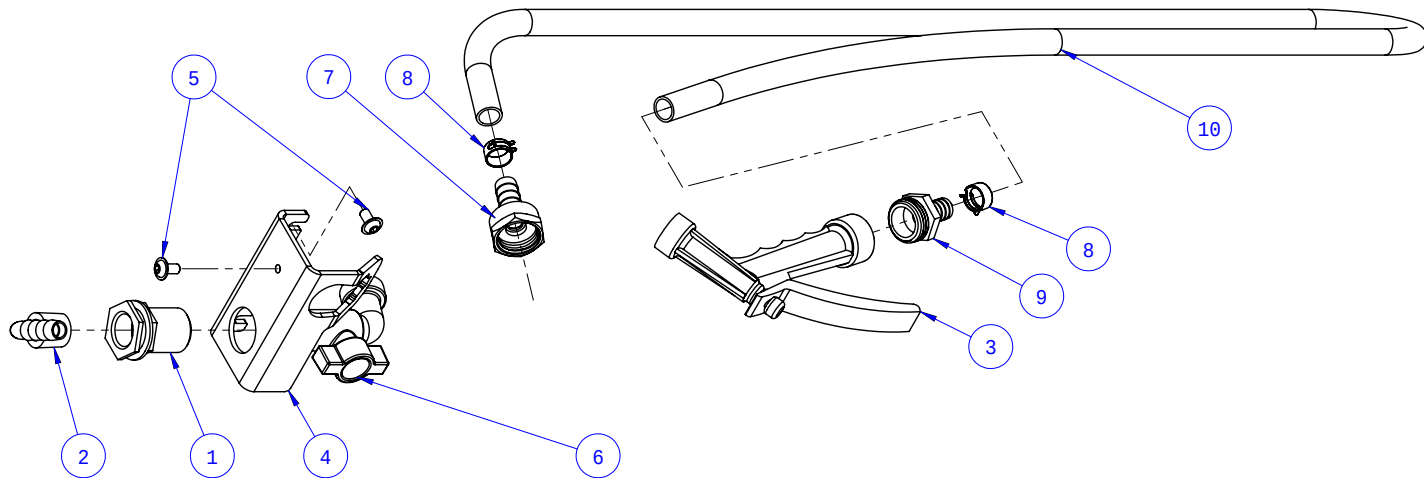


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Fitting, Right Angle Manifold, 2x 3/4 in. NPT Inlets (Female) - 3x 1/2 in. NPT Outlets (Female), Aluminum (PN 51557)	McMaster-Carr: 5469K203	1
2	Fitting, Straight Adapter, 3/4 in. NPT (Male) - 3/4 in. Barb, Brass (PN 51556)	McMaster Carr: 5346K28	2
3	Fitting, Plug (Internal Hex), 1/2 in. NPT (Male), Brass (PN 51378)	McMaster-Carr: 50785K115	1
4	Screw, Socket Head Cap, M6 × 1 - 60 (PN 30356)	McMaster-Carr: 91290A344	2
5	Bracket, Coolant Manifold, 1500MX (PN 51562)	—	1
6	Standoff, 16 mm, M6 × 1 - 13 mm Male, M6 × 1 - 10 mm Female, Steel (PN 51566)	McMaster-Carr: 93655A255	2
7	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 90909A727	2
8	Fitting, Straight Adapter, 1/2 in. NPT (Male) - 1/2 in. Barb, Brass (PN 51678)	McMaster-Carr: 5346K25	1
9	Fitting, Elbow Adapter, 1/2 in. NPT (Male) - 1/2 in. Barb (PN 51512)	McMaster-Carr: 53525K58	1

Washdown Gun Kit

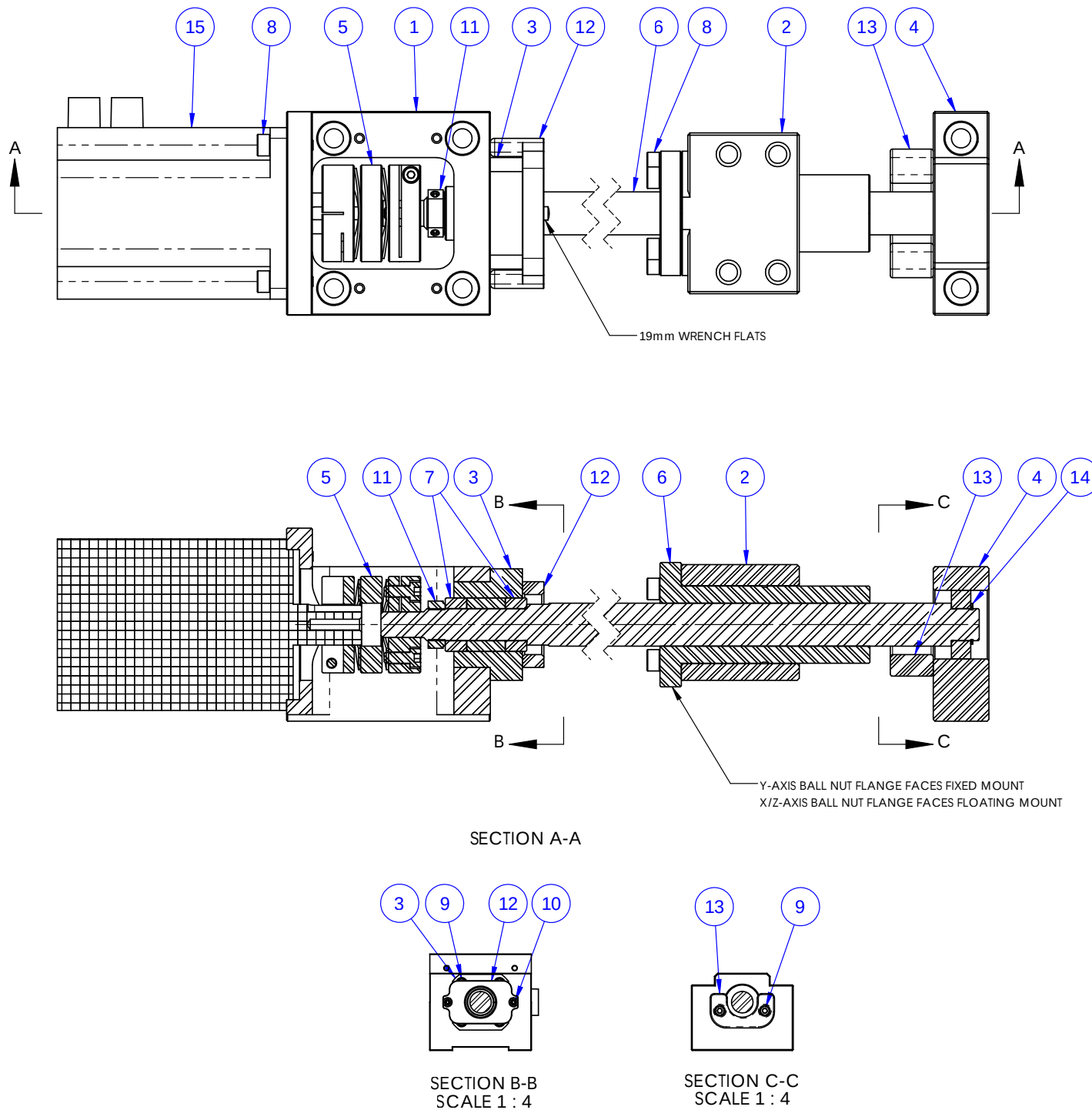


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Fitting, Tank Bulkhead, 3/4 in. GHT (Male) - 1/2 in. NPT (Female) (PN 51508)	—	1
2	Fitting, Elbow Adapter, 1/2 in. NPT (Male) - 1/2 in. Barb (PN 51512)	McMaster-Carr: 53525K58	1
3	Hose Nozzle, 3/4 in. GHT (PN 51513)	—	1
4	Hose Nozzle Bracket (PN 51621)	—	1
5	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 90909A727	2
6	Fitting, Hose Bibb (Quarter-Turn), 1/2 in. NPT (Male) - 3/4 in. GHT (Male) (PN 51511)	McMaster-Carr: 4792K61	1
7	Fitting, Straight, 3/4 in. GHT (Female) - 1/2 in. Barbed, Brass (PN 52412)	McMaster-Carr: 70705T63	1
8	Hose Clamp, Spring, for 5/8 in. OD Hose (PN 51679)	McMaster Carr: 7329K42	2
9	Fitting, Straight, 3/4 in. GHT (Male) - 1/2 in. Barbed, Brass (PN 52411)	McMaster-Carr: 2706N22	1
10	Hose, 1/2 in. ID × 5/8 in. OD, PVC (PN 51516)	McMaster-Carr: 5108K62	1

12.1.6 Linear Actuator Assembly

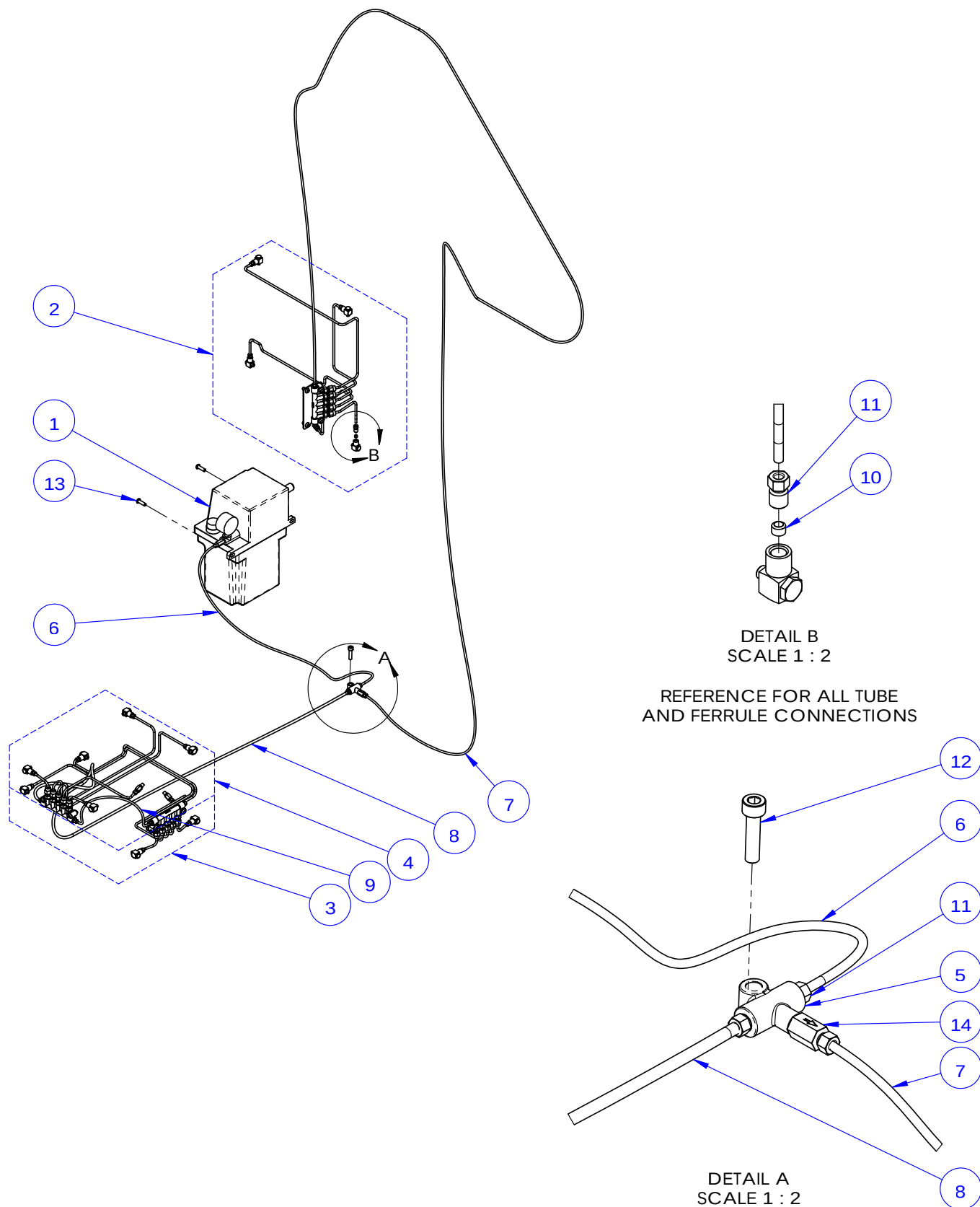


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Servo Motor Mount, 80 mm Frame, 70 mm Pilot (PN 51260)	–	1
2	Ball Nut Bracket, 20 mm (PN 51255)	–	1
3	Ball Screw Support, Fixed-Side (PN 51256)	–	1
4	Ball Screw Support, Floating-Side, 15 mm ID, 45 mm Bore Height (PN 51261)	–	1
5	Coupler, Double Disc, 12 mm Bore × 19 mm Bore (PN 51300)	–	1
6	X-Axis Ball Screw Assembly, 20 mm OD (PN 51744) Y-Axis Ball Screw Assembly, 20 mm OD (PN 51279) Z-Axis Ball Screw Assembly, 20 mm OD (PN 51745)	–	1
7	Spacer, Ball Screw Fixed Side Support, 25 mm OD × 15 mm ID × 10 mm Thick (PN 51336)	–	2
8	Screw, Socket Head Cap, M6 × 1 - 20 (PN 30832)	McMaster-Carr: 91290A326	10
9	Screw, Socket Head Cap, M5 × 0.8 - 16 (PN 30546)	McMaster- Carr: 91290A232	6
10	Screw, Socket Head Cap, M3 × 0.5 - 20 (PN 38572)	McMaster- Carr: 91290A123	2
11	Ball Screw Lock Nut, M15 × 1 (PN 51307)	Misumi: BNRC15	1
12	Servo Motor Mount Bumper (PN 51302)	–	1
13	Ball Screw Support Bumper (PN 51303)	–	1
14	Retaining Ring, External, OD, 15 mm (PN 51338)	McMaster- Carr: 98541A410	1
15	X-Axis/Y-Axis Servo Motor, 750W (PN 51810) Z-Axis Servo Motor, 750W (PN 51258)	–	1
16	X-Axis Servo Power Cable (PN 51571) Y-Axis Servo Power Cable (PN 51572) Z-Axis Servo Power Cable (PN 51573)	–	1
17	X-Axis Servo Encoder Cable (PN 51568) Y-Axis Servo Encoder Cable (PN 51569) Z-Axis Servo Encoder Cable (PN 51570)	–	1

12.1.7 Lubrication Assembly

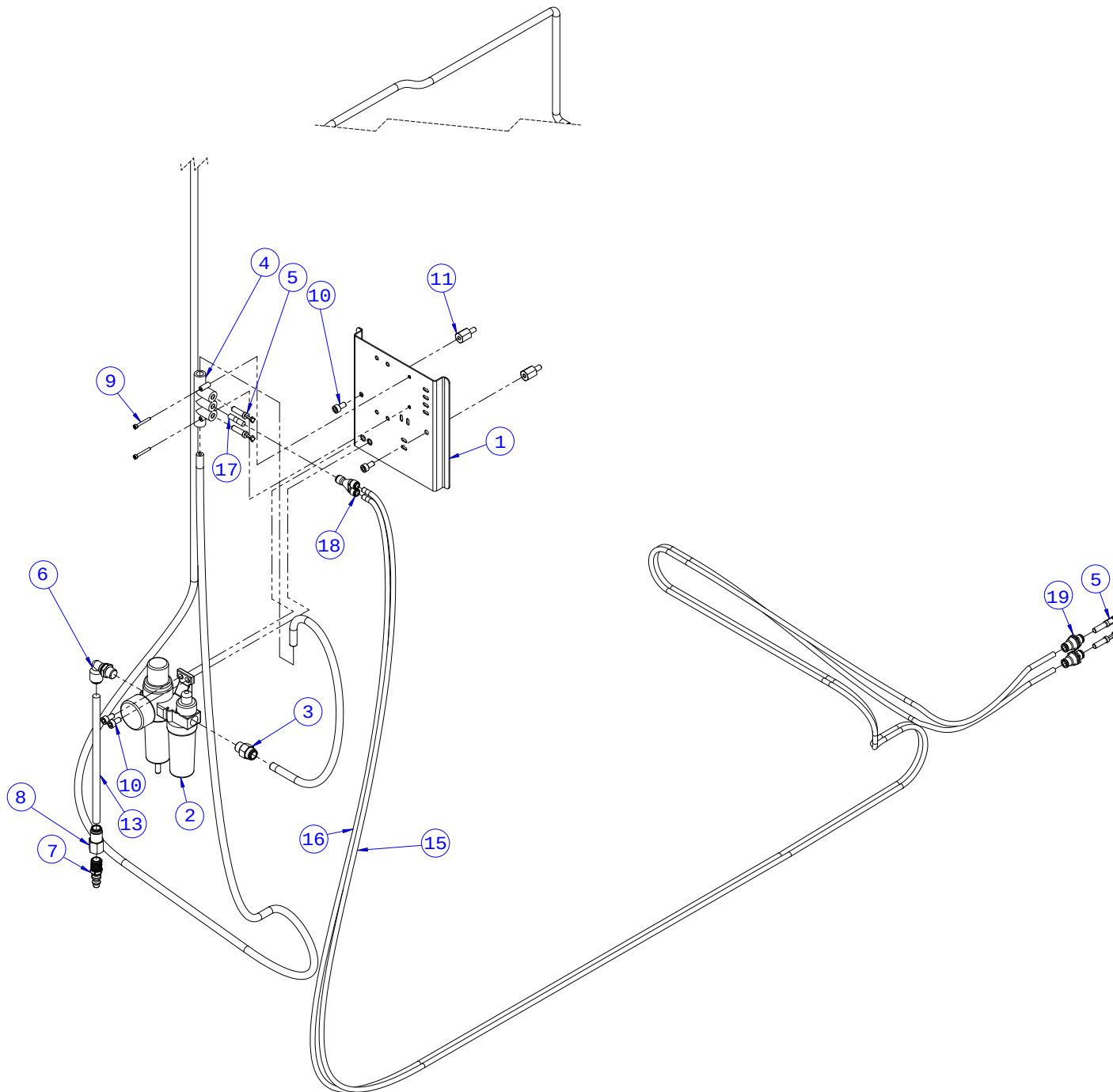


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	<u>Automatic Oiler Kit: 230 Vac (PN 31374)</u>	–	1
2	Z-Axis Lubrication Assembly, 1500MX (PN 51433)	–	1
3	Y-Axis Lubrication Assembly, 1500MX (PN 51404)	–	1
4	X-Axis Lubrication Assembly, 1500MX (PN 51407)	–	1
5	Fitting, Tee, 4 mm Tube, M8 × 1.0 Thread (PN 32354)	–	1
6	Tubing, Nylon, 4 mm OD, Semi-Clear, 72 cm Long (PN 31304)	McMaster-Carr: <u>50405K33</u>	1
7	Tubing, Nylon, 4 mm OD, Semi-Clear, 430 cm Long (PN 31304)	McMaster-Carr: <u>50405K33</u>	1
8	Tubing, Nylon, 4 mm OD, Semi-Clear, 140 cm Long (PN 31304)	McMaster-Carr: <u>50405K33</u>	1
9	Tubing, Nylon, 4 mm OD, Semi-Clear, 29 cm Long (PN 31304)	McMaster-Carr: <u>50405K33</u>	1
10	<u>Fitting, Ferrule, 4 mm Tube (PN 31309)</u>	–	3
11	<u>Fitting, Compression Nut, 4 mm Tube (PN 31310)</u>	–	3
12	Screw, Socket Head Cap, M6 × 1 - 25 (PN 31685)	McMaster-Carr: <u>91290A330</u>	1
13	Screw, Button Head Cap, M6 × 1 - 20, Stainless Steel (PN 51700)	McMaster-Carr: <u>92095A240</u>	2
14	Fitting, Check Valve, M8 × P1.0 - 4 mm Tube (PN 52912)	–	1

12.1.8 Pneumatics Assembly

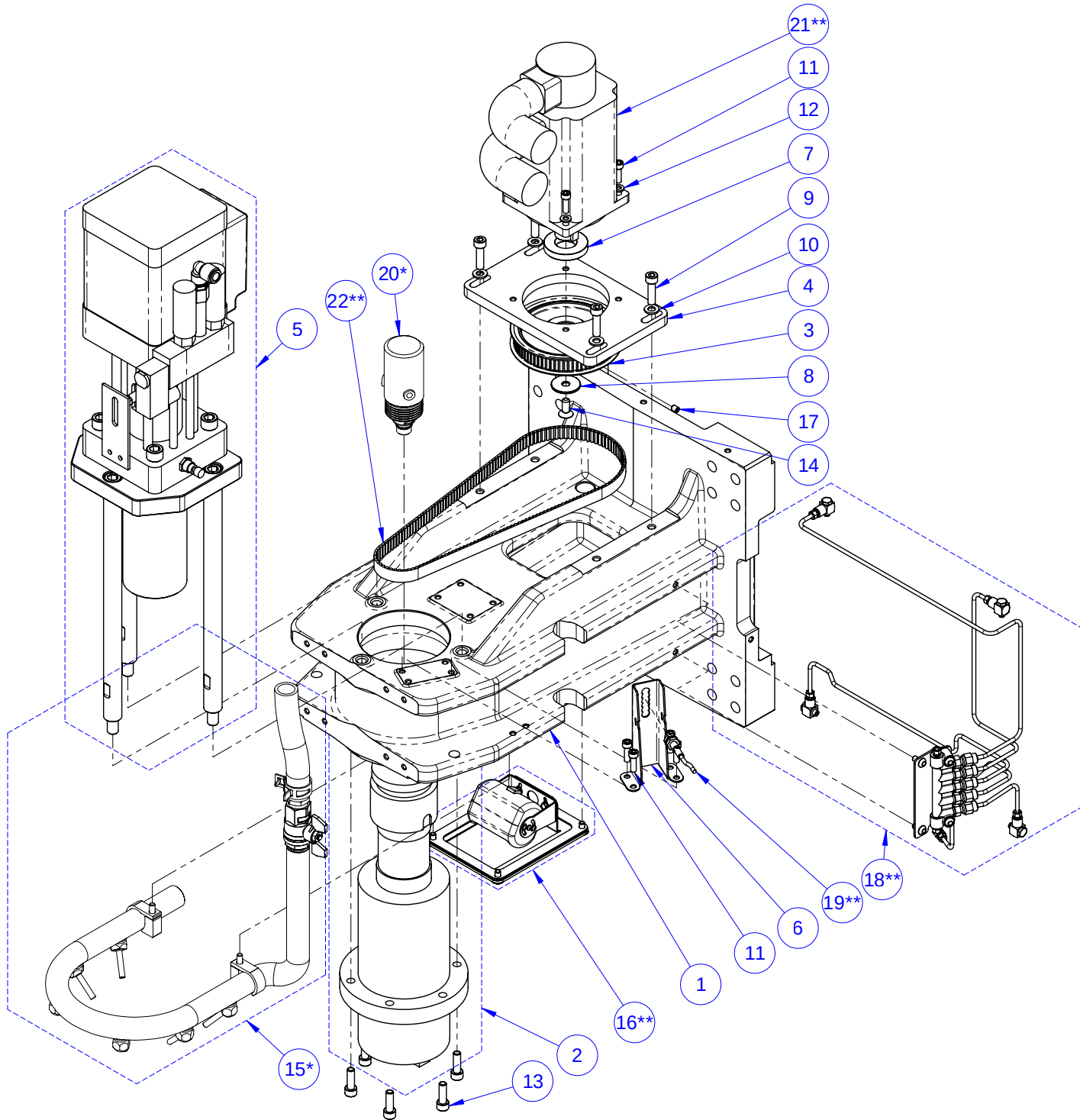


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Machine Pneumatics Bracket, 1500MX (PN 51627)	–	1
2	FRL, 1/4 in. NPT Inlet × 1/4 in. NPT Outlet (PN 51635)	–	1
3	Fitting, Straight, 1/4 in. NPT (Male) - 3/8 in. PTC (PN 52317)	–	1
4	Fitting, Reducing Manifold Union, 2x 3/8 in. PTC Ports - 3x 1/4 in. PTC Ports (PN 52316)	–	1
5	Fitting, Plug, 1/4 in. PTC, Plastic (PN 51629)	–	4
6	Fitting, Elbow, 1/4 in. NPT (Male) - 3/8 in. PTC (PN 52318)	–	1
7	Fitting, Brass Coupling, 1/4 Male NPT (PN 31989)	McMaster Carr: 1077T17	1
8	Fitting, Straight, 1/4 in. NPT (Female) - 3/8 in. PTC (PN 52319)	–	1
9	Screw, Socket Head Cap, M3 × 0.5 - 25 (PN 50768)	McMaster-Carr: 91290A125	2
10	Screw, Socket Head Cap, M6 × 1 - 12 (PN 51421)	McMaster-Carr: 91290A318	4
11	Standoff, 16 mm, M6 × 1 - 13 mm Male, M6 × 1 - 10 mm Female, Steel (PN 51566)	McMaster-Carr: 93655A255	2
12	Tubing, Polyurethane, 3/8 in. OD, Black, 23 cm Long (PN 52437)	McMaster-Carr: 5648K261	1
13	Tubing, Polyurethane, 3/8 in. OD, Black, 23 cm Long (PN 52437)	McMaster-Carr: 5648K261	1
14	Tubing, Polyurethane, 3/8 in. OD, Black, 23 cm Long (PN 52437)	McMaster-Carr: 5648K261	1
15	Tube, 1/4 in. OD, Polyethylene (Black), 310 cm Long (PN 31457)	McMaster-Carr: 5180K71	1
16	Tube, 1/4 in. OD, Polyethylene (Black), 310 cm Long (PN 31457)	McMaster-Carr: 5180K71	1
17	Tube, 1/4 in. OD, Polyethylene (Black), 40 mm Long (PN 31457)	McMaster-Carr: 5180K71	1
18	Fitting, Wye, 1/4 in. PTC (PN 38550)	–	1
19	Fitting, Bulkhead Union, 1/4 in. PTC (PN 38884)	–	2

12.1.9 Spindle Head

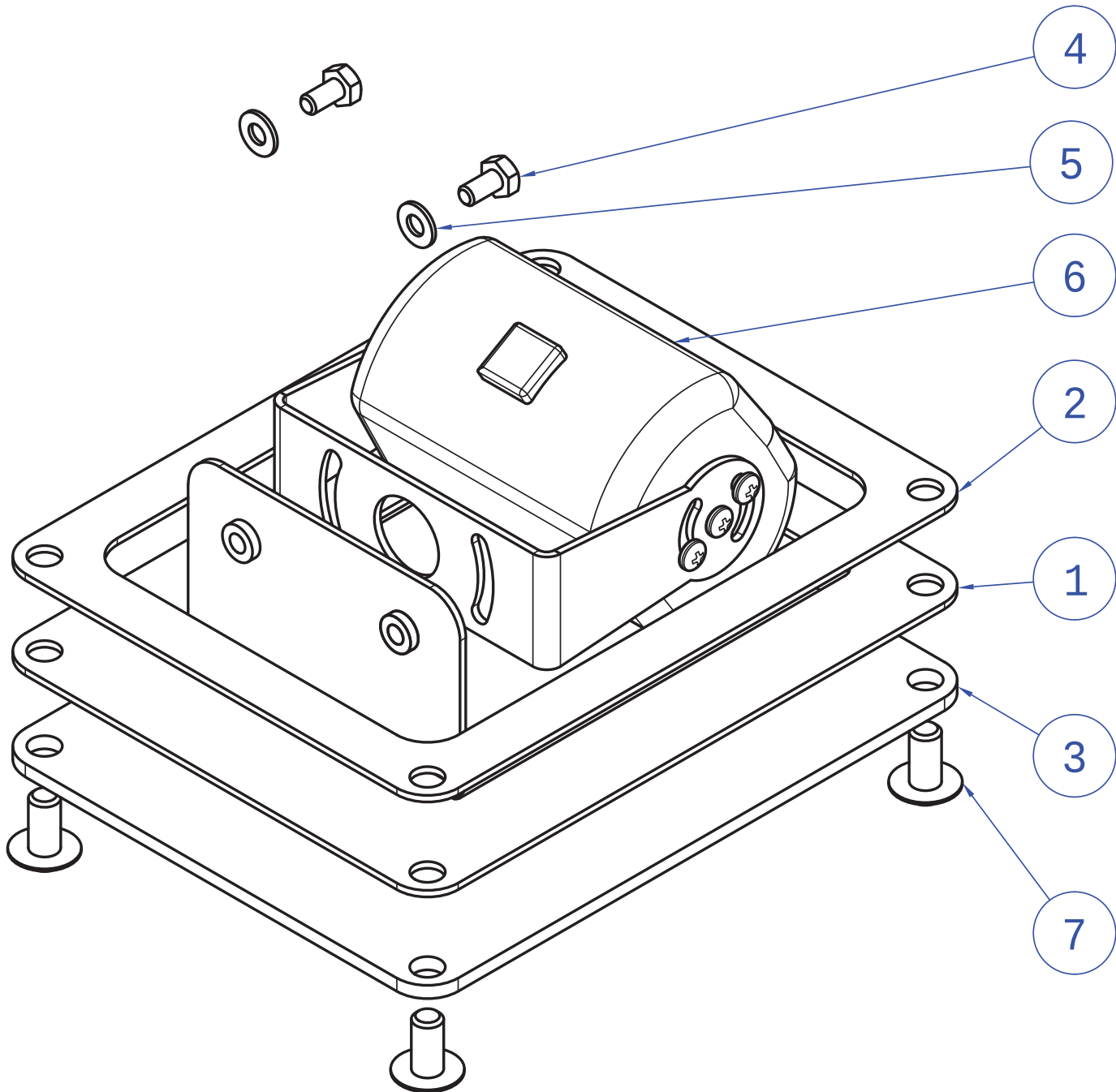


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Spindle Head Casting, 1500MX (PN 51234)	–	1
2	1500MX Spindle Cartridge Assembly, BT30, 10000 rpm, 5MHTD-36T Pulley, Through Spindle Coolant (CTS) (PN 51347)	–	1
3	Spindle Motor Pulley, 1500MX (PN 51235)	–	1
4	Spindle Motor Mount Plate, 1500MX (PN 51236)	–	1
5	<u>Power Drawbar Cylinder Assembly, 1500MX (PN 51237)</u>	–	1
6	Spindle Index Sensor Bracket, 1500MX (PN 51244)	–	1
7	Spindle Motor Pulley Spacer, 1500MX (PN 52217)	–	1
8	Spindle Motor Pulley Washer, 1500MX (PN 52218)	–	1
9	Screw, Socket Head Cap, M8 × 1.25 - 30 (PN 30544)	McMaster-Carr: 91290A434	4
10	Washer, Flat, M8 (PN 30531)	McMaster-Carr: 91166A270	4
11	Screw, Socket Head Cap, M6 × 1 - 20 (PN 30832)	McMaster-Carr: 91290A326	8
12	Washer, Flat, M6 (PN 31676)	McMaster-Carr: 91455A120	4
13	Screw, Socket Head Cap, M8 × 1.25 - 25 (PN 34635)	McMaster-Carr: 91290A432	6
14	Screw, Socket Head Countersunk, M8 × 1.25 - 20 (PN 52222)	McMaster-Carr: 91294A284	1
15*	Coolant Ring Assembly, 1500MX (PN 51247)	–	1
16**	<u>Spindle Head Camera Assembly, 1500MX (PN 52463)</u>	–	1
17	Screw, Cup Point Set, M6 × 1 - 8 (PN 30810)	McMaster-Carr: 91390A127	1
18**	Z-Axis Lubrication Assembly, 1500MX (PN 51433)	–	1
19**	Proximity Sensor, PNP-NO, 3-Wire, 8 mm Body (PN 51547)	–	1
20*	Through Spindle Coolant Rotary Union, 1500MX (PN 51604)	–	1
21**	Servo Motor, 1500 W, 220 V, 10.8 A, 3000 RPM, Oil Seal (PN 51152)	–	1
22**	<u>Belt, 1500MX Spindle (PN 51735)</u> Belt, 1500MX Spindle	Gates 800-5M-15 McMaster-Carr: 7939K26	1
* Optional accessory, not included with base machine. ** Component not included in this assembly, but shown here for context.			

12.1.10 Spindle Head Camera Assembly

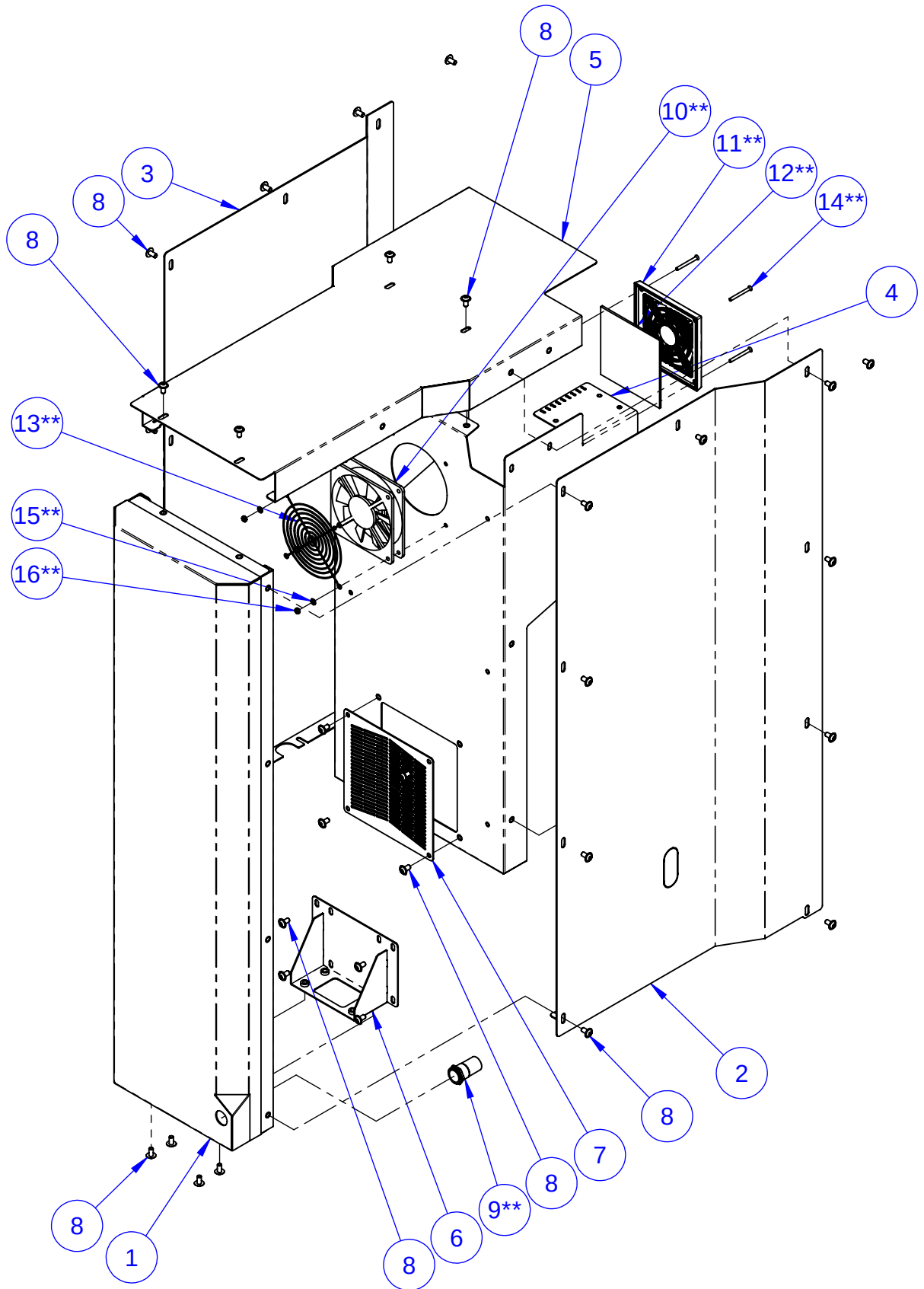


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Camera Bracket, 1500MX (PN 52460)	–	1
2	Camera Seal, 1500MX (PN 52461)	–	1
3	Camera Window, 1500MX (PN 52462)	–	1
4	Screw, Hex Head, M4 × 0.7 - 8, Black Oxide Steel (PN 52755)	–	2
5	Washer, Flat, M4 (PN 31087)	McMaster-Carr: 91166A230	2
6	Camera, USB (PN 51240)	–	1
7	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	4

12.1.11 Spindle Head Sheet Metal Cover Assembly



12: DIAGRAMS AND PARTS LISTS

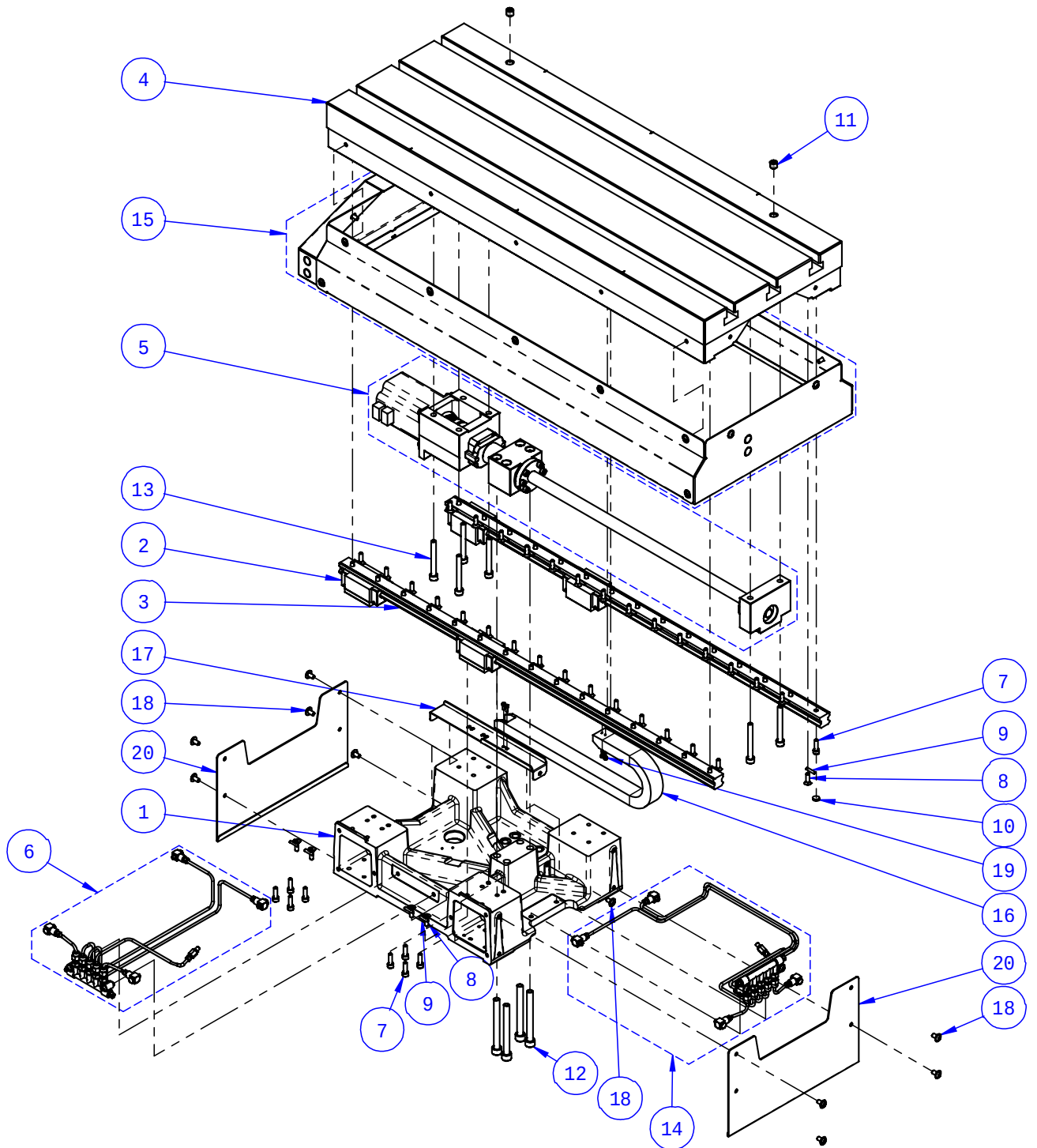
12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Spindle Head Front Panel, 1500MX (PN 51241)	–	1
2	Spindle Head Right Side Panel, 1500MX (PN 51243)	–	1
3	Spindle Head Left Side Panel, 1500MX (PN 51474)	–	1
4	Spindle Head Back Panel, 1500MX (PN 51242)	–	1
5	Spindle Head Top Panel, 1500MX (PN 51475)	–	1
6	Spindle Head Cover Mounting Bracket, 1500MX (PN 51444)	–	1
7	Spindle Head Access Panel, 1500MX (PN 51769)	–	1
8	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	36
9**	Push Button, 1NO1NC, White LED (PN 51239)	–	1
10**	Fan (24 Vdc, 2.5 A, 120 mm) (PN 37526)	McMaster-Carr: 8774N18	1
11**	Electrical Cabinet Exhaust Cover Retainer (PN 37947)	McMaster-Carr: 19155K23	1
12**	Electrical Cabinet Exhaust Filter (PN 37948)	McMaster-Carr: 19155K53	1
13**	Fan Guard, Wire (PN 30515)	McMaster-Carr: 19155K96	1
14**	Screw, Phillips Head Countersunk, M4 × 0.7 - 40, Zinc Plated (PN 51327)	McMaster-Carr: 91420A250	4
15**	Washer, Flat, M4 (PN 31087)	McMaster-Carr: 91166A230	4
16**	Nut, Hex, M4, Zinc Plated (PN 38358)	McMaster-Carr: 90591A255	4

* Optional accessory not included with base mill.

** Component not included in this assembly, but shown here for context.

12.1.12 X-Axis Assembly

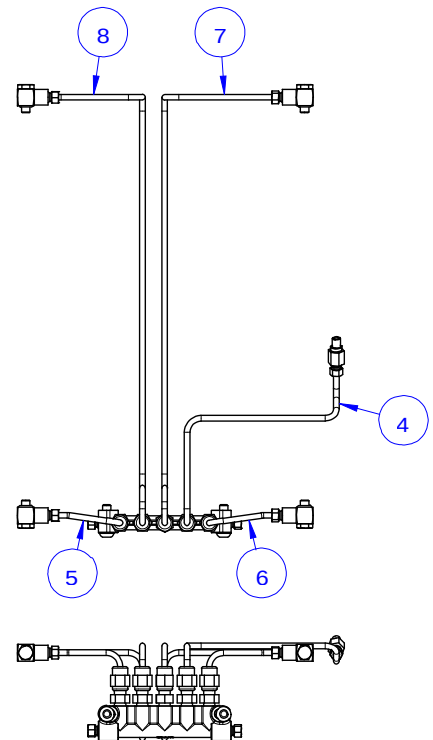
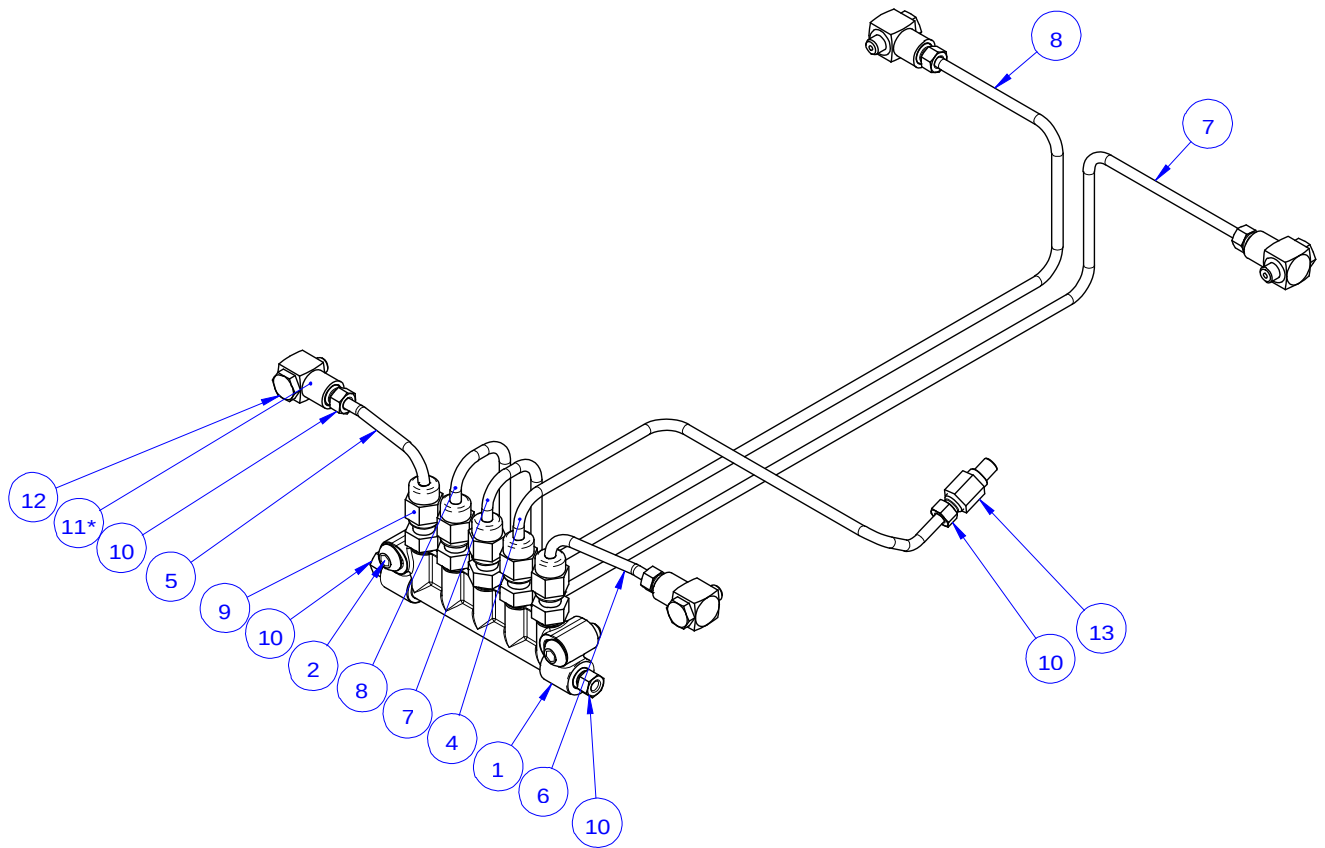


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Saddle Casting, 1500MX (PN 51232)	–	1
2	Linear Guide Block, 25 mm, Precision H, ZA Preload, Interchangeable, M6 Top Down Mount (PN 51341)	–	4
3	Linear Rail, 25 mm, 880 mm Long, Precision H, M6 Top-Down Mount (PN 51339)	–	2
4	Mill Table Casting, 1500MX (PN 51218)	–	1
5	<u>Linear Actuator Assembly, 500 mm Travel, 10 mm Lead (PN 51333)</u>	–	1
6	X-Axis Lubrication Assembly, 1500MX (PN 51407)	–	1
7	Screw, Socket Head Cap, M6 × 1 - 20 (PN 30832)	McMaster-Carr: 91290A326	46
8	Screw, Socket Head Countersunk, M6 × 1 - 20 (PN 51321)	McMaster-Carr: 92125A240	34
9	Pin, 4 × 20 (PN 51342)	McMaster-Carr: 91595A167	34
10	Linear Guide Rail Bolt Cap, M6, Plastic with O-Ring (PN 51350)	–	30
11	Screw, Cup Point Set, M12 × 1.75 - 12 (PN 51699)	McMaster-Carr: 91390A169	2
12	Screw, Socket Head Cap, M10 × 1.5 - 100 (PN 51696)	McMaster-Carr: 91290A548	4
13	Screw, Socket Head Cap, M8 × 1.25 - 70 (PN 51751)	McMaster-Carr: 91290A460	6
14	Y-Axis Lubrication Assembly, 1500MX (PN 51404)	–	1
15	<u>X-Axis Sheet Metal Cover Assembly, 1500MX (PN 51231)</u>	–	1
16	X-Axis Drag Chain, 1500MX (PN 51422)	–	1
17	X-Axis Drag Chain Guide, 1500MX (PN 51767)	–	1
18	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	10
19	Screw, Socket Head Cap, M3 × 0.5 - 10 (PN 51953)	McMaster-Carr: 91290A115	4
20	Saddle Cover Right/Left Panel, 1500MX (PN 51448)	–	2

12.1.13 X-Axis Lubrication Assembly

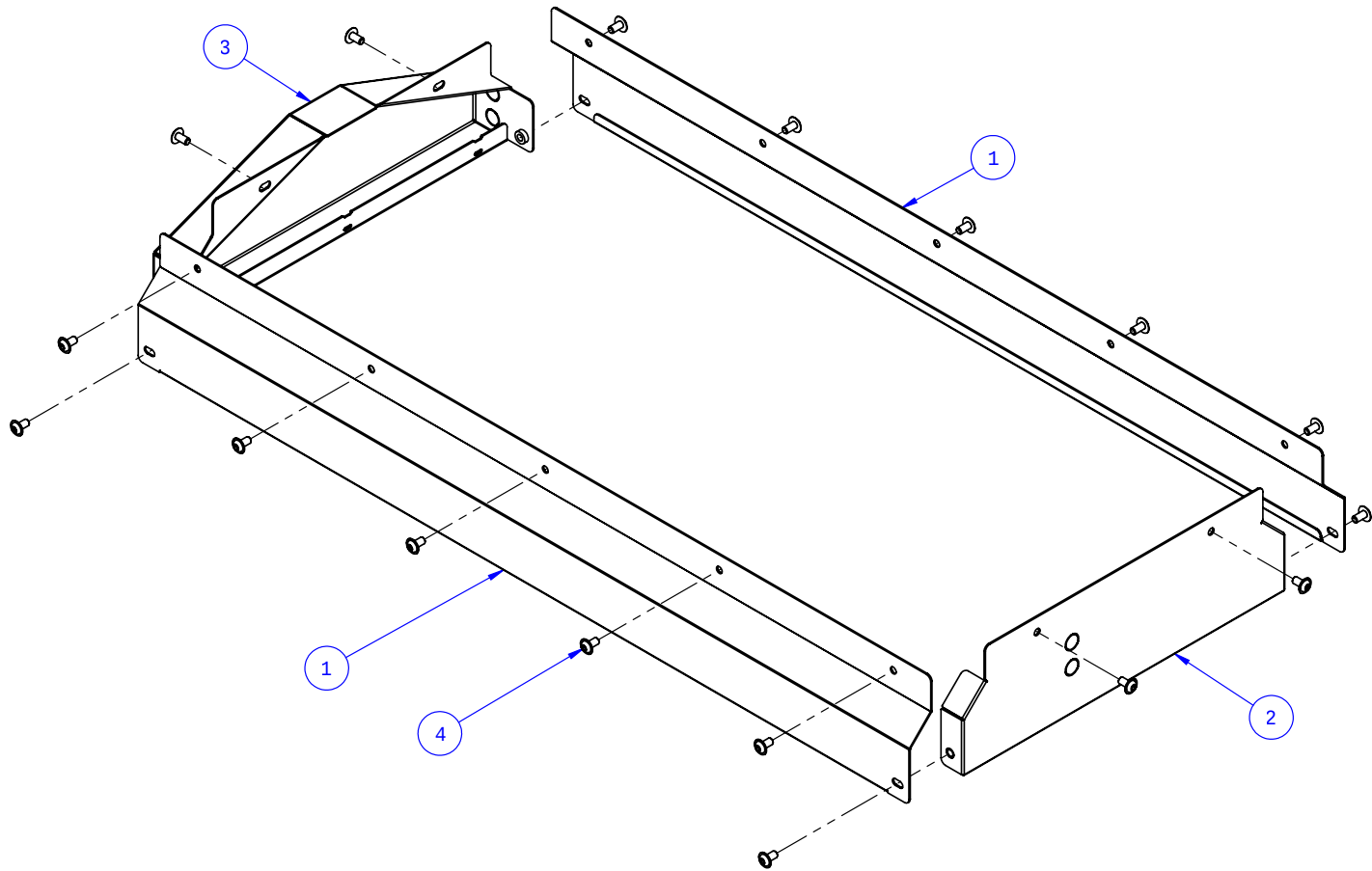


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	5-Port Manifold (PN 30442)	–	1
2	Screw, Button Head Cap, M6 × 1 - 20, Stainless Steel (PN 51700)	McMaster-Carr: 92095A240	2
3	Tubing, Nylon, 4 mm OD (PN 31304)	McMaster-Carr: 50405K33	1
4	Lubrication Line, Copper, 1500MX X-Axis Ball Nut (PN 52514)	–	1
5	Lubrication Line, Copper, 1500MX X-Axis Bearing 1 (PN 52515)	–	1
6	Lubrication Line, Copper, 1500MX X-Axis Bearing 2 (PN 52516)	–	1
7	Lubrication Line, Copper, 1500MX X-Axis Bearing 3 (PN 52517)	–	1
8	Lubrication Line, Copper, 1500MX X-Axis Bearing 4 (PN 52518)	–	1
9	Fitting, Proportional Orifice, M8 × 1 (Male) - 4 mm (OD) Tube (PN 52511)	–	5
10	<u>Fitting, Compression Nut, 4 mm Tube (PN 31310)</u>	–	7
11*	<u>Fitting, Ferrule, 4 mm Tube (PN 31309)</u>	–	6
12	<u>Fitting, Banjo Elbow, M6 × 1 - 4 mm Tube (PN 31311)</u>	–	4
13	Fitting, Adapter, M6 × 0.75 P (Male) to M8 × 1 (Female) (PN 52512)	–	1
*Hidden inside fittings. See tube and ferrule connections reference in "Lubrication Assembly" (page 317).			

12.1.14 X-Axis Sheet Metal Cover Assembly

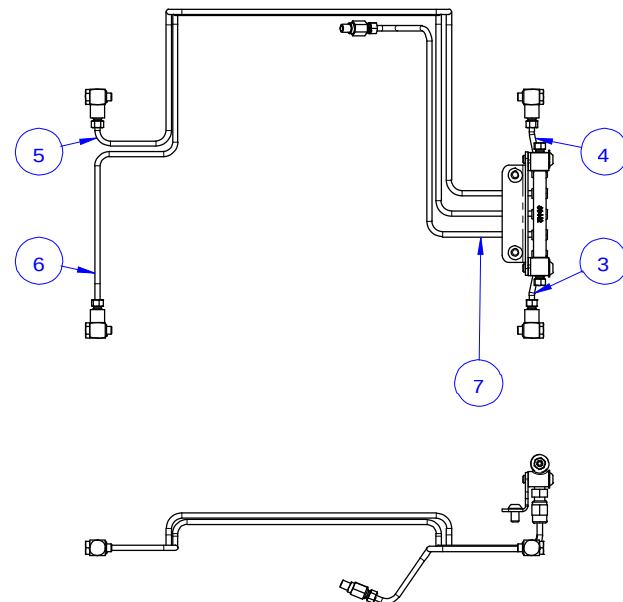
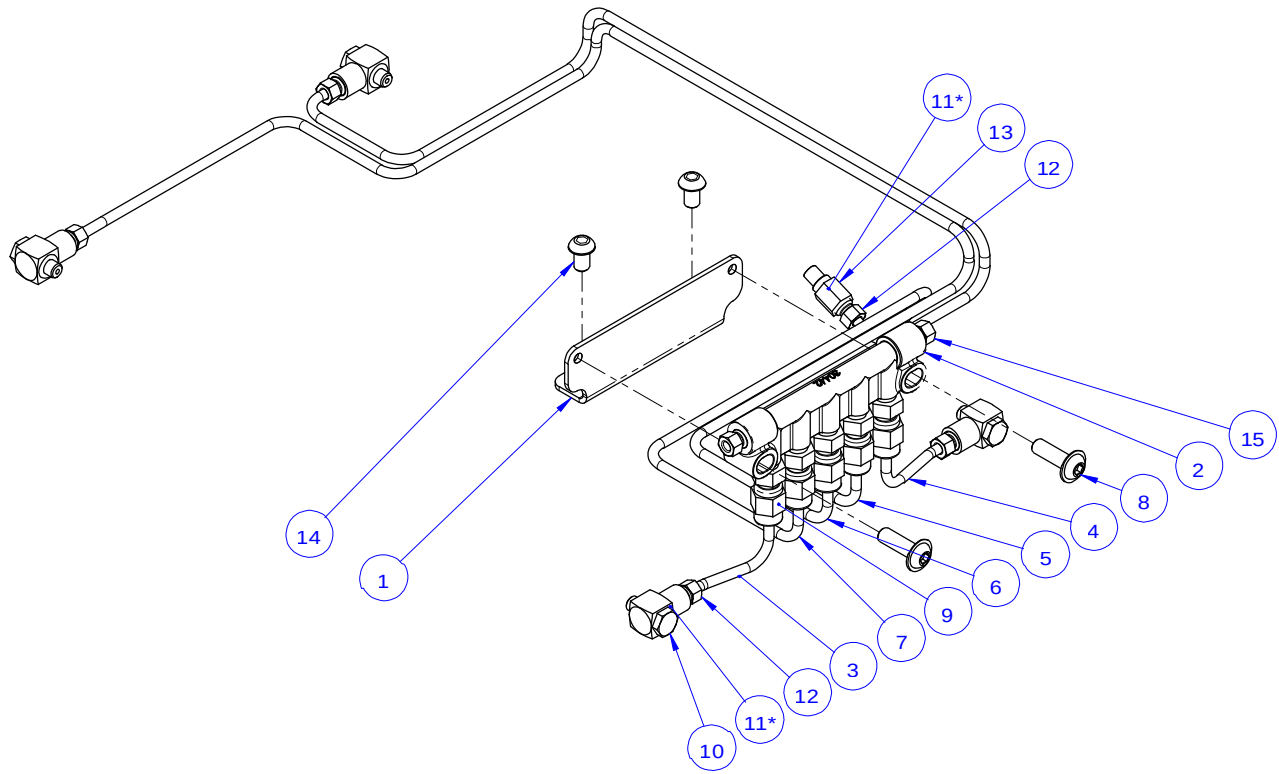


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	X-Axis Sheet Metal Cover Front/Rear Panel, 1500MX (PN 51446)	–	2
2	X-Axis Sheet Metal Cover Right Panel, 1500MX (PN 51447)	–	1
3	X-Axis Sheet Metal Cover Left Panel, 1500MX (PN 51811)	–	1
4	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	18

12.1.15 Y-Axis Lubrication Assembly

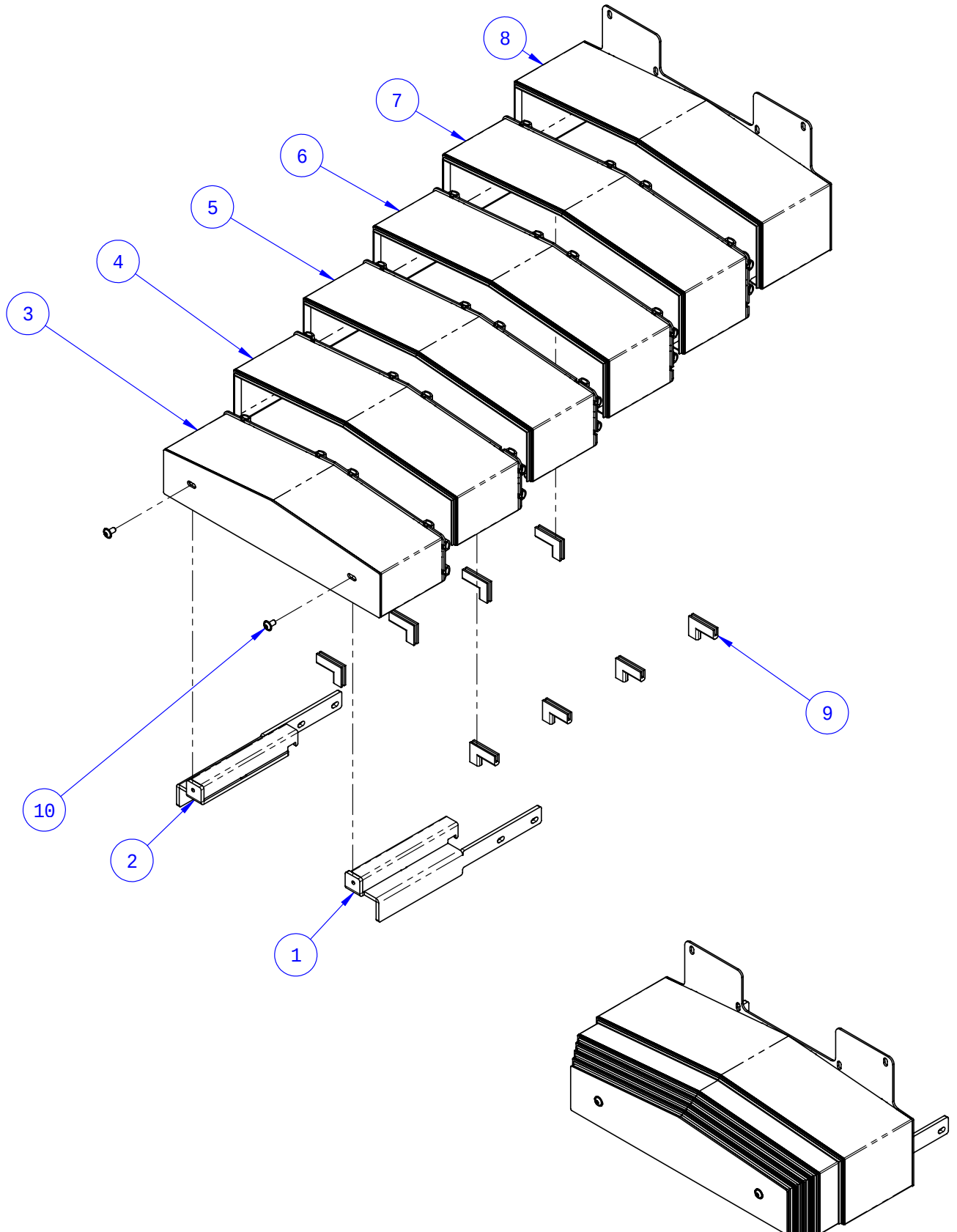


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Y-Axis Lubrication Manifold Bracket, 1500MX (PN 51408)	–	1
2	5-Port Manifold (PN 30442)	–	1
3	Lubrication Line, Copper, 1500MX Y-Axis Bearing 1 (PN 52233)	–	1
4	Lubrication Line, Copper, 1500MX Y-Axis Bearing 2 (PN 52234)	–	1
5	Lubrication Line, Copper, 1500MX Y-Axis Bearing 3 (PN 52235)	–	1
6	Lubrication Line, Copper, 1500MX Y-Axis Bearing 4 (PN 52236)	–	1
7	Lubrication Line, Copper, 1500MX Y-Axis Ball Nut (PN 52231)	–	1
8	Screw, Button Head Cap, Flanged M6 × 1 - 20, 18-8 Stainless (PN 51418)	–	2
9	Fitting, Proportional Orifice, M8 × 1 (Male) - 4 mm (OD) Tube (PN 52511)	–	5
10	<u>Fitting, Banjo Elbow, M6 × 1 - 4 mm Tube (PN 31311)</u>	–	4
11*	<u>Fitting, Ferrule, 4 mm Tube (PN 31309)</u>	–	7
12	<u>Fitting, Compression Nut, 4 mm Tube (PN 31310)</u>	–	7
13	Fitting, Adapter, M6 × 0.75 P (Male) to M8 × 1 (Female) (PN 52512)	–	1
14	Screw, Button Head Cap, M6 × 1 - 10, Stainless Steel (PN 52513)	McMaster-Carr: 92095A224	2
15	Fitting, Plug, M8 × 1, Compression Type (PN 53005)	–	1
*Hidden inside fittings. See tube and ferrule connections reference in "Lubrication Assembly" (page 317).			

12.1.16 Y-Axis Front Way Cover Assembly

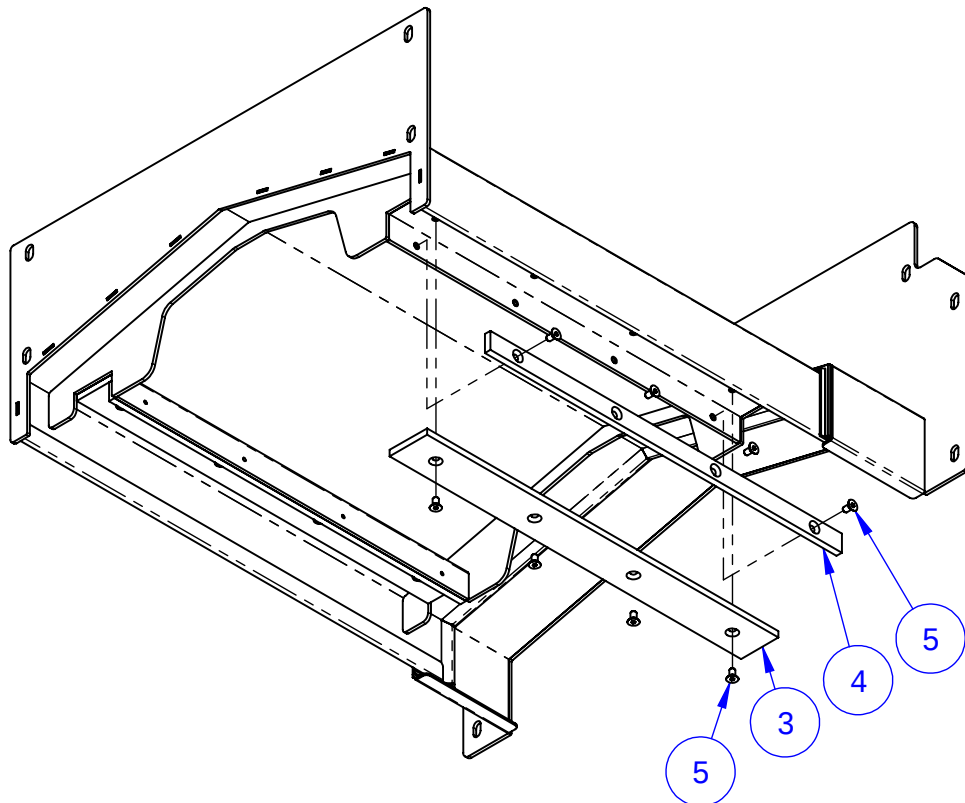
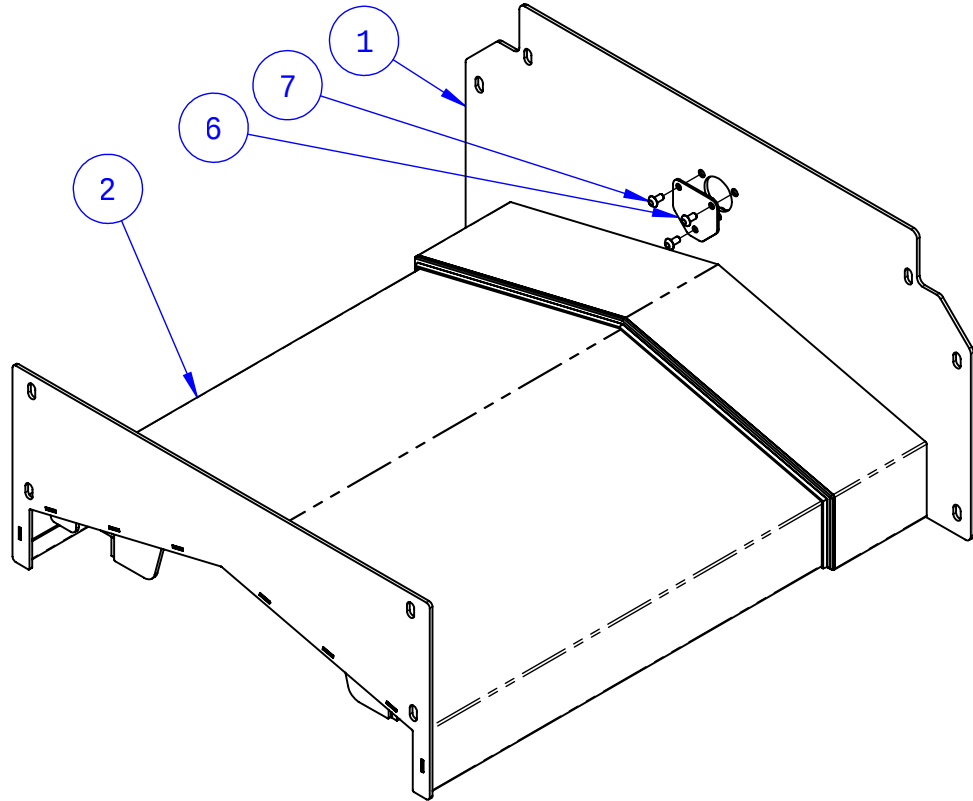


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Right Mounting Bracket, Y-Axis Front Way Cover, 1500MX (PN 51648)	–	1
2	Left Mounting Bracket, Y-Axis Front Way Cover, 1500MX (PN 51649)	–	1
3	Base Segment, Y-Axis Front Way Cover, 1500MX (PN 51647)	–	1
4	Intermediate Segment 1, Y-Axis Front Way Cover, 1500MX (PN 51650)	–	1
5	Intermediate Segment 2, Y-Axis Front Way Cover, 1500MX (PN 51651)	–	1
6	Intermediate Segment 3, Y-Axis Front Way Cover, 1500MX (PN 51652)	–	1
7	Intermediate Segment 4, Y-Axis Front Way Cover, 1500MX (PN 51653)	–	1
8	Top Segment, Y-Axis Front Way Cover, 1500MX (PN 51646)	–	1
9	Linear Rail Slider Trim, Y-Axis Front Way Cover, 1500MX (PN 51656)	–	8
10	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	2

12.1.17 Y-Axis Rear Way Cover Assembly

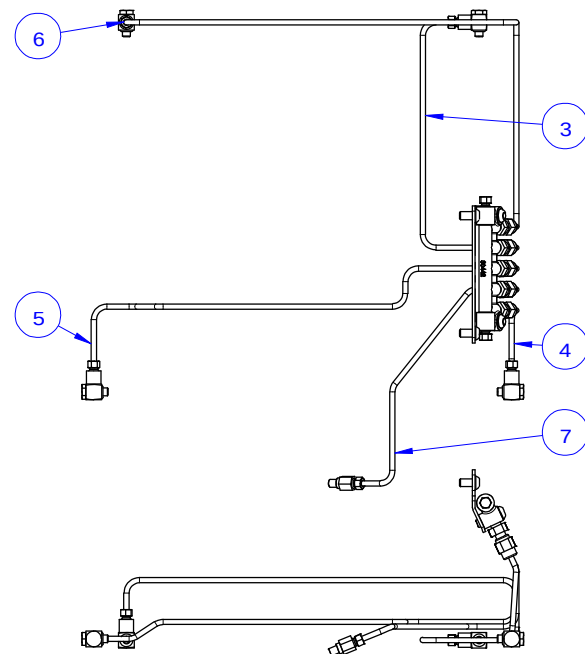
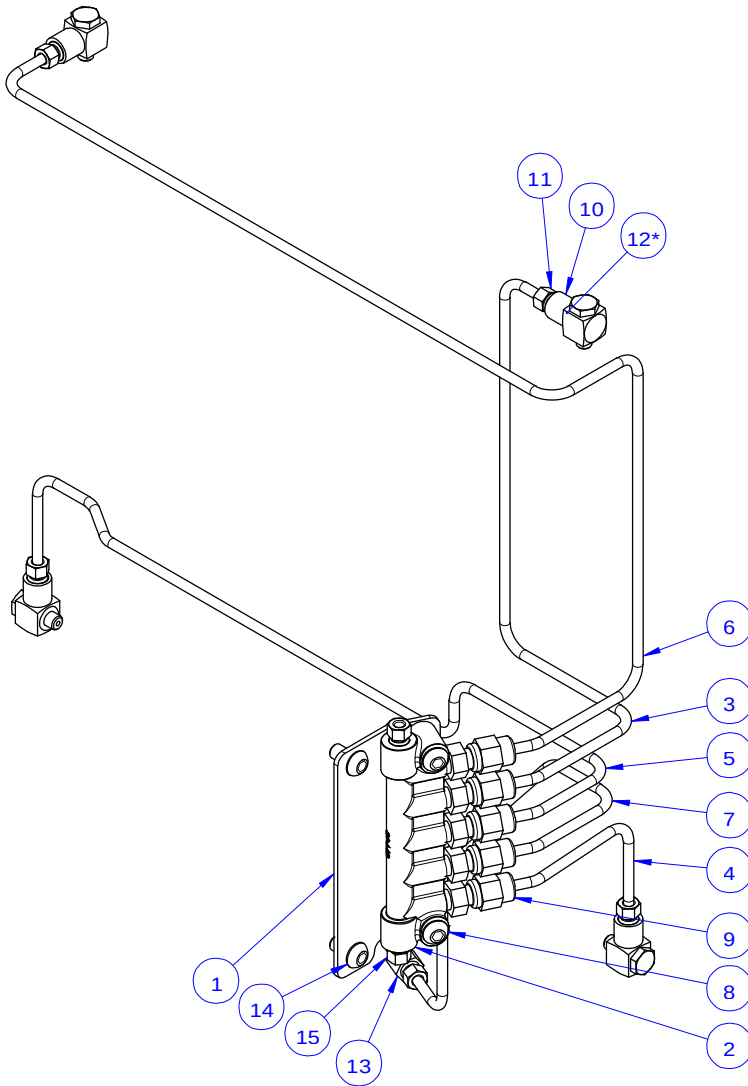


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Base Segment, Y-Axis Rear Way Cover, 1500MX (PN 51636)	–	1
2	Moving Segment, Y-Axis Rear Way Cover, 1500MX (PN 51637)	–	1
3	Wide Slide Plate, Y-Axis Rear Way Cover, 1500MX (PN 51644)	–	2
4	Narrow Slide Plate, Y-Axis Rear Way Cover, 1500MX (PN 51645)	–	2
5	Screw, Socket Head Countersunk, M4 × 0.7 - 8, Stainless Steel (PN 51672)	McMaster-Carr: 92125A188	16
6	Washdown Cover Plate, Y-Axis Rear Way Cover, 1500MX (PN 51675)	–	1
7	Screw, Button Head Cap, M4 × 0.7 - 8, Stainless Steel (PN 50838)	McMaster-Carr: 92095A189	3

12.1.18 Z-Axis Lubrication Assembly

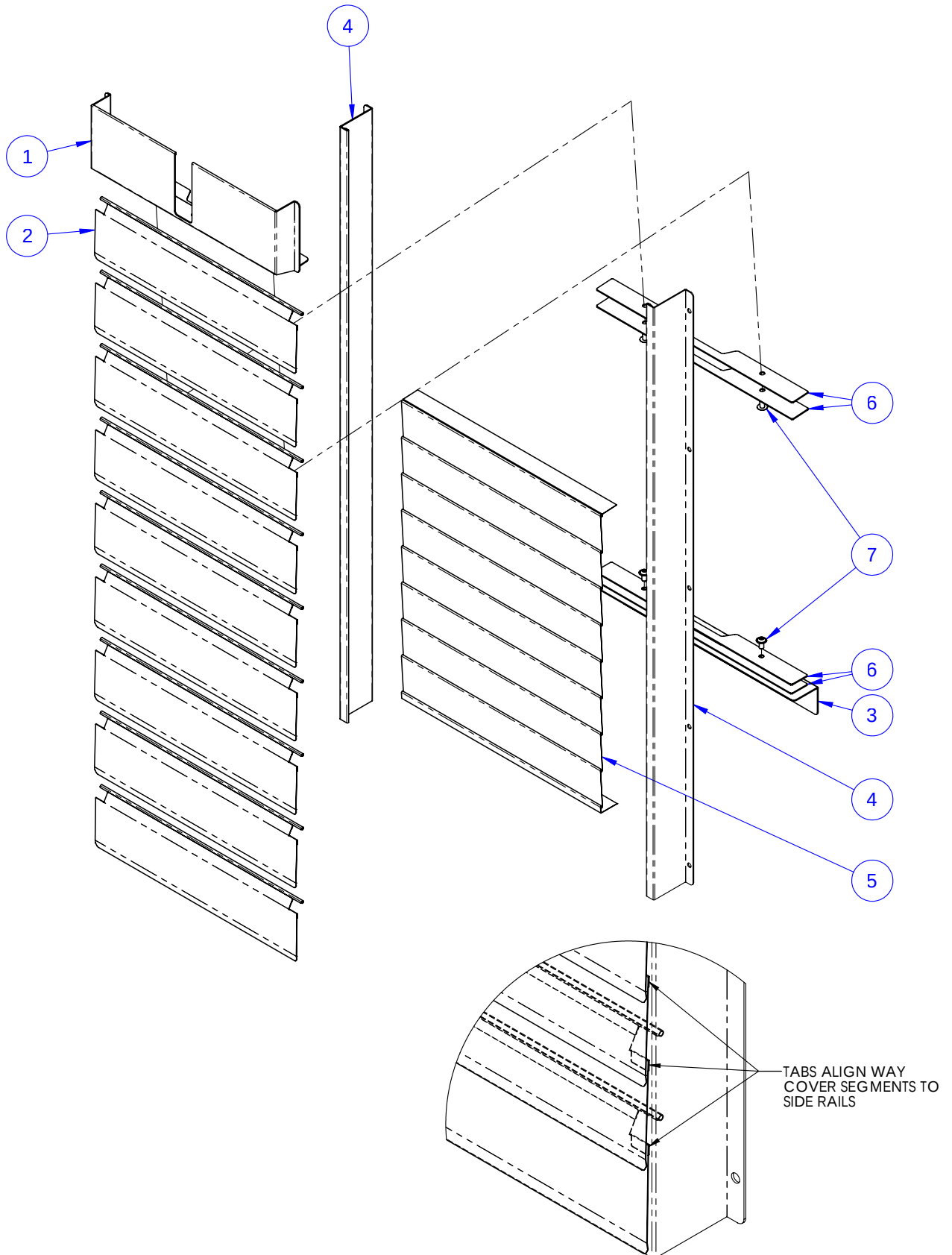


12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Bracket, Z-Axis Oil Distributor Mount, 1500MX (PN 51402)	—	1
2	5-Port Manifold (PN 30442)	—	1
3	Lubrication Line, Copper, 1500MX Z-Axis Bearing 1 (PN 52238)	—	1
4	Lubrication Line, Copper, 1500MX Z-Axis Bearing 2 (PN 52239)	—	1
5	Lubrication Line, Copper, 1500MX Z-Axis Bearing 3 (PN 52240)	—	1
6	Lubrication Line, Copper, 1500MX Z-Axis Bearing 4 (PN 52241)	—	1
7	Lubrication Line, Copper, 1500MX Z-Axis Ball Nut (PN 52237)	—	1
8	Screw, Button Head Cap, M6 × 1 - 20, Stainless Steel (PN 51700)	McMaster-Carr: 92095A240	2
9	Fitting, Proportional Orifice, M8 × 1 (Male) - 4 mm (OD) Tube (PN 52511)	—	5
10	<u>Fitting, Banjo Elbow, M6 × 1 - 4 mm Tube (PN 31311)</u>	—	4
11	<u>Fitting, Compression Nut, 4 mm Tube (PN 31310)</u>	—	7
12*	<u>Fitting, Ferrule, 4 mm Tube (PN 31309)</u>	—	7
13	Fitting, Adapter, M6 × 0.75 P (Male) to M8 × 1 (Female) (PN 52512)	—	1
14	Screw, Button Head Cap, M6 × 1 - 12, Stainless Steel (PN 51597)	McMaster-Carr: 92095A226	2
15	Fitting, Plug, M8 × 1, Compression Type (PN 53005)	—	1
*Hidden inside fittings. See tube and ferrule connections reference in "Lubrication Assembly" (page 317).			

12.1.19 Z-Axis Way Cover Assembly



12: DIAGRAMS AND PARTS LISTS

12.1 Mill Diagrams and Parts Lists

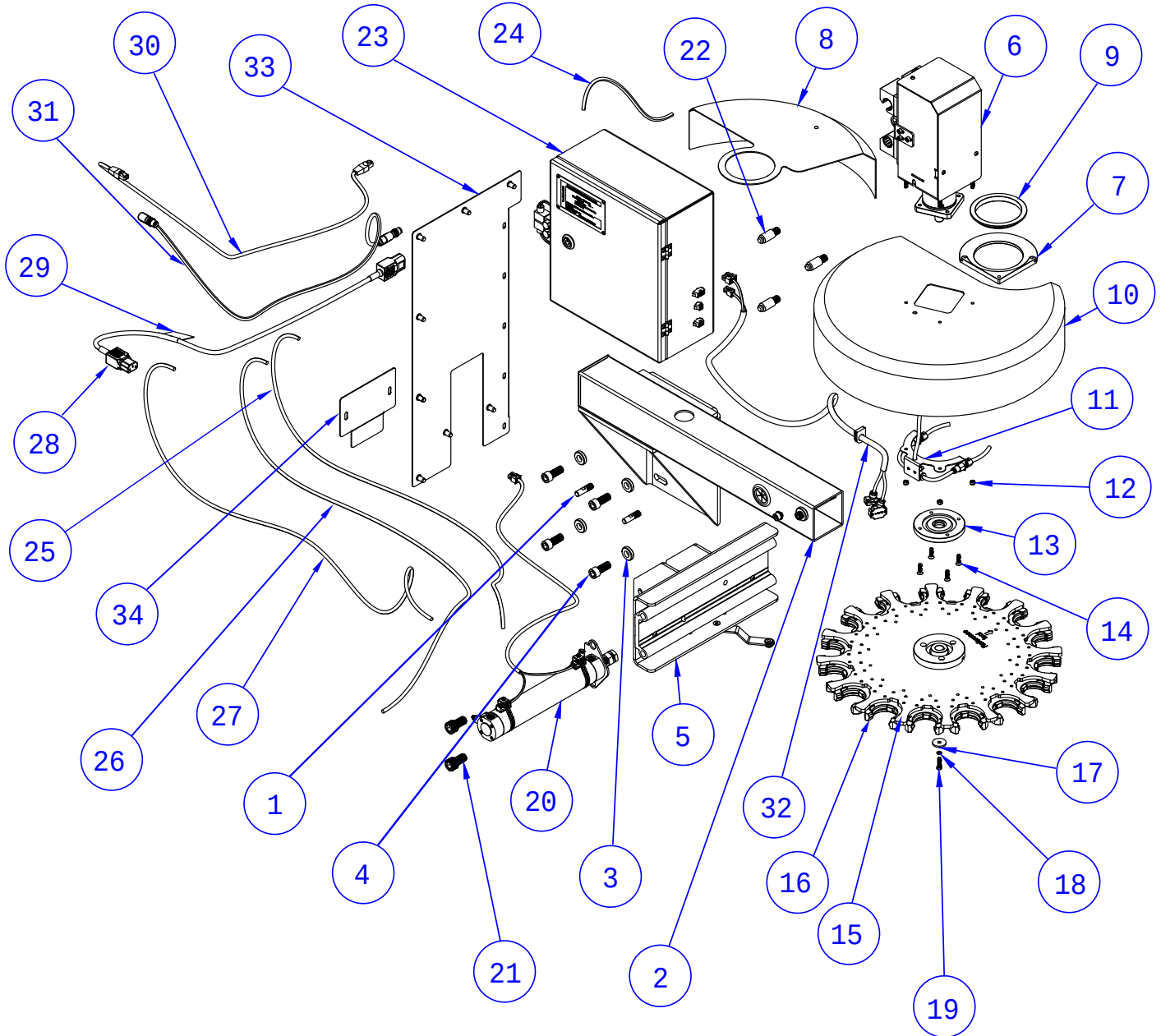
ID	Description	Alternative Part Number	Quantity
1	Top Segment, Z-Axis Way Cover, 1500MX (PN 51582)	–	1
2	Middle Segment, Z-Axis Way Cover, 1500MX (PN 51586)	–	9
3	Bottom Segment, Z-Axis Way Cover, 1500MX (PN 51589)	–	1
4	Side Rail, Z-Axis Way Cover, 1500MX (PN 51585)	–	2
5	Liner, Z-Axis Way Cover, 1500MX (PN 51670)	–	1
6	Liner Clamp, Z-Axis Way Cover, 1500MX (PN 51673)	–	4
7	Screw, Button Head Cap (Flanged), M6 × 1 - 12, Stainless Steel (PN 38206)	McMaster-Carr: 97654A380	4

12.2 ACCESSORY DIAGRAMS AND PARTS LISTS

12.2.1 Automatic Tool Changer.....	344
12.2.2 microARC 6.....	347
12.2.3 Mist Collector.....	350
12.2.4 MQL Solenoid Assembly, 24 Vdc.....	353
12.2.5 Oil Skimmer Kit.....	355
12.2.6 Washdown Kit Assembly.....	357

12.2 Accessory Diagrams and Parts Lists

12.2.1 Automatic Tool Changer



12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

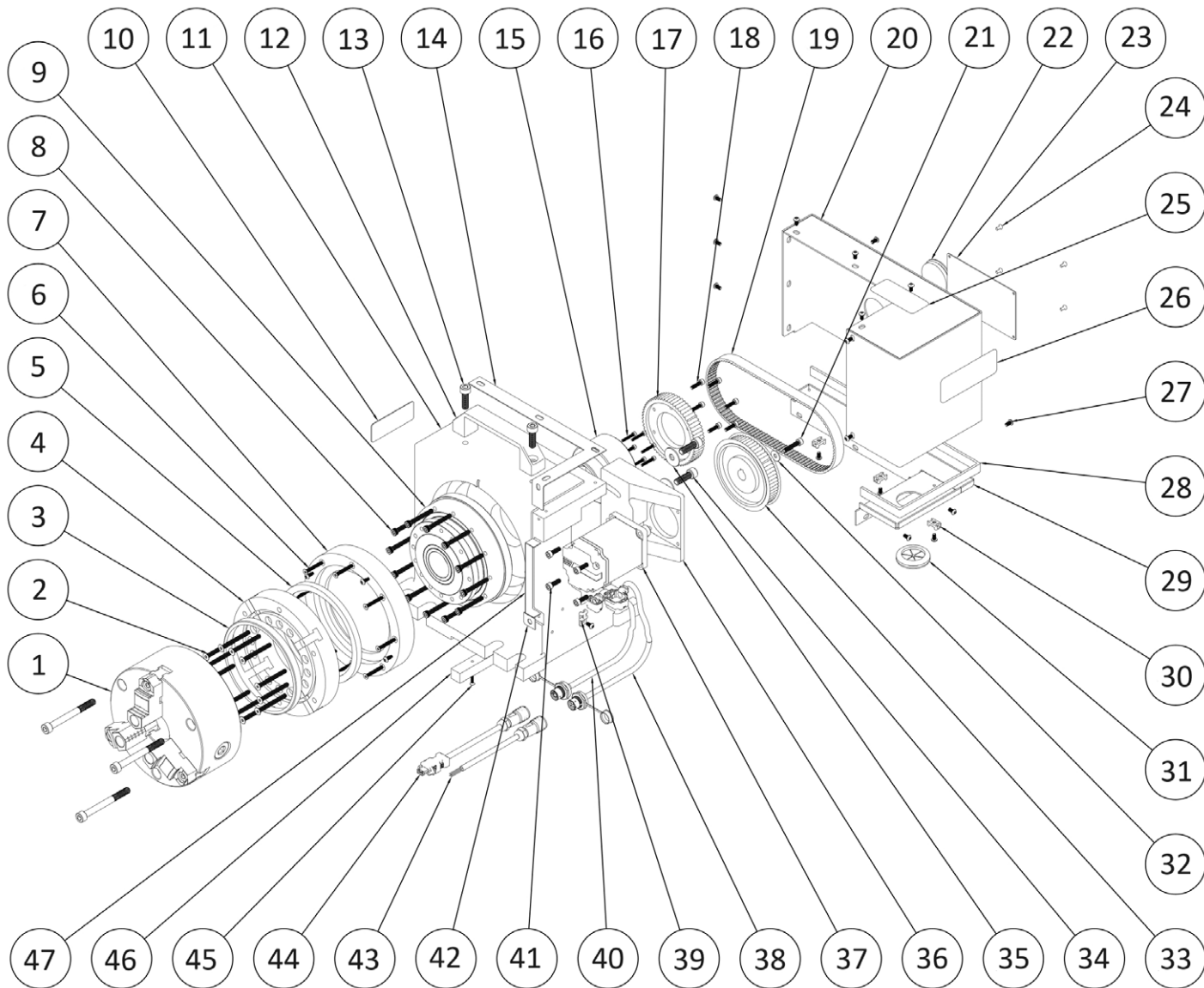
ID	Description	Quantity
1	ATC Slide Pin 10 mm, 1500MX (PN 52492)	2
2	ATC Column Mount Assembly, 1500MX (PN 51857)	1
3	ATC Custom Standoff Washer, M12, 1500MX (PN 52288)	4
4	Screw, Socket Head Cap, M12 × 1.75 - 30 (PN 52448)	4
5	ATC Slide Assembly, 1500MX (PN 51852)	1
6	ATC Motor Box Assembly, 1500MX (PN 51853)	1
7	ATC Chip Door Turning Box, Base, Black Delrin, 1500MX (PN 53036)	1
8	ATC Chip Door, BT30 16T (PN 51865)	1
9	ATC Chip Door Turning Box, Top, Black Delrin, 1500MX (PN 53035)	1
10	ATC Cowling, 1500MX (PN 53030)	1
11	ATC Blast Assembly, 1500MX (PN 51854)	1
12	Locknut, Hex, M5 × 0.8 (PN 53054)	3
13	ATC Gearbox Spacer, 1500MX (PN 51864)	1
14	Screw, Hex (Flat), M5 × 0.8 - 20, Black Oxide Steel (PN 52384)	4
15	ATC Tool Tray Assembly, 1500MX (PN 51855)	1
16	ATC Fork for MX Mills (BT30) (PN 38519)	16
17	Custom Stainless Steel Washer, M5 (PN 52482)	1
18	Washer, Pressure, 1/4 in. (PN 52587)	1
19	Screw, Hex Head, M5 × 0.8 - 20, A2 Stainless Steel (PN 53034)	1
20	ATC Actuator Assembly, 1500MX (PN 51859)	1
21	Screw, Socket Head Cap, M14 × 2.0 - 25, Black Oxide (PN 53055)	2
22	Cabinet Standoffs, M12 × 15 (PN 51974)	3
23	ATC Electrical Cabinet Assembly, 1500MX (PN 51949)	1
24	Tubing, Polyethylene Air Line, 1/4 in. OD, Black, 40 cm (PN 31457)	1
25	Tubing, Polyethylene Air Line, 1/4 in. OD, Red, 125 cm (PN 52323)	1
26	Tubing, Polyethylene Air Line, 1/4 in. OD, Black, 135 cm (PN 31457)	1
27	Tubing, Polyethylene Air Line, 1/4 in. OD, Black, 125 cm (PN 31457)	1
28	IEC 320 C13 to C14 Cable, 250 V, 10 A, 1 M, Black (PN 51969)	1
29	Vinyl Decal, microARC 6, Cord Label 38 × 77 mm (PN 52497)	1
30	Servo Drive Comm. EtherCAT Cable, 1M (PN 51970)	1
31	External STO/24 V Harness (PN 51965)	1
32	External Encoder/Motor Power Harness (PN 51967)	1

12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

ID	Description	Quantity
33	Mount Cover Panel, 1500MX (PN 52374)	1
34	Mount Gap Plate, 1500MX (PN 52450)	1

12.2.2 microARC 6



12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

ID	Description	Quantity
1	3-Jaw Chuck, microARC 6 (PN 51822)	1
2	Screw, Flat Head Cap, M5 × 0.8 - 50, 18-8 Stainless (PN 52433)	12
3	Pilot Ring, microARC 6 (PN 51826)	1
4	Face Plate, microARC 6 (PN 51825)	1
5	Shaft Seal, microARC 6 (PN 51828)	1
6	Screw, Flat Head Cap, M4 × 0.7 - 30, 18-8 Stainless (PN 51849)	8
7	Rotary Shaft Seal, microARC 6 (PN 51827)	1
8	Screw, Socket Head Cap, M5 × 0.8 - 40, 18-8 Stainless (PN 51840)	12
9	Harmonic Gearbox, 80 mm Trade Size, 50:1 Ratio (PN 51829)	1
10	Resin Decal, microARC6, Left View, 28 × 75 mm (PN 52494)	1
11	Body Casting, microARC 6 (PN 51819)	1
12	Grab Handle, 140 mm OAL × 41 mm Height (PN 51831)	1
13	Screw, Socket Head Cap, M8 × 1.25 - 25, 18-8 Stainless (PN 52489)	2
14	Pulley Cover Gasket 1, 1 mm, Neoprene, microARC 6 (PN 52924)	1
15	Pulley Connector, microARC 6 (PN 51830)	1
16	Screw, Socket Head Cap, M3 × 0.5 - 20, 18-8 Stainless (PN 52909)	6
17	Gearbox Pulley, microARC 6 (PN 51834)	1
18	Screw, Socket Head Cap, M4 × 0.7 - 16, 18-8 Stainless (PN 51847)	6
19	Timing Belt, S5M, 565 mm Length, 15 mm Width (PN 51835)	1
20	Pulley Cover 1, microARC 6 (PN 51820)	1
21	Screw, Socket Head Cap, M5 × 0.8 - 25, 18-8 Stainless (PN 51844)	1
22	Closed Hole Grommet, 35 × 40 mm × 3 mm, Rubber (PN 52910)	1
23	Tormach Steel Part Number Plate, microARC 6 (PN 52493)	1
24	Rivet Aluminum, 1/8 in. × 3/8 in. (PN 52731)	4
25	Resin Decal, microARC6, Top View, 32 × 77 mm (PN 52496)	1
26	Resin Decal, microARC6, Right View, 37 × 100 mm (PN 52495)	1
27	Screw, Button Head Cap, M4 × 0.7 - 8, 18-8 Stainless (PN 52434)	23
28	Lid Seal 1/2 in. × 1/8 in., MicroARC6 0.5 m (PN 52427)	0.5 m
29	Pulley Cover 2, microARC 6 (PN 51821)	1
30	Fastener, Cable Tie Mount, 9/16 in. × 3/8 in. (PN 52354)	3
31	Hole Grommet, 30 mm × 35 mm × 3 mm, Rubber microARC 6 (PN 51836)	1
32	Washer, Fender, 5.3 mm × 15 mm, 1.0-1.4 mm, 18-8 Stainless (PN 51845)	1

12: DIAGRAMS AND PARTS LISTS

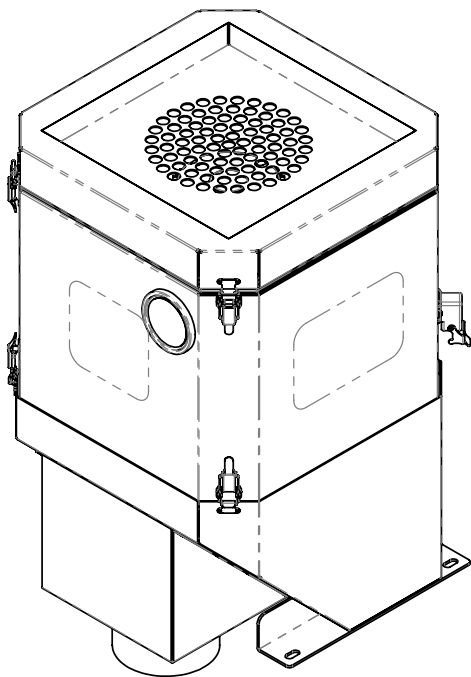
12.2 Accessory Diagrams and Parts Lists

ID	Description	Quantity
33	Motor Pulley, microARC 6 (PN 51833)	1
34	Screw, Socket Head Cap, M8 × 1 .25 - 25, 18-8 Stainless (PN 52489)	2
35	Washer, Fender, 8.7 mm × 25.4 mm, 1.5 • 1.7 mm, 18-8 Stainless (PN 52937)	2
36	Motor Bracket, microARC 6 (PN 51832)	1
37	Servo Motor, 400 W, 220 V, 2.8 A, 3000 rpm, Oil Seal (PN 51196)	1
38	Power Cable, Inside Cabinet, microarc 6 (PN 53100)	1
39	Wire Tie Holder (PN 38558)	1
40	Encoder Cable, Inside Cabinet, microARC 6 (PN 53102)	1
41	Screw, Socket Head Cap, M5 × 0.8 - 16. 18-8 Stainless (PN 51843)	4
42	Pulley Cover Gasket 2, 1 mm, Neoprene, microARC 6 (PN 52925)	1
43	Power Cable, Outside Cabinet, microARC 6 (PN 53101)	1
44	Encoder Cable, Outside Cabinet, microARC 6 (PN 53103)	1
45	Screw, Flat Head Cap, M3 × 0.5 - 20, 18-8 Stainless (PN 51839)	1
46	T-Slot Alignment Key. microARC 6 (PN 51851)	1
47	Lid Seal 1/2 in. × 1/8 in., microARC6 (PN 52427)	0.14 m

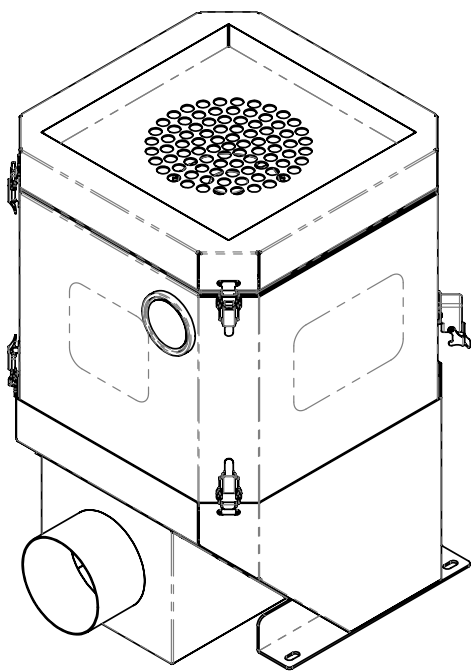
12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

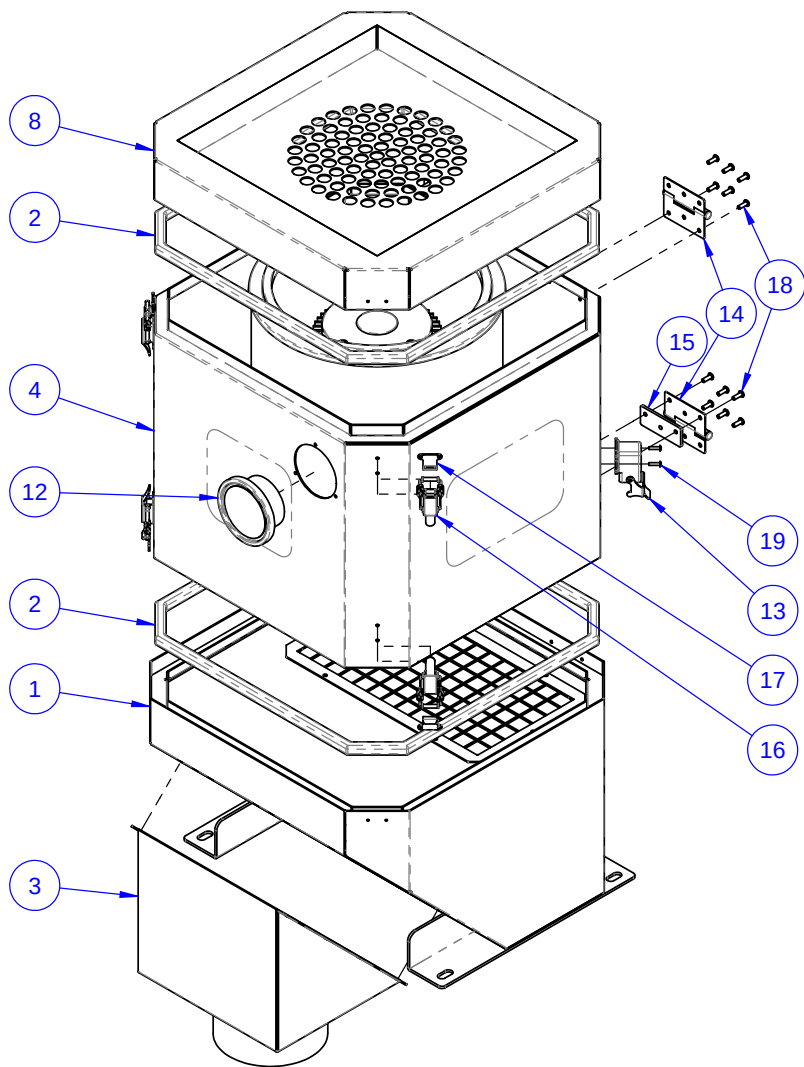
12.2.3 Mist Collector



SCALE 1:8
VERTICAL INLET PLENUM
STANDARD INSTALLATION

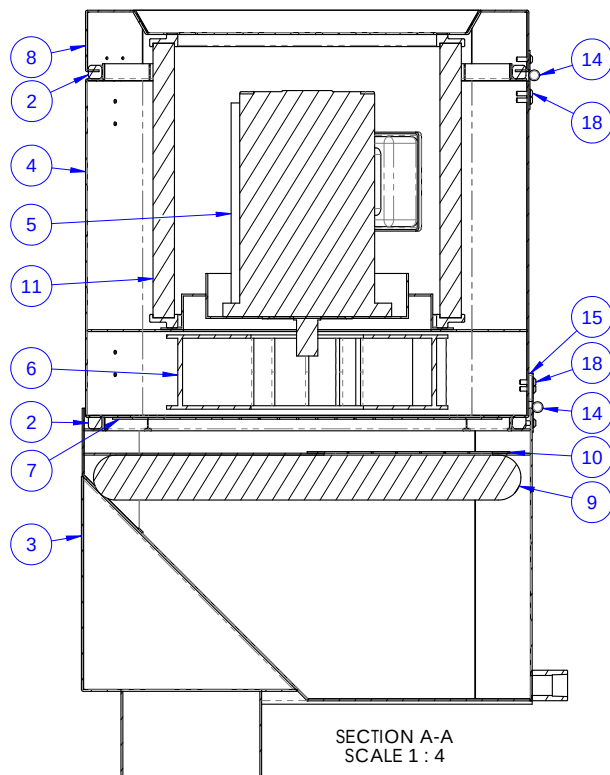
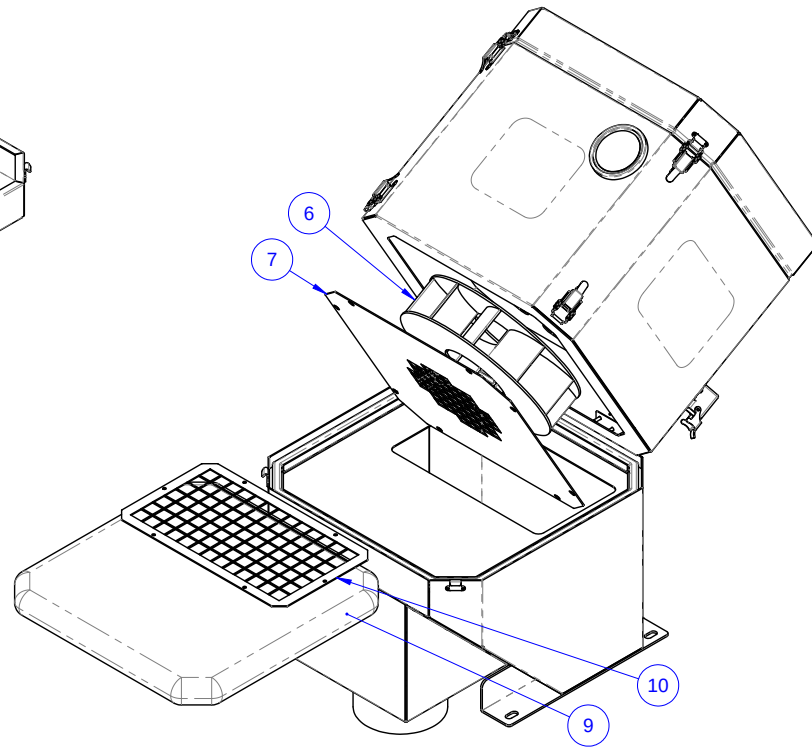
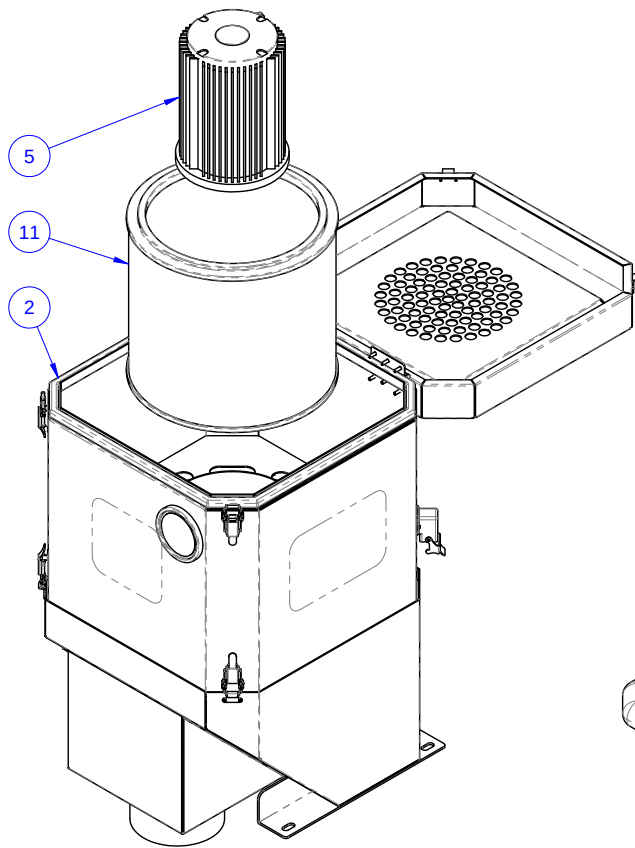


SCALE 1:8
HORIZONTAL INLET PLENUM
ALTERNATE INSTALLATION



12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

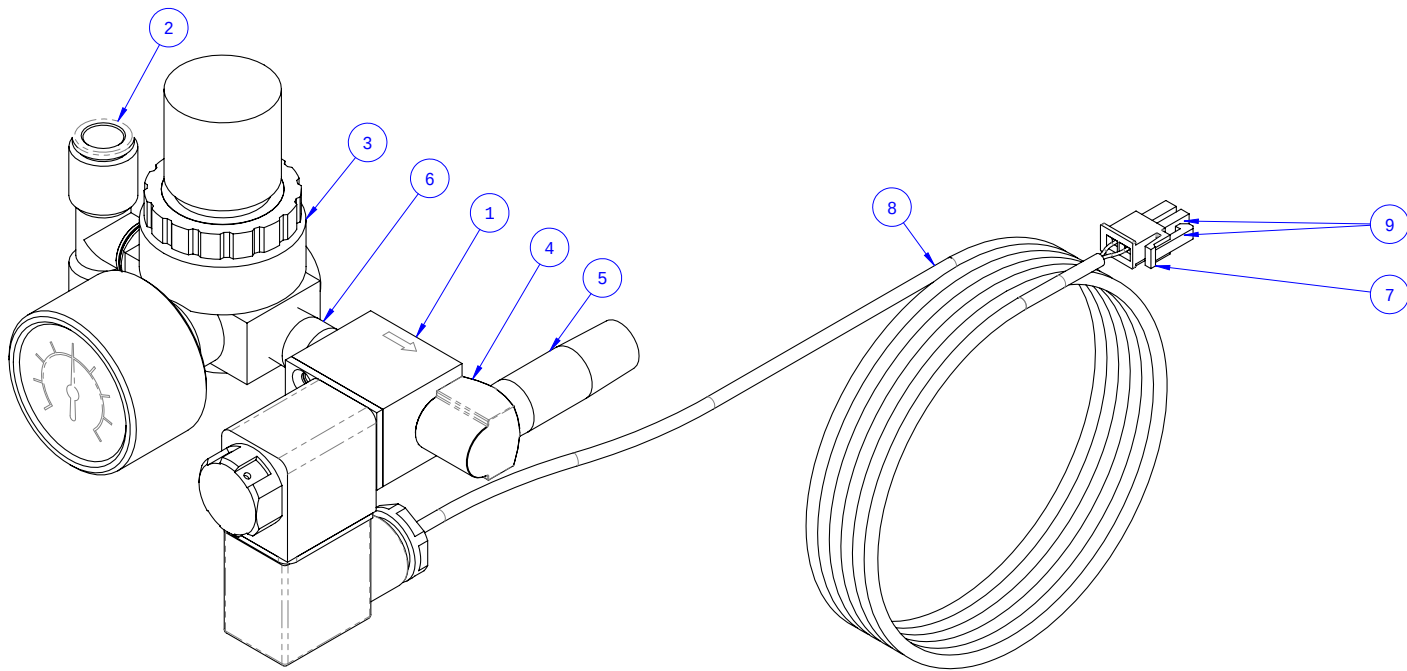


12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

ID	Description	Quantity
1	Base Section, Mist Collector Housing (PN 53118)	1
2	Mist Collector Housing Seal (PN 53130)	2
3	Inlet Plenum, Mist Collector Housing (PN 53121)	1
4	Middle Section, Mist Collector Housing (PN 53119)	1
5	Mist Collector Motor (PN 53131)	1
6	Mist Collector Impeller (PN 53133)	1
7	Mist Collector Impeller Cover Grill (PN 53135)	1
8	Top Section (Second-Stage Filter Door), Mist Collector Housing (PN 53120)	1
9	Mist Collector First-Stage (Coalescing) Filter (PN 53122)	1
10	Mist Collector First-Stage Filter Grill (PN 53134)	1
11	Mist Collector Second-Stage Filter (PN 53123)	1
12	Mist Collector Gauge (PN 53124)	1
13	Mist Collector Power Connector Bulkhead (PN 53125)	1
14	Mist Collector Hinge (PN 53128)	4
15	Mist Collector Hinge Spacer (PN 53136)	2
16	Mist Collector Latch (PN 53127)	4
17	Mist Collector Latch Hook (PN 53129)	4
18	Screw, Button Head Cap, M4 × 0.7 - 12, Stainless Steel	24
19	Screw, Button Head Cap, M3 × 0.5- 12, Stainless Steel	2

12.2.4 MQL Solenoid Assembly, 24 Vdc

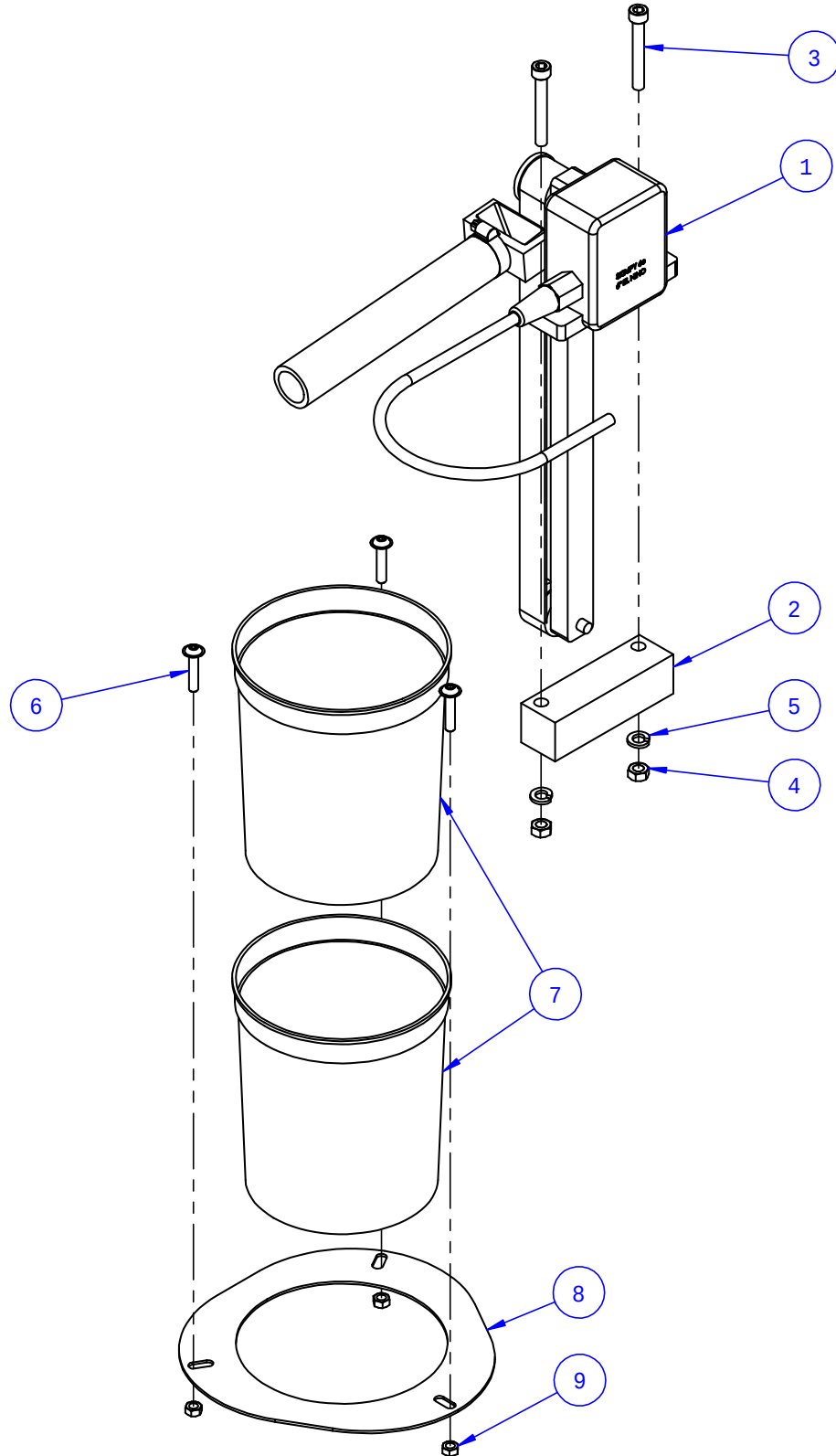


12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Two Port, Two Way, Two Position, 24 Vdc, Single Solenoid Valve, 1/4 in. (Inlet/Outlet), Normally Closed (PN 38827)	—	1
2	Fitting, Branch Tee, 1/4 in. NPT (Male) - 3/8 in. PTC (PN 52399)	—	1
3	Pressure Regulator, 1/4 n. NPT × 1/4 in. NPT, 1/8 in. NPT Gauge Port, 7-125 psi, 150 psi (PN 39356)	—	1
4	Fitting, Street Elbow, 1/4 in. NPT (Male) - 1/4 in. NPT (Female), Brass (PN 52398)	McMaster-Carr: 50785K431	1
5	Fitting, Pipe Nipple, 1/4 NPT × 2 in., Brass (PN 53416)	McMaster-Carr: 2729K26	1
6	Fitting, Pipe Nipple, 1/4 NPT × 1.5 in., Brass (PN 52401)	McMaster-Carr: 2729K21	1
7	Rectangular Connector, 2 Pin Female Dual Row, Receptacle, White 0.165 in. (4.2 mm) (PN 51663)	—	1
8	Cable, SJEOOW, 18/2 AWG, 300 Vac (PN 52404)	—	2 m
9	Crimp Terminal, Molex Mini-Fit Jr., Female, 18-24 AWG (PN 52285)	—	2
10	Cable Tie, 4 in., Nylon, Black (PN 31719)	McMaster-Carr: 7130K52	2
11	7 Tube, 3/8 in. OD, Polyurethane (Black) (PN 52437)	McMaster-Carr: 5648K261	2 m

12.2.5 Oil Skimmer Kit

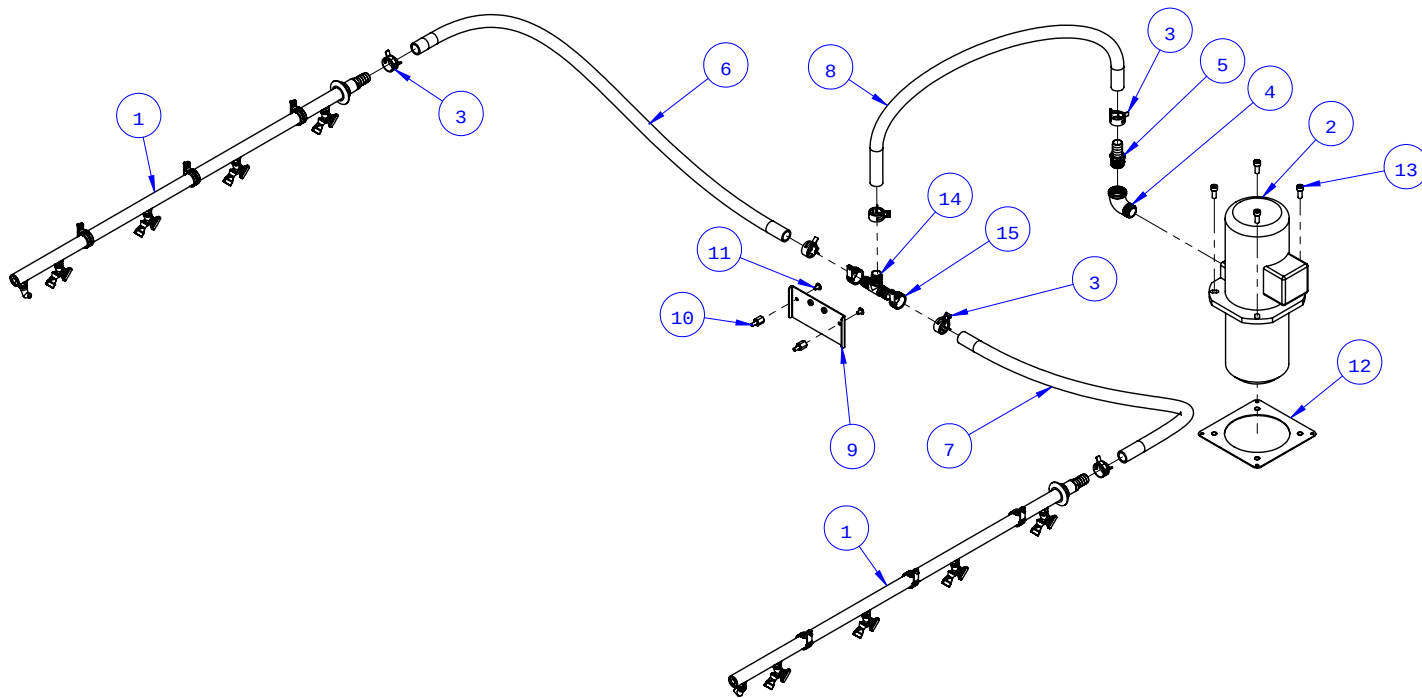


12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

ID	Description	Quantity
1	Skimpy Skimmer, El Nino 9 in. with Hose and Clamp (PN 53858)	1
2	Spacer Block, Skimpy El Nino 6 in. Skimmer, 1 in. (PN 35592)	1
3	Screw, Socket Head Cap, M6 × 1 - 45 (PN 31332)	2
4	Nut, Hex, M6 × 1, Zinc (PN 34896)	2
5	Washer, Split Lock, M6 (PN 31379)	2
6	Screw, Button Head Cap, Flanged, M5 × 0.8 - 25 (PN 38892)	3
7	Oil Collection Container (PN 39128)	2
8	Skimmer Bucket Adapter Plate (PN 53696)	1
9	Nut, Hex, M5 × 0.8 (PN 31201)	3

12.2.6 Washdown Kit Assembly



12: DIAGRAMS AND PARTS LISTS

12.2 Accessory Diagrams and Parts Lists

ID	Description	Alternative Part Number	Quantity
1	Coolant Washdown Bar Assembly, 1500MX(PN 51377)	–	2
2	Coolant Pump, Dual Voltage (Preset to 240), 1/2 hp, 180 mm Length, 3/4 NPT Outlet, 2 m 14 AWG Cord (with Right-Angle C14 Plug) (PN 51385)	–	1
3	Hose Clamp, Spring, for 1 in. OD Hose (PN 51558)	McMaster Carr: 7329K16	6
4	Fitting, Street Elbow Adapter, 3/4 in. NPT (Male) - 3/4 in. NPT (Female), Brass (PN 51606)	McMaster Carr: 4429K154	1
5	Fitting, Straight Adapter, 3/4 in. NPT (Male) - 3/4 in. Barb, Brass (PN 51556)	McMaster Carr: 5346K28	1
6	Hose, 3/4 in. ID × 1 in. OD, PVC, 1150 mm Long (PN 51608)	McMaster-Carr: 5233K71	1
7	Hose, 3/4 in. ID × 1 in. OD, PVC, 1150 mm Long (PN 51608)	McMaster-Carr: 5233K71	1
8	Hose, 3/4 in. ID × 1 in. OD, PVC, 1150 mm Long (PN 51608)	McMaster-Carr: 5233K71	1
9	Bracket, Washdown Coolant Tee Fitting, 1500MX (PN 52500)	–	1
10	Standoff, 16 mm, M6 × 1 - 13 mm Male, M6 × 1 - 10 mm Female, Steel (PN 51566)	McMaster-Carr: 93655A255	2
11	Screw, Button Head Cap, Flanged M6 × 1 - 10, 18-8 Stainless (PN 51616)	McMaster Carr: 90909A726	2
12	Coolant Pump Mounting Plate, 1/2 hp, 1500MX (PN 52459)	–	1
13	Screw, Socket Head Cap, M8 × 1.25 - 20 (PN 31895)	McMaster-Carr: 91290A426	4
14	Fitting, Tee, 3/4 in. Barbed, Brass (PN 52498)	McMaster-Carr: 91355K54	1
15	Loop Clamp, 25 mm ID (PN 51379)	McMaster-Carr: 3177T16	2

ELECTRICAL SCHEMATICS

IN THIS SECTION, YOU'LL LEARN:

- About the electrical schematics for this machine's electronics.

CONTENTS

13.1 Mill Schematics	360
13.2 Accessory Schematics	377

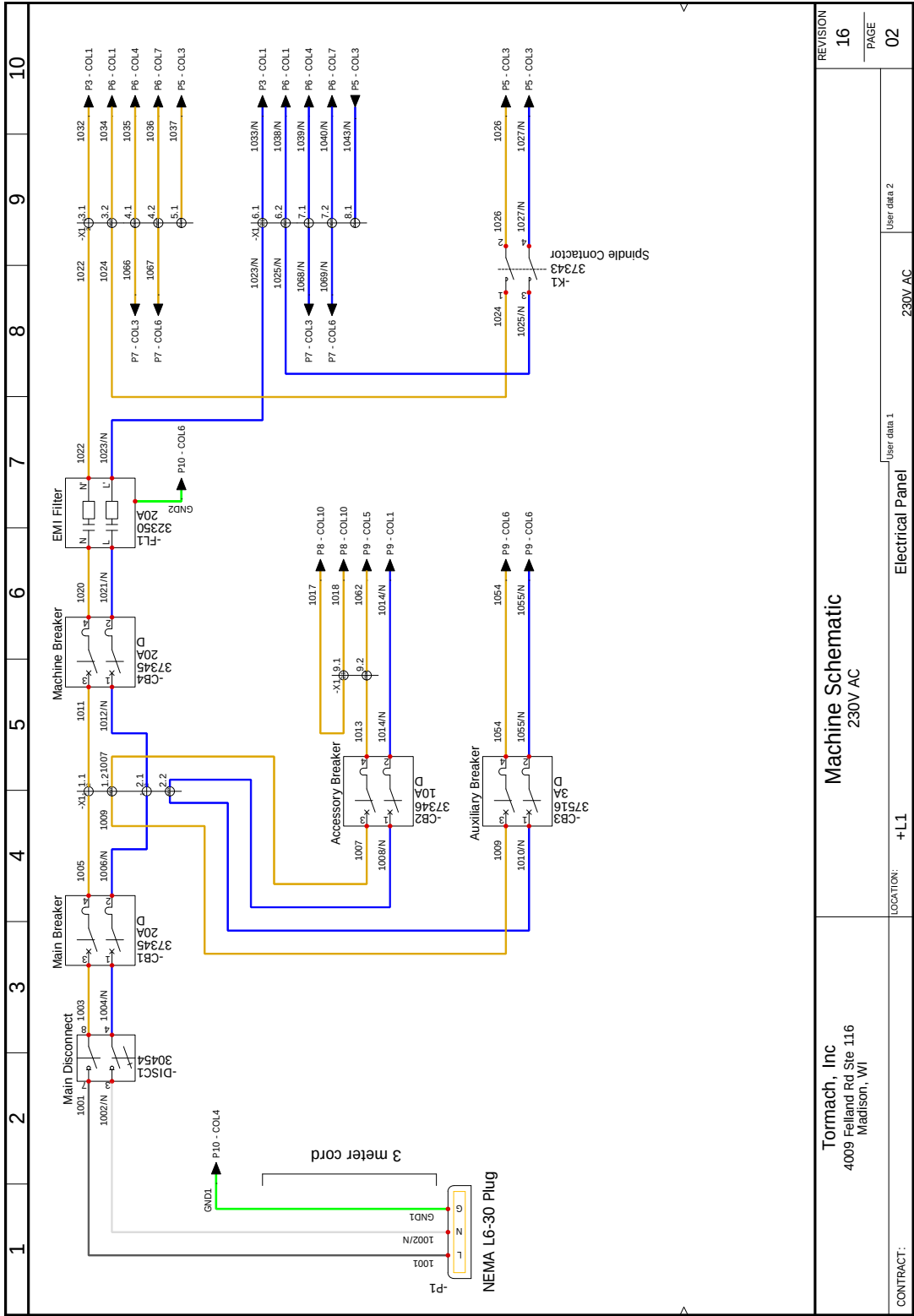
13: ELECTRICAL SCHEMATICS

13.1 Mill Schematics

13.1 MILL SCHEMATICS

13.1.1 230 Vac Power (Page 2).....	361
13.1.2 24 Vdc Controls (Page 3).....	362
13.1.3 Safety Systems (Page 4).....	363
13.1.4 Spindle Drive (Page 5).....	364
13.1.5 X-, Y-, and Z-Axis Drives (Page 6).....	365
13.1.6 A- and B-Axis Drives (Page 7).....	366
13.1.7 EtherCAT IO Board (Page 8).....	367
13.1.8 Accessory / Auxiliary (Page 9).....	368
13.1.9 Grounds (Page 10).....	369
13.1.10 -X1 AC Terminal Strip (Pages 11-13).....	370
13.1.11 -X2 Control Terminal Strip (Page 14).....	373
13.1.12 -X3 Grounds Terminal Strip (Page 15).....	374
13.1.13 Bill of Materials (Pages 16-17).....	375

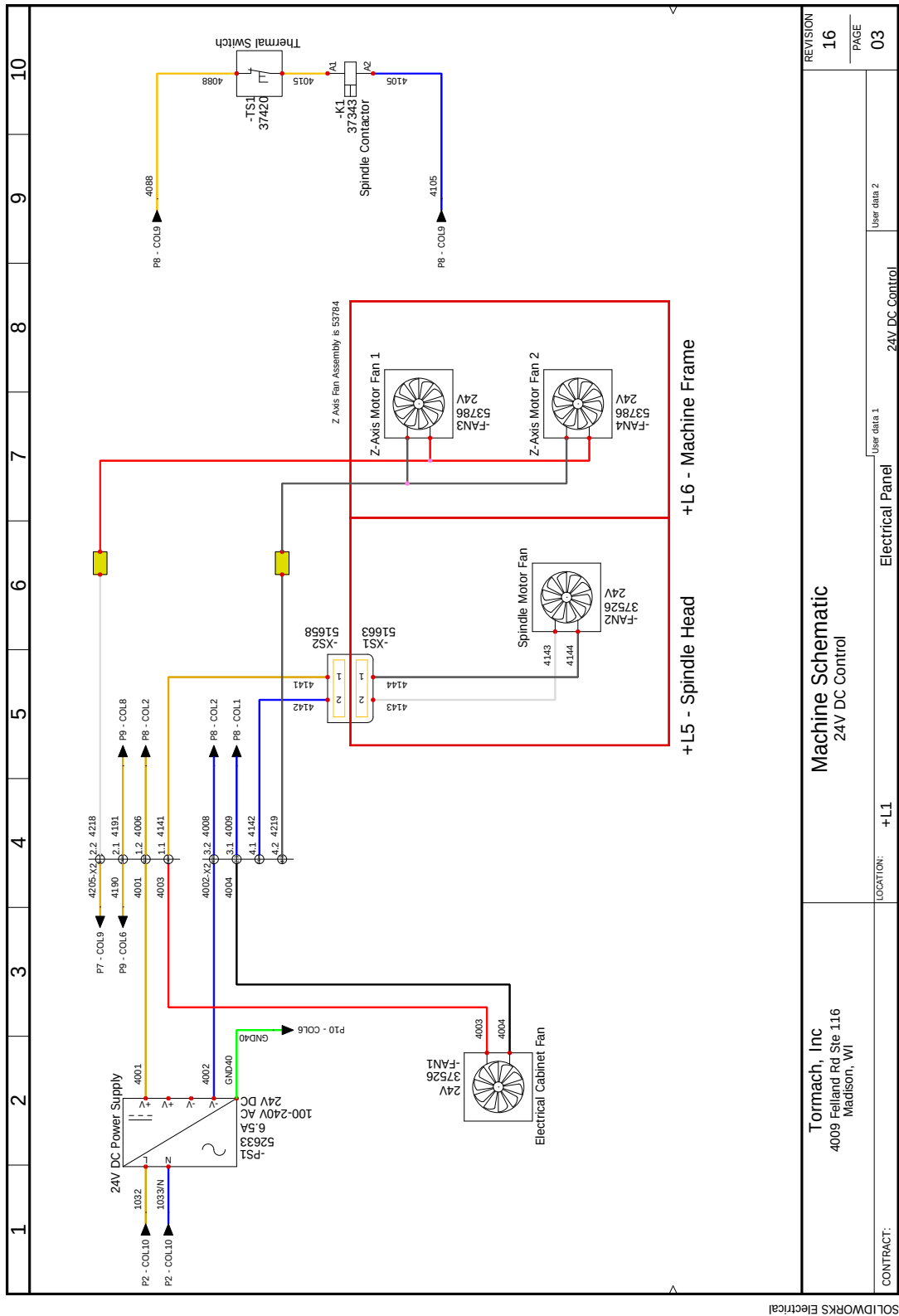
13.1.1 230 Vac Power (Page 2)



SOLIDWORKS Electrical

13.1 Mill Schematics

13.1.2 24 Vdc Controls (Page 3)



+L2 - Operator Panel

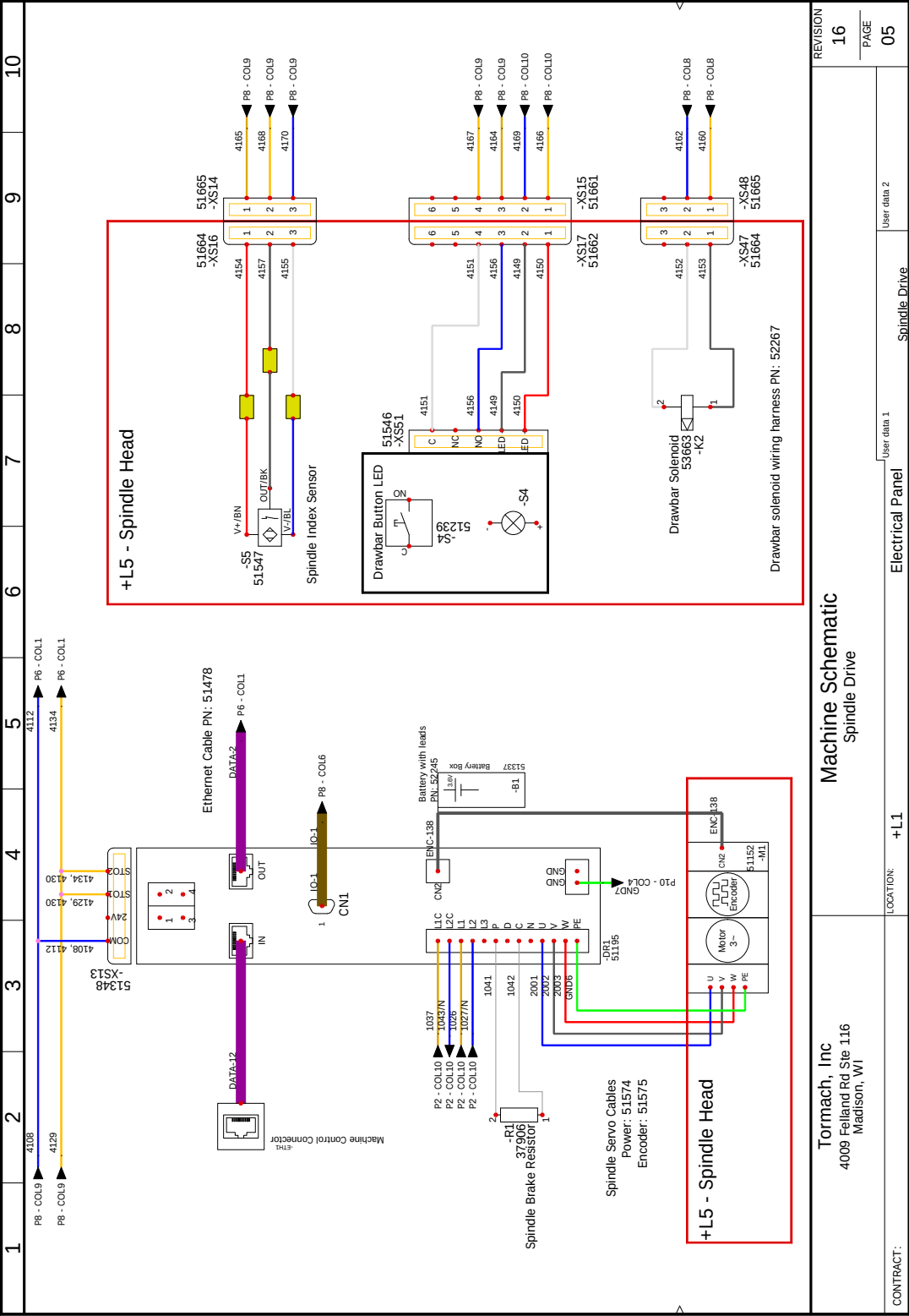
NOTE: For illustration purposes only. Operator panel wiring is defined in Operator Console schematic

+L4 - Machine Door

Door Latch Button

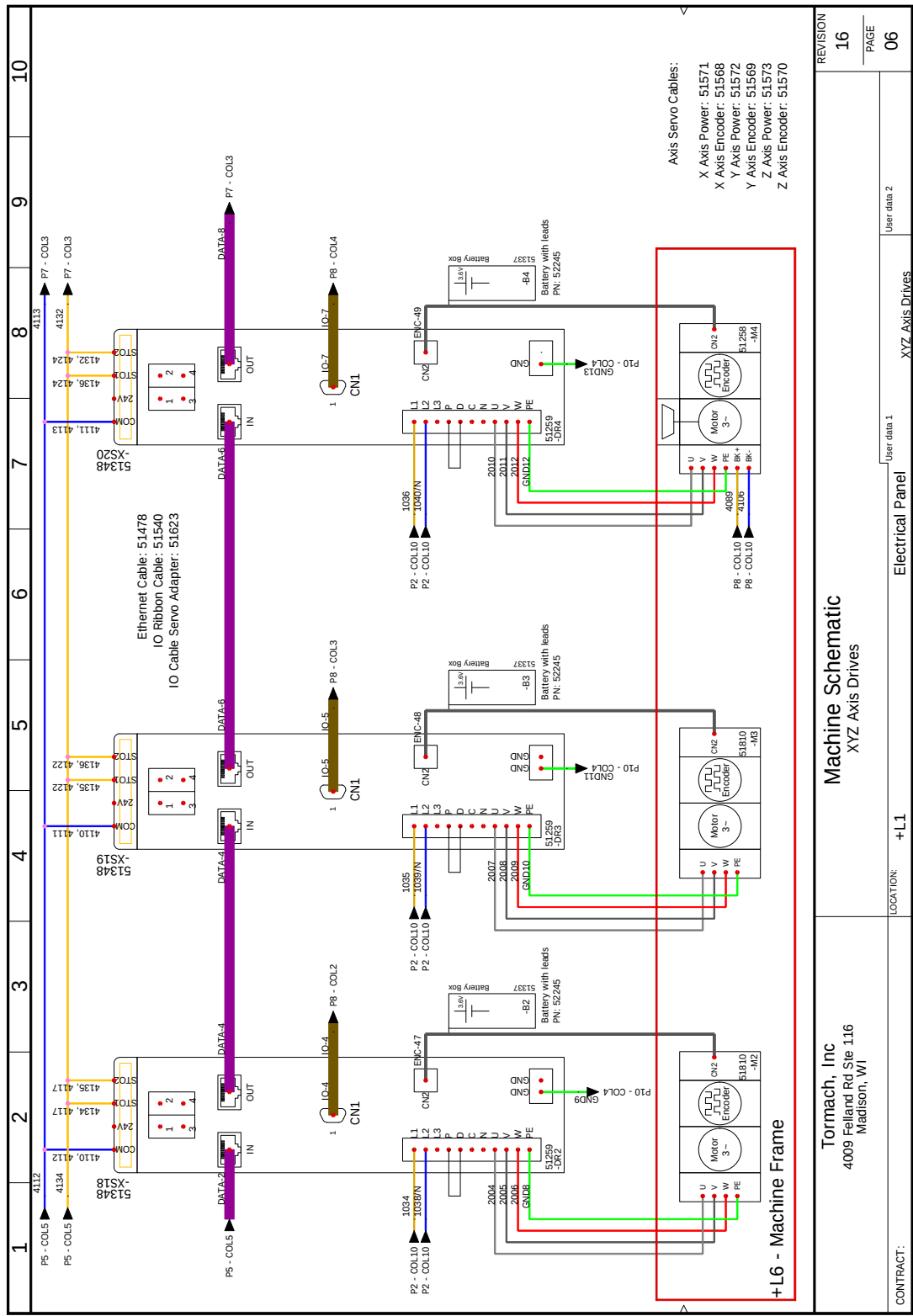
13: ELECTRICAL SCHEMATICS
13.1 Mill Schematics

13.1.4 Spindle Drive (Page 5)



SOLIDWORKS Electrical

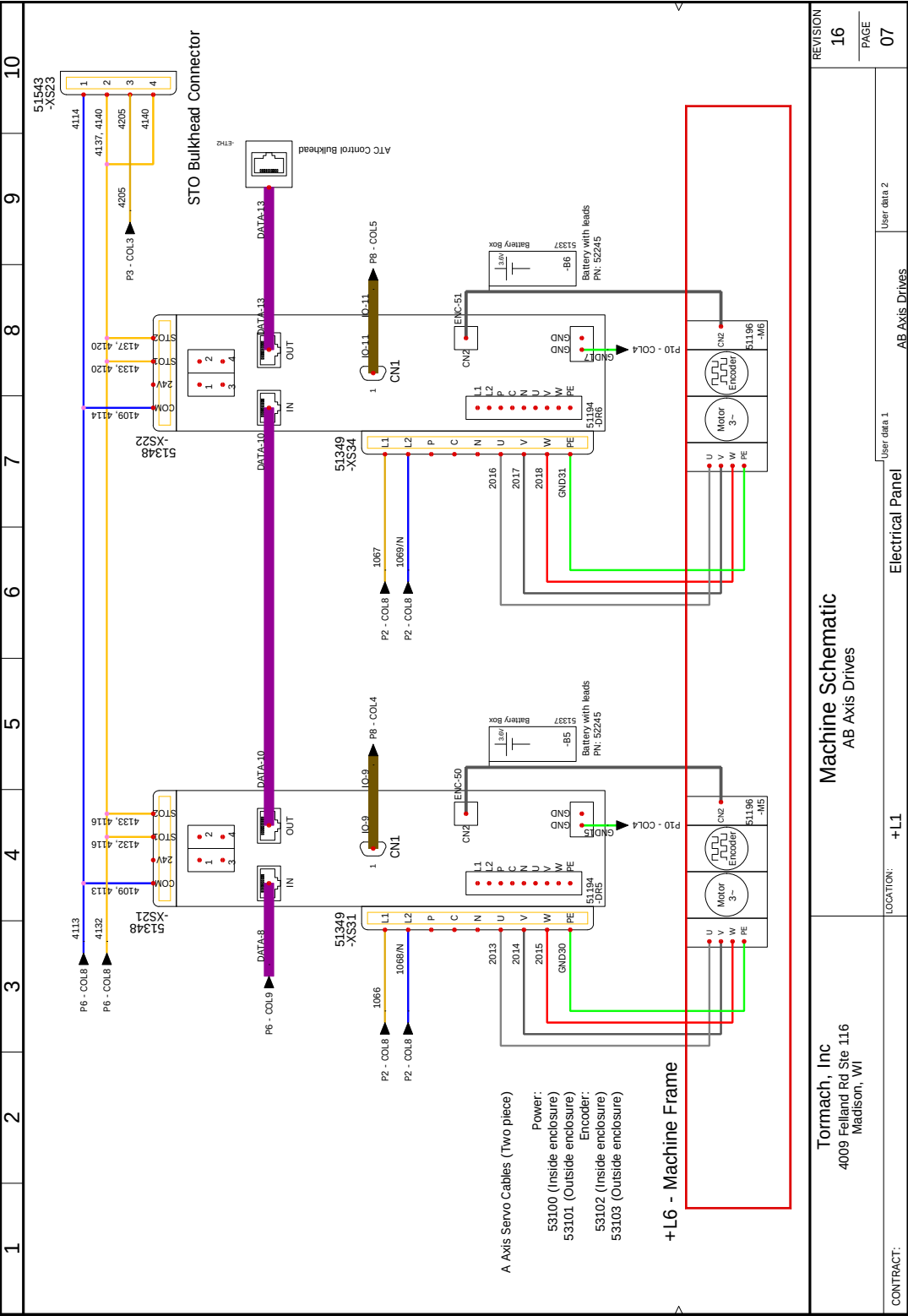
13.1.5 X-, Y-, and Z-Axis Drives (Page 6)



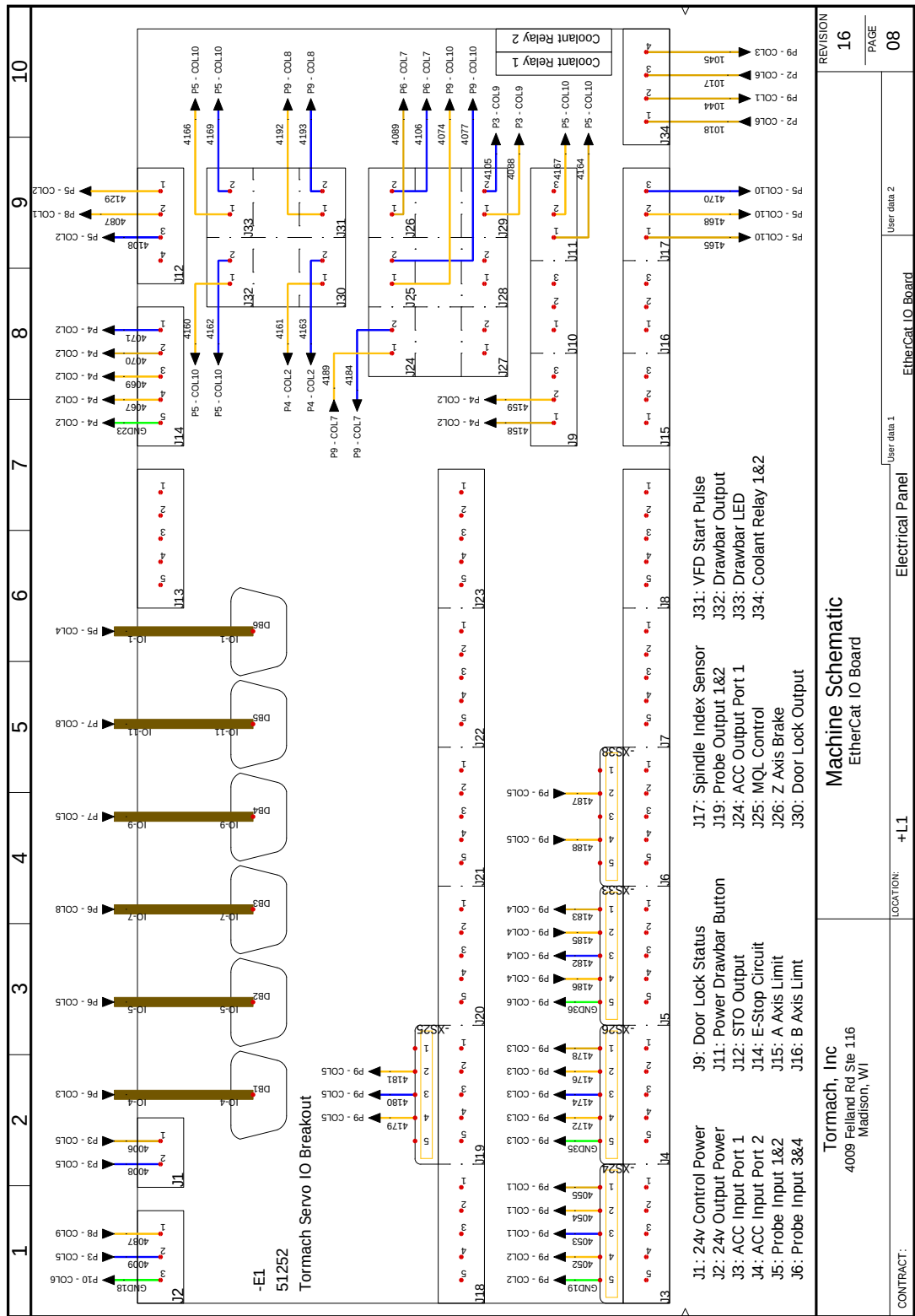
13: ELECTRICAL SCHEMATICS

13.1 Mill Schematics

13.1.6 A- and B-Axis Drives (Page 7)



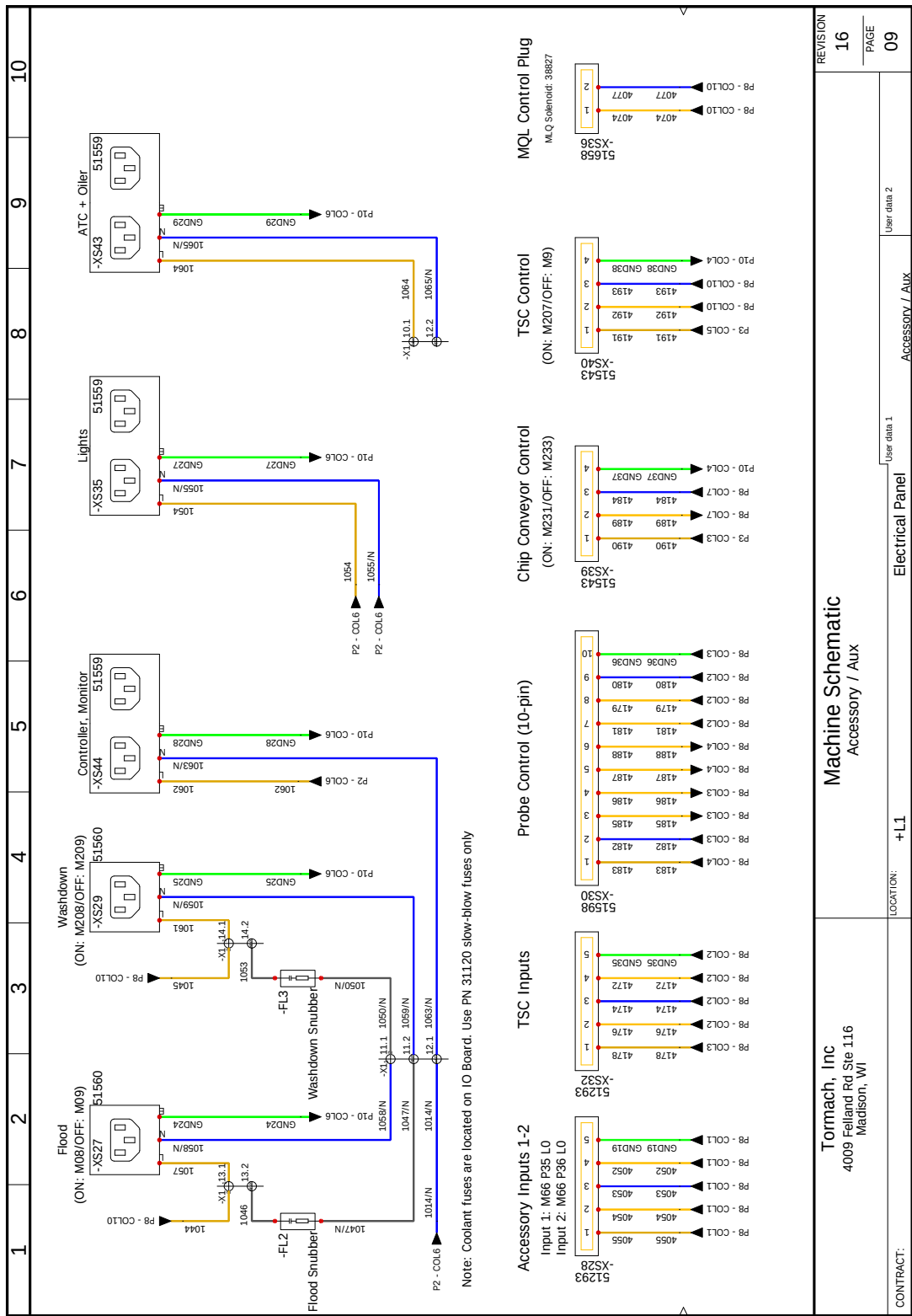
13.1.7 EtherCAT IO Board (Page 8)



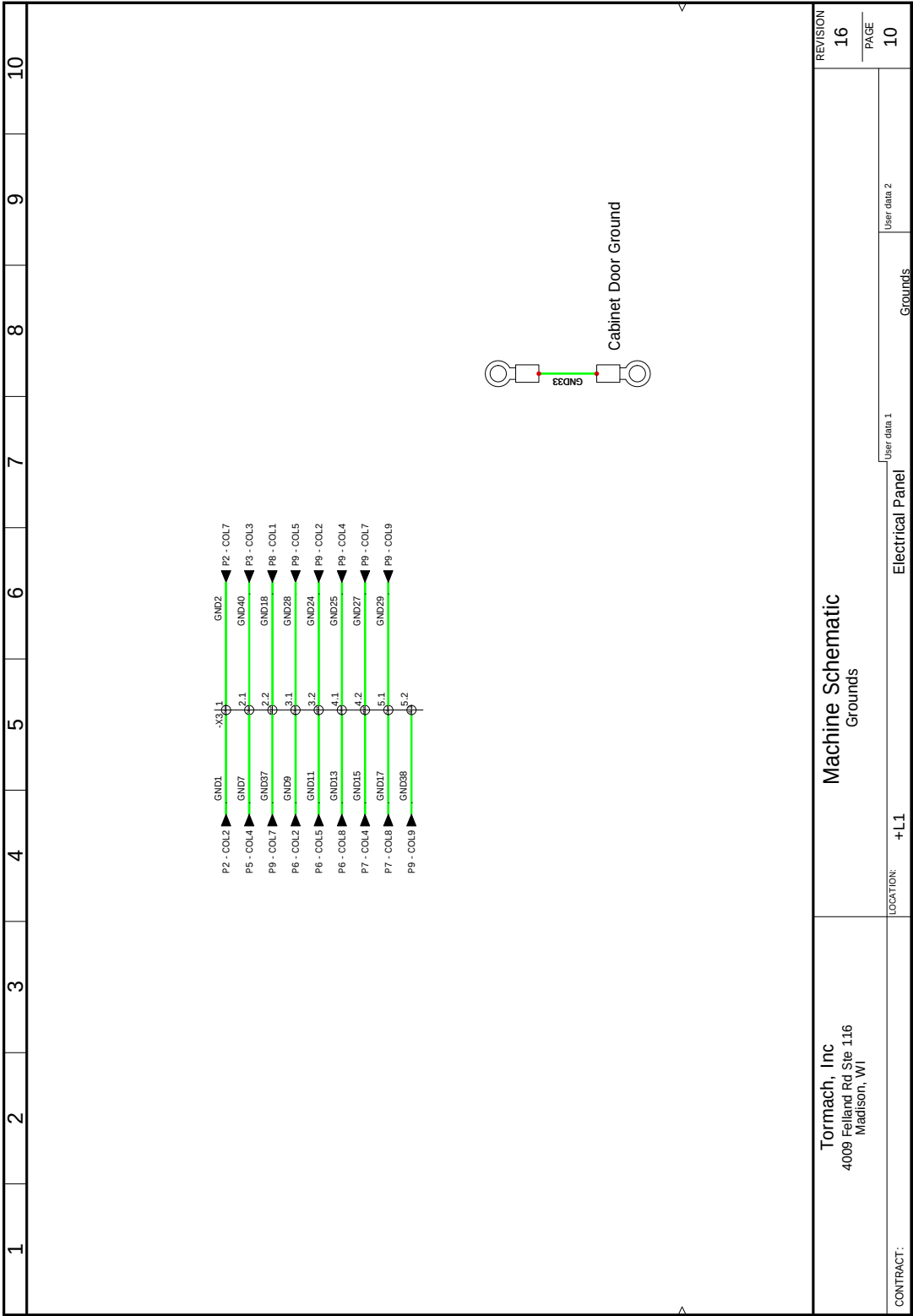
SOLIDWORKS Electrical

13.1 Mill Schematics

13.1.8 Accessory / Auxiliary (Page 9)

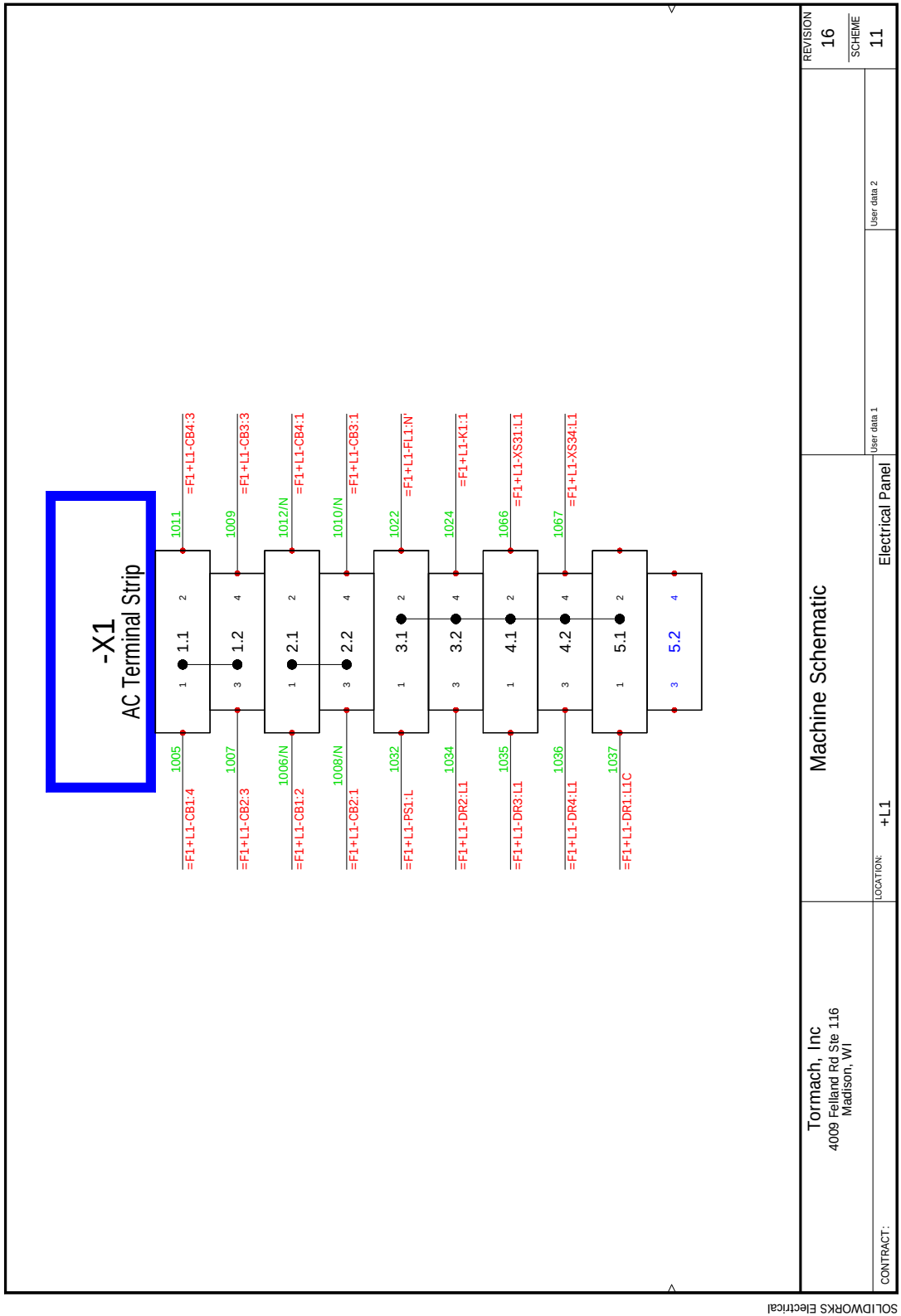


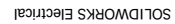
13.1.9 Grounds (Page 10)



13.1 Mill Schematics

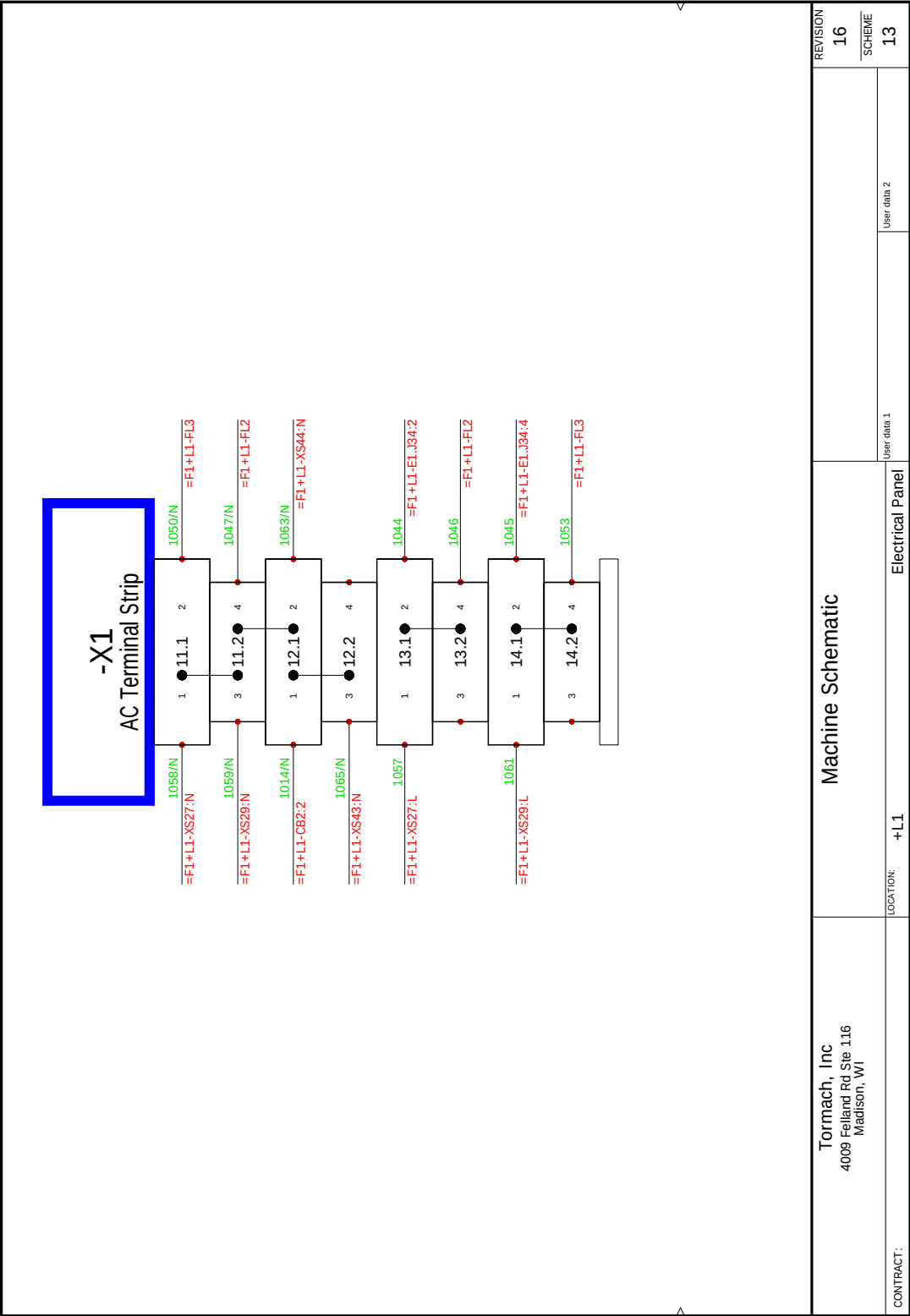
13.1.10 -X1 AC Terminal Strip (Pages 11-13)





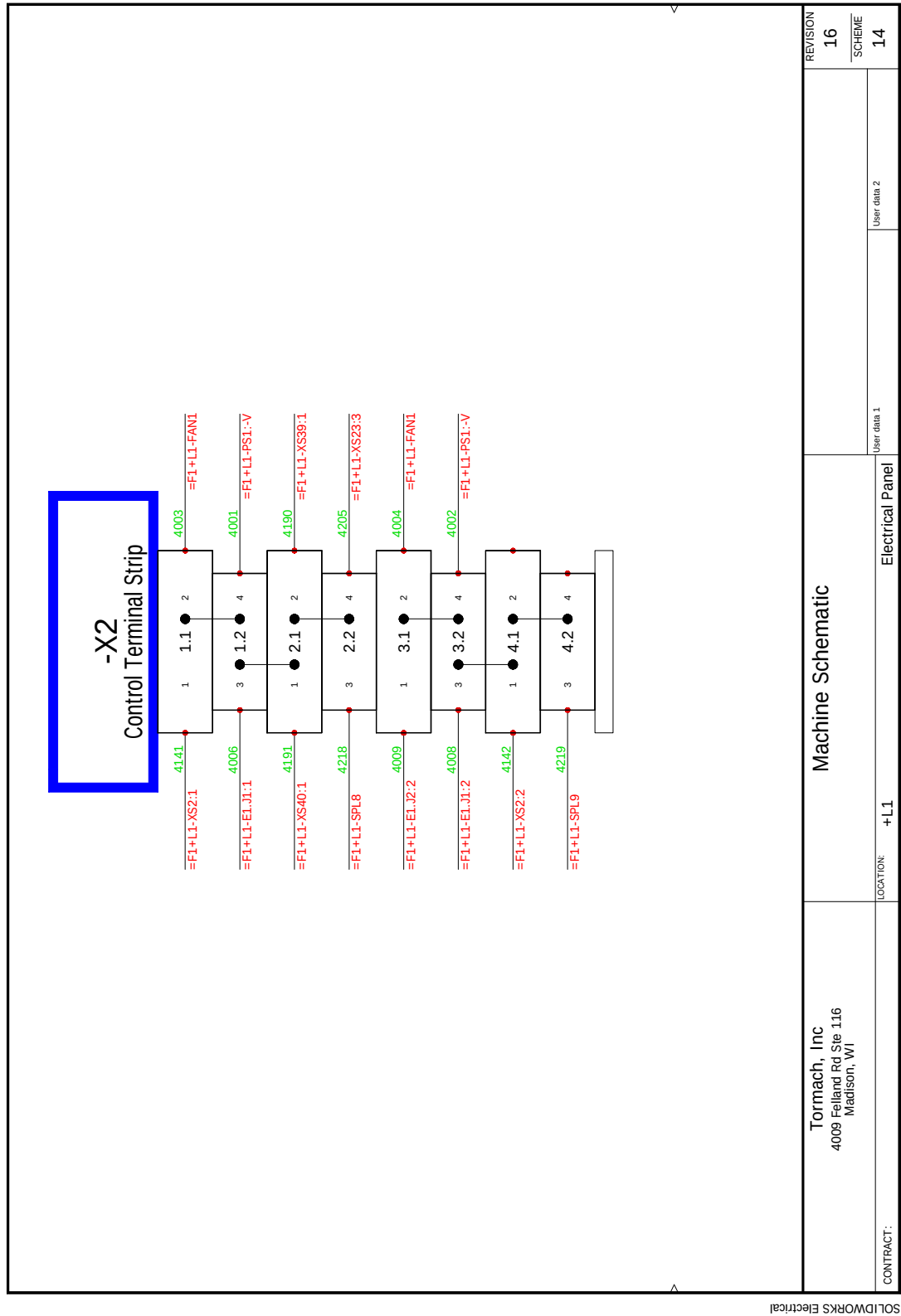
13: ELECTRICAL SCHEMATICS

13.1 Mill Schematics



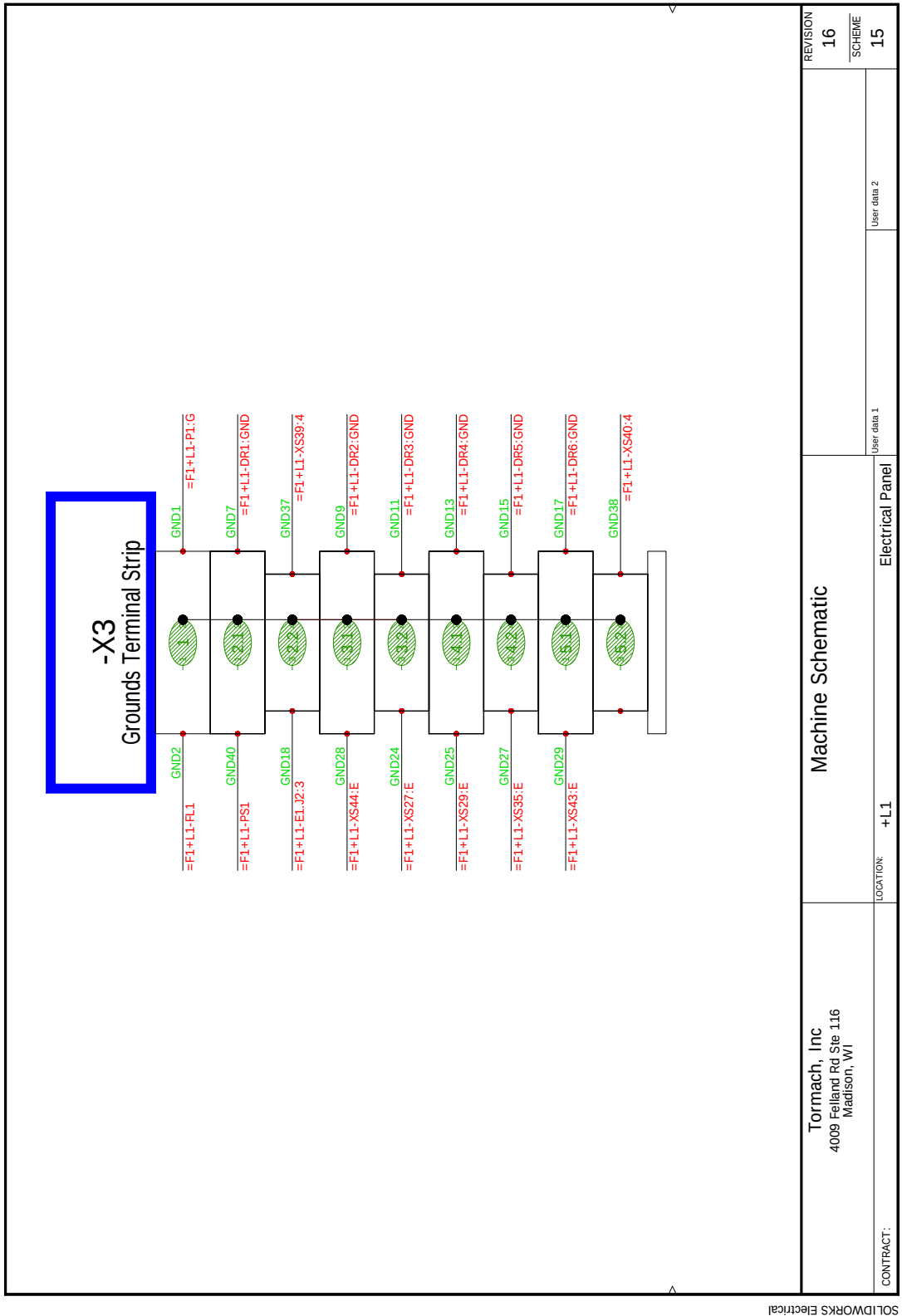
SOLIDWORKS Electrical

13.1.11 -X2 Control Terminal Strip (Page 14)



13.1 Mill Schematics

13.1.12 -X3 Grounds Terminal Strip (Page 15)



13.1.13 Bill of Materials (Pages 16-17)

Reference	Mark	Location	Location description	Description	Quantity
51874	-S2, -S3	+L9	ATC Frame	Proximity Sensor, Cylinder Mount Piston Position Sensor, 24Vdc	2
30454	-DJS21	+L1	Electrical Panel	Main Disconnect Switch	1
37345	-B1, -C84	+L1	Electrical Panel	Circuit Breaker, 2-Pole, 20A, 230/400VAC, D Curve, DIN Mount	2
37346	-C82	+L1	Electrical Panel	Circuit Breaker, 2-Pole, 10A, 230/400VAC, D Curve, DIN Mount	1
37388	-F12, -F13	+L1	Electrical Panel	Electrical Noise Suppressor, DIN Mount	2
37516	-C83	+L1	Electrical Panel	Circuit Breaker, 2-Pole, 3A, 230/400VAC, D Curve, DIN Mount	1
53304	-P1	+L1	Electrical Panel	Plug, Male, 250 VAC, 30 Amps, Locking Connector, NEMA L5-30P	1
51152	-M1	+L5	Spindle Head	Invancec Servo Motor, 1500W, 220V, 10.8A, 3000RPM, Oil Seal	1
51194	-DR5, -DR6	+L1	Electrical Panel	SV660N EtherCat AC Servo Drive, Size A	2
51195	-DR1	+L1	Electrical Panel	SV660N EtherCat AC Servo Drive, Size D	1
51196	-M1, -M5, -M6	+L9 +L6	ATC Frame; Machine Frame	Invancec Servo Motor, 400W, 220V, 2.8A, 3000RPM, Oil Seal	3
51258	-M4	+L6	Machine Frame	Servo Motor, 750W, 220V, 4.8A, 3000RPM, Oil Seal and Brake	1
51259	-DR2, -DR3, -DR4	+L1	Electrical Panel	SV660N EtherCat AC Servo Drive, Size B	3
51337	-B1, -B2, -B3, -B4, -B5, -B6	+L1	Electrical Panel	Invancec SV660N Battery Box	6
51348	-XS13, -XS18, -XS19, -XS20, -XS21, -XS22	+L1	Electrical Panel	Invancec STO Connector	6
51349	-XS31, -XS34	+L1	Electrical Panel	CON SV660A 9P	2
51810	-M2, -M3	+L6	Machine Frame	Servo Motor, 750W, 220V, 4.8A, 3000RPM, Oil Seal	2
32360	-F11	+L1	Electrical Panel	EMI Filter	1
51800	-XS45, -XS46	+L4	Machine Door	Connector, Plug, 2-pin Female JST, 2.5mm Pitch	2
51801	-XS41, -XS42	+L4	Machine Door	Connector, Receptacle, 2-pin Male JST, 2.5mm Pitch	2
52633	-P51	+L1	Electrical Panel	Power Supply, 24 VDC, 150W, 125mm Height	1
51658	-XS2, -XS38	+L1	Electrical Panel	Rectangular Connector, 2 Pin Male Vertical, Plug, White 0.165" (4.2mm)	2
51659	-X2, -XS4	+L9 +L4	ATC Frame; Machine Door	Rectangular Connector, 4 Pin Female Dual Row, Receptacle, White 0.165" (4.2mm)	2
51660	-XS6	+L1	Electrical Panel	Rectangular Connector, 4 Pin Male Dual Row, Plug, White 0.165" (4.2mm)	1
51661	-XS15	+L1	Electrical Panel	Rectangular Connector, 6 Pin Male Dual Row, Plug, White 0.165" (4.2mm)	1
51662	-X6, -XS17	+L9 +L5	ATC Frame; Spindle Head	Molex Mini-Fit J CONN RECEPT 6POS DUAL, Rectangular Connector, 6 Pin Female Dual Row, Receptacle, White 0.165" (4.2mm)	2
51663	-XS1	+L5	Spindle Head	Rectangular Connector, 2 Pin Female Vertical, Receptacle, White 0.165" (4.2mm)	1
51664	-XS16, -XS47	+L5	Spindle Head	Rectangular Connector, 3 Pin Female Vertical, Receptacle, White 0.165" (4.2mm)	2
51665	-XS14, -XS48	+L1	Electrical Panel	Rectangular Connector, 3 Pin Male Vertical, Plug, White 0.165" (4.2mm)	2
52296	-X4	+L9	ATC Frame	Rectangular Connector, 8 Pin Female Dual Row, Receptacle, White 0.165" (4.2mm)	1
0023012057	-XS24, -XS25, -XS26, -XS33, -XS38	+L1	Electrical Panel	CONN HOUSING 5POS, 100 W/PAMP	5

Tormach, Inc
4009 Folland Rd Ste 116
Madison, WI

Machine Schematic

+L1

Electrical Panel

REVISION
16

PAGE
16

User data 1

User data 2

SOLIDWORKS Electrical

13: ELECTRICAL SCHEMATICS

13.1 Mill Schematics

Reference	Mark	Location	Location description	Description	Quantity
51547	-S5	+L5	Spindle Head	Proximity Sensor, PNP-NO, 3-Wire, 8mm Body	1
52245	-B1, -B2, -B3, -B4, -B5, -B6	+L1	Electrical Panel	SY600N Encoder Battery Assembly	6
51559	-XS35, -XS43, -XS44	+L1	Electrical Panel	Power Outlet (IEC 320, C13 Double Socket), Spade Terminals	3
51560	-XS27, -XS39	+L1	Electrical Panel	Power Outlet (IEC 320-2-2/F, C13 Single Socket), Spade Terminals	2
37855	-ETH1, -ETH2	+L1	Electrical Panel	R45 Bulkhead Connector (Ethernet)	2
37420	-TS1	+L1	Electrical Panel	Thermal Switch (Pushbutton Reset)	1
53786	-FAN3, -FAN4	+L6	Machine Frame	Cooling Fan, 24V - 21CFM	2
37906	-B1	+L1	Electrical Panel	Brake Resistor, 70 Ohm, 300 Watt w/ 20' leads	1
39462	-S2	+L2	Operator Panel	Switch, E-stop Pushbutton, Normally Closed,	1
37942	-S3	+L2	Operator Panel	Reset Pushbutton	1
51239	-S1, -S4	+L4 +L5	Machine Door, Spindle Head	Pushbutton, INOINC, White LED	2
51546	-XS49, -XS51, -S1, -S4	+L4 +L5	Machine Door, Spindle Head	Button Wiring Pigtail, 5-pin, For Tayse TM822 Buttons	4
53663	-X2	+L5	Spindle Head	Drawbar Solenoid Assembly, 1500MX Drawbar	1
51283	-XS28, -XS32	+L1	Electrical Panel	M12 Socket, Panel lead through, for rear mounting, A-coding, Crimp termination, 5 pin	2
51543	-XS23, -XS38, -XS40	+L1	Electrical Panel	M12 Plug, Panel Mount, Female Pins, 4 Position, A Keying	3
51252	-E1	+L1	Electrical Panel	Tormach Servo IO Breakout	1
37526	-FAN1, -FAN2	+L1 +L5	Electrical Panel, Spindle Head	Fan, 120mm, 24V, 0.29A	2
51289	-X3-2, -X3-3, -X3-4, -X3-5	+L1	Electrical Panel	Terminal Block, GND, 24-10AWG, 4 position, Spring Type, Internally Jumped	4
51290	-X2-1, -X1-1, -X1-2, -X2-2, -X2-3, -X1-4, -X1-5, -X1-6, -X2-6, -X1-7, -X1-8, -X1-9, -X1-10, -X1-11, -X1-12, -X1-13, -X1-14	+L1	Electrical Panel	Terminal Block, 24-10AWG, 4 position, Spring Type, Internally Jumped	18
51291	-X1, -X2, -X3	+L1	Electrical Panel	Terminal Block End Plate, JMT3-4/2-2 Series	3
51750	-X3-1	+L1	Electrical Panel	Terminal Block, GND, 2 position, Screw Type, Internally Jumped	1
37827	-XS12	+L2	Operator Panel	Circular Connector, Receptacle, 5 Pin Male, 20mm Cutout, Round, Solder	1
39283	-XS5	+L2	Operator Panel	Circular Connector, Plug, 5 Pin Male, PVC Jacket, Solder	1
51163	-XS11	+L2	Operator Panel	Circular Connector, Plug, 5 Pin Female, PVC Sleeve, Solder	1
51538	-XS3	+L1	Electrical Panel	Circular Connector, Front-Nut Mount Receptacle, 5 Pin Female, 20mm Cutout, Round, Solder	1
51598	-XS30	+L1	Electrical Panel	Circular Connector, Front-Nut Mount Receptacle, Push-Pull, 10 Pin Female, 20mm Cutout, Round, Solder	1
37343	-X1	+L1	Electrical Panel	Contactor Relay, 3 position 220V 12A, 24V DC Coil, Screw Terminal	1

Tormach, Inc 4009 Felland Rd Ste 116 Madison, WI	Machine Schematic		REVISION	
			16	PAGE
	+L1		17	
	Electrical Panel		User data 1	User data 2

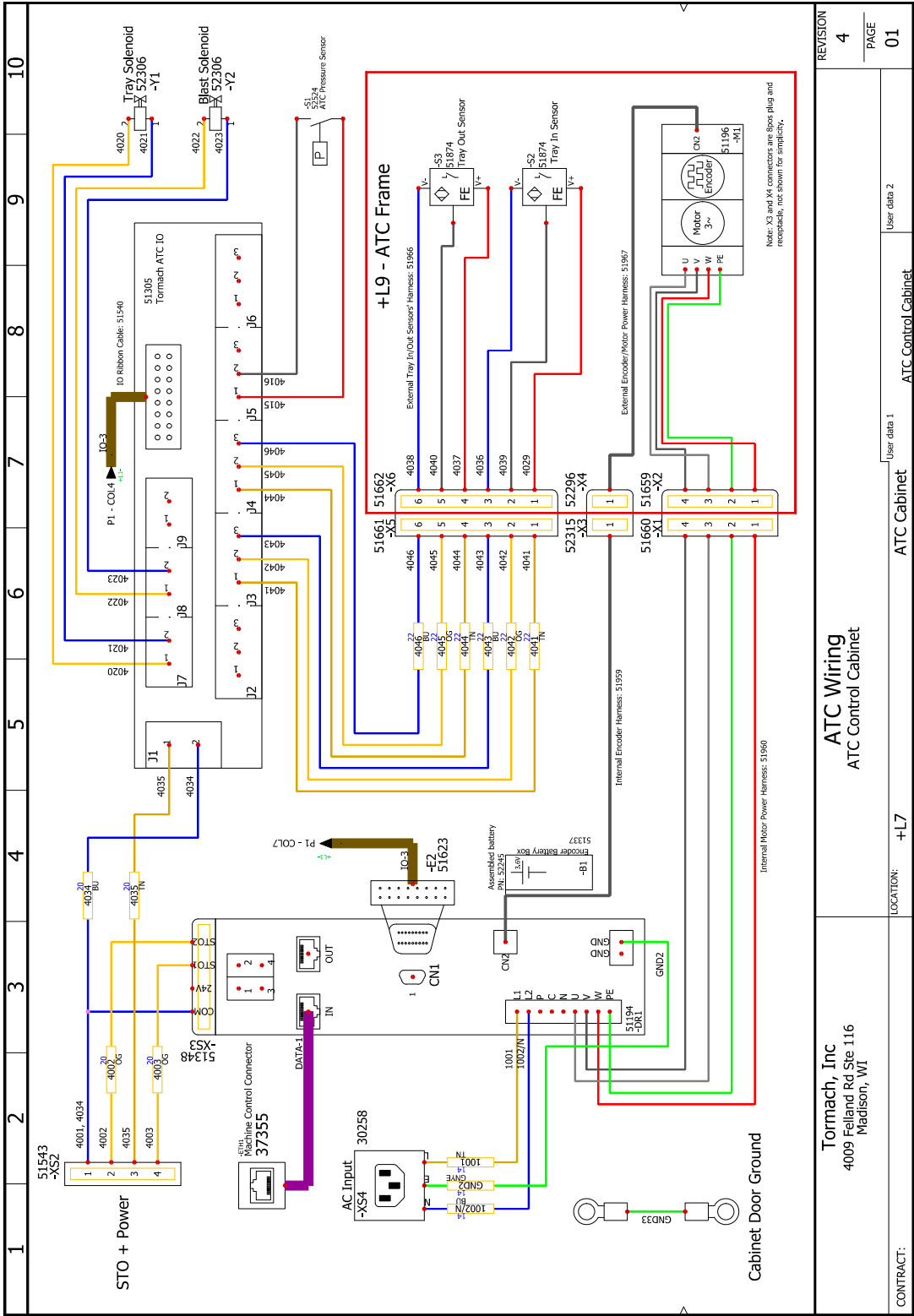
Document released with version 1.2024.5.0. 04053

13.2 ACCESSORY SCHEMATICS

13.2.1 Automatic Tool Changer (ATC) Electrical Schematic	378
13.2.2 Through-Spindle Coolant Electrical Schematic	380
13.2.3 Chip Conveyor Electrical Schematic	383

13: ELECTRICAL SCHEMATICS
13.2 Accessory Schematics

13.2.1 Automatic Tool Changer (ATC) Electrical Schematic



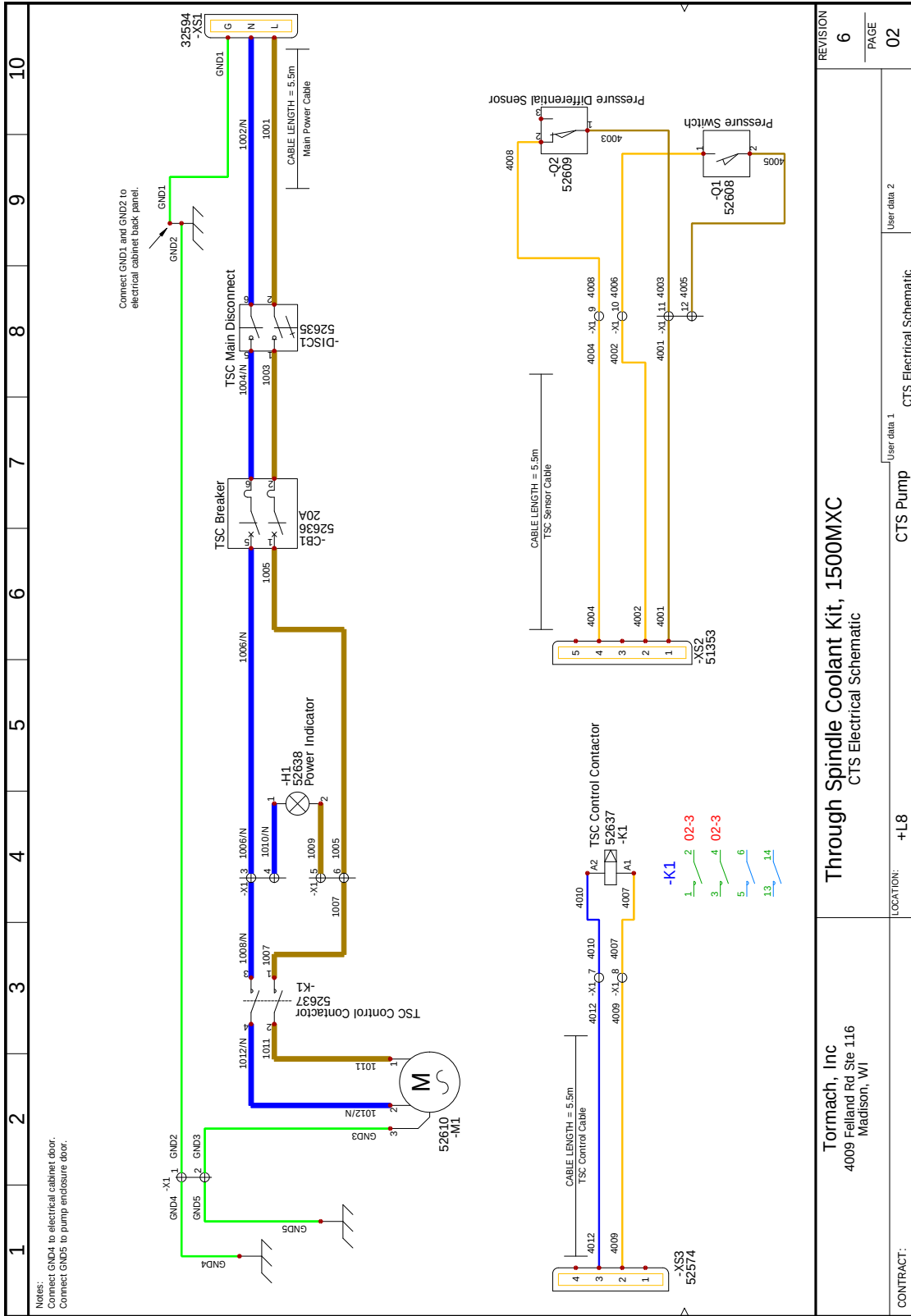
SOLIDWORKS Electrical

Tormach, Inc 4009 Folland Rd Ste 116 Madison, WI	ATC Wiring ATC Control Cabinet		REVISION 4
	LOCATION: +L7	ATC Cabinet	PAGE 01
CONTRACT:	User data 1		User data 2

Document released with version : 240225-5.0.0.0053

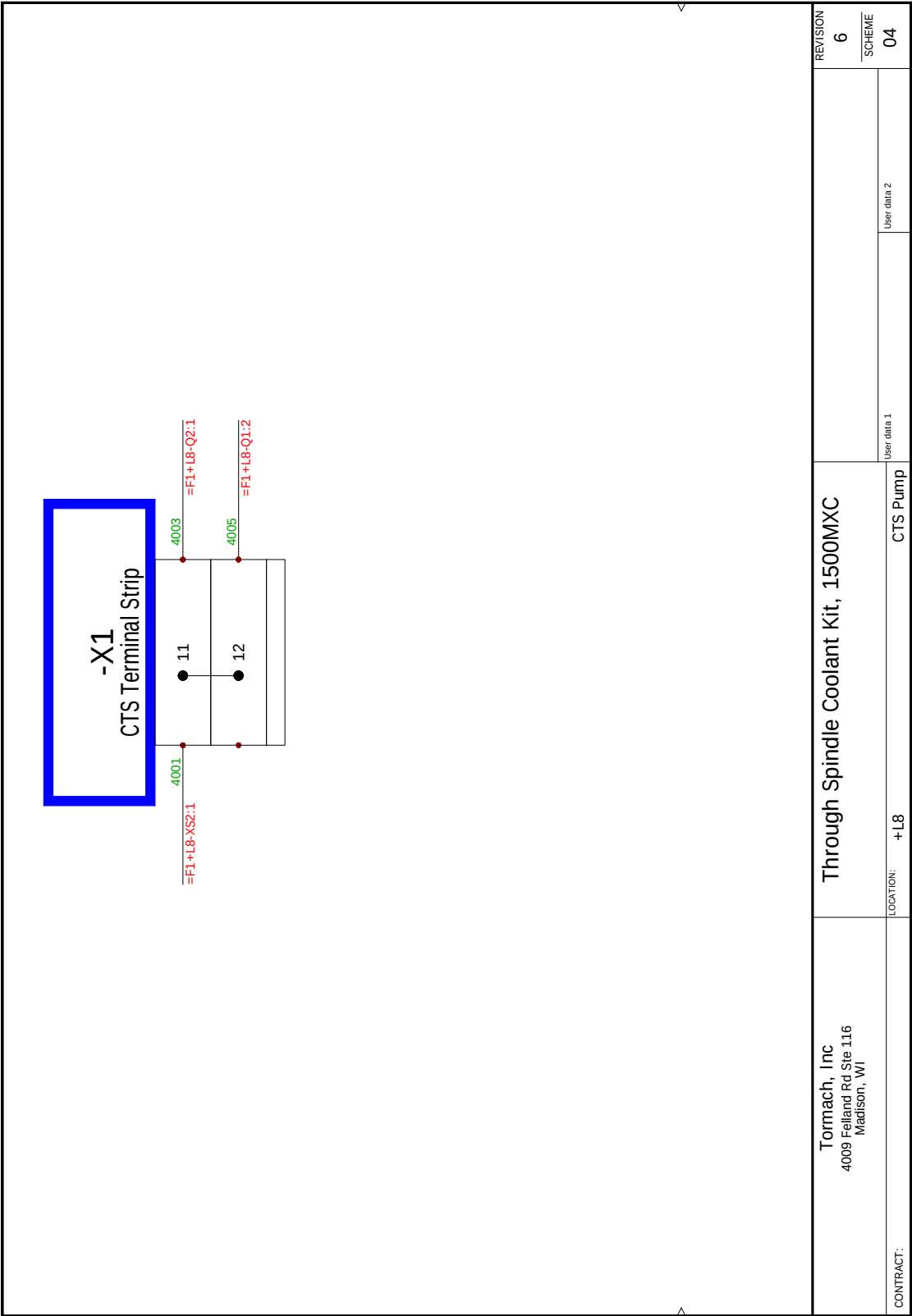
13.2 Accessory Schematics

13.2.2 Through-Spindle Coolant Electrical Schematic



13: ELECTRICAL SCHEMATICS

13.2 Accessory Schematics

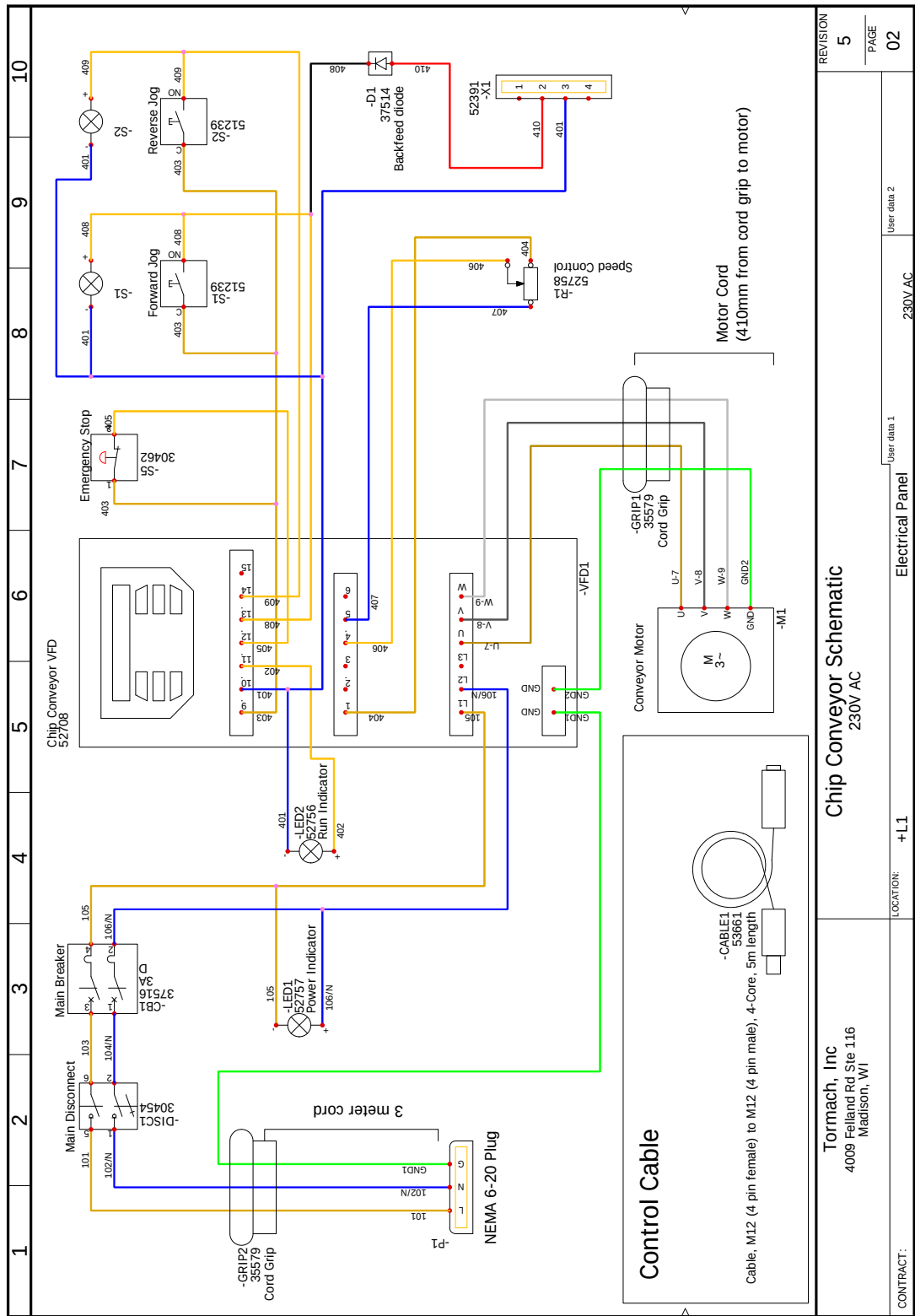


SOLIDWORKS Electrical

Tormach, Inc 4009 Felland Rd Ste 116 Madison, WI	Through Spindle Coolant Kit, 1500MXC		REVISION 6
	CONTRACT:	LOCATION: +L8	SCHEME 04
		User data 1	User data 2

Document created with version : 2012.0.3.6

13.2.3 Chip Conveyor Electrical Schematic



SOLIDWORKS Electrical

13: ELECTRICAL SCHEMATICS

13.2 Accessory Schematics

18AWG Protection-GNYE						-> 24V DC + Control-OG					
Wire number	Section	Color code	Origin	Destination	Length (mm)	Wire number	Section	Color code	Origin	Destination	Length (mm)
GND1	18 (AWG)	GNYE	=F1+L1:P1.G	=F1+L1:VPD1.GND	0	408	20 (AWG)	OG	=F1+L1:SI:NO	=F1+L1:VPD1.I3	0
GND2	18 (AWG)	GNYE	=F1+L1:M1.GND	=F1+L1:VPD1.GND	0	409	20 (AWG)	OG	=F1+L1:S2:+	=F1+L1:S2:NO	0
					0	409	20 (AWG)	OG	=F1+L1:S2:NO	=F1+L1:VPD1.I4	0
18AWG Three Phase-BK						24V DC + Control-TN					
Wire number	Section	Color code	Origin	Destination	Length (mm)	Wire number	Section	Color code	Origin	Destination	Length (mm)
V-8	18 (AWG)	BK	=F1+L1:M1.V	=F1+L1:VPD1.V	0	403	20 (AWG)	TN	=F1+L1:SS.1	=F1+L1:VPD1.9	0
					0	403	20 (AWG)	TN	=F1+L1:S2.C	=F1+L1:SS.1	0
18AWG Three Phase-BN						24V DC + Control Red Black-BK					
Wire number	Section	Color code	Origin	Destination	Length (mm)	Wire number	Section	Color code	Origin	Destination	Length (mm)
U-7	18 (AWG)	BN	=F1+L1:M1.U	=F1+L1:VPD1.U	0	403	20 (AWG)	TN	=F1+L1:SI.C	=F1+L1:S2.C	0
					0	404	20 (AWG)	TN	=F1+L1:R1	=F1+L1:VPD1.1	0
					0						0
18AWG Three Phase-GY						24V DC + Control Red Black-RO					
Wire number	Section	Color code	Origin	Destination	Length (mm)	Wire number	Section	Color code	Origin	Destination	Length (mm)
W-9	18 (AWG)	GY	=F1+L1:M1.W	=F1+L1:VPD1.W	0	410	20 (AWG)	RO	=F1+L1:DI	=F1+L1:SI.2	0
					0						0
24V DC + Control-BU						N L1 - 18AWG-BU					
Wire number	Section	Color code	Origin	Destination	Length (mm)	Wire number	Section	Color code	Origin	Destination	Length (mm)
401	20 (AWG)	BU	=F1+L1:ED2:-	=F1+L1:VPD1.I0	0	102/N	18 (AWG)	BU	=F1+L1:DISC1.1	=F1+L1:P1.N	0
401	20 (AWG)	BU	=F1+L1:ED2:-	=F1+L1:SI:-	0	104/N	18 (AWG)	BU	=F1+L1:CBL1.1	=F1+L1:DISC1.2	0
401	20 (AWG)	BU	=F1+L1:SI:-	=F1+L1:S2:-	0	106/N	18 (AWG)	BU	=F1+L1:CBL1.2	=F1+L1:LED1:+	0
401	20 (AWG)	BU	=F1+L1:VPD1.I0	=F1+L1:SI.3	0	106/N	18 (AWG)	BU	=F1+L1:CBL1.2	=F1+L1:VPD1.I2	0
407	20 (AWG)	BU	=F1+L1:R1	=F1+L1:VPD1.5	0						0
					0						0
24V DC + Control-OG						N L1 - 18AWG-TN					
Wire number	Section	Color code	Origin	Destination	Length (mm)	Wire number	Section	Color code	Origin	Destination	Length (mm)
402	20 (AWG)	OG	=F1+L1:ED2:+	=F1+L1:VPD1.I1	0	101	18 (AWG)	TN	=F1+L1:DISC1.5	=F1+L1:P1.L	0
405	20 (AWG)	OG	=F1+L1:SS.2	=F1+L1:VPD1.I2	0						
406	20 (AWG)	OG	=F1+L1:R1	=F1+L1:VPD1.4	0						
408	20 (AWG)	OG	=F1+L1:SI:+	=F1+L1:SI:NO	0						
					0						

Tormach, Inc
4009 Feland Rd Ste 116
Madison, WI

Chip Conveyor Schematic

5

REVISION

+L1

Electrical Panel

03

PAGE

User data 1

User data 2

Document created with version : 202206-0.0-8026-0

SOLIDWORKS Electrical

-> NL1 - 18AWG-TN

Document realized with version : 2025.0.0.5050

Chip Conveyor Schematic

