Post Processor Training Guide
For use with Fusion 360 CAM, Inventor CAM, HSMWorks
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1 Introduction to Post Processors

1.1 Scope
This manual is intended for those who wish to make their own edits to existing post processors. The scope of the manual covers everything you will need to get started; an introduction to the recommended editor (Autodesk Fusion 360 Post Processor Editor), a JavaScript overview (the language of Autodesk post processors), in-depth coverage of the callback functions (onOpen, onSection, onLinear, etc.), and a lot more information useful for working with the Autodesk post processor system.

It is expected that you have some programming experience and are knowledgeable in the requirements of the machine tool that you will be creating a post processor for.

1.2 What is a Post Processor?
A post processor, sometimes simply referred to as a "post", is the link between the CAM system and your CNC machine. A CAM system will typically output a neutral intermediate file that contains information about each toolpath operation like tool data, type of operation (drilling, milling, turning, etc.), and tool center line data. This intermediate file is fed into the post processor where it’s translated into the language that a CNC machine understands. In most cases this language is a form of ISO/EIA standard G-code, even though some controls have their own proprietary language or use a more conversational language. All examples in this manual uses the ISO/EIA G-code format.

If you would like a bit more information on the G-code format the Fundamentals of CNC Machining guide contains a lot of useful information including a further explanation of the G-code format in Chapter 5 CNC Programming Language.

Though most controls recognize the G-code format the machine configuration can be different and some codes could be supported on one machine and not another, or the codes could be interpreted differently, for example one machine may support circular interpolation while another requires linear moves to cut the circle, which is why you will probably need a separate post processor for each of your machine tools.
1.3 Finding a Post Processor

The first step in creating a post processor is to find an existing post that comes close to matching your requirements and start with that post processor as a seed. You will never create a post processor from scratch. You will find all the generic posts created by Autodesk on our online Post Library. From here you can search for the machine you are looking for by the machine type, the manufacturer of the machine or control, or by post processor name.

Other places to check for a post processor include the HSM Post Processor Forum or HSM Post Processor Ideas.

It is possible that Autodesk has already created a post processor for your machine, but has not officially released it yet. These posts are considered to be in Beta mode and are awaiting testing from the community before placing into production. You can visit the HSM Post Processor Ideas site and search for your post here. This site contains post processor requests from users and links to the posts that are in Beta mode. You can search for your machine and/or controller to see if there is a post processor available.
Searching For a Post Processor on Ideas or the Forum

If your post processor is not found, then you should search the HSM Post Processor Forum using the same method you used on the HSM Post Processor Ideas site. The Post Processor Forum is used by the HSM community to ask questions and help each other out. It is possible that another user has created a post to run your machine.

You should always take care when running output from a post processor for the first time on your machine, no matter where the post processor comes from. Even though the post processor refers to your exact name, it may be setup for options that your machine does not have or the output may not be in the exact format that you are used to running on the machine.

1.4 Downloading and Installing a Post Processor

Once you find the post processor that closely matches your machine you will need to download it and install it in a common folder on your computer. If you are working on a network with others then this should be in a networked folder so everyone in your company has access to the same library of post processors.
When using Fusion 360 it is recommended that you enable cloud posts and place it in your Asset Library. This way post processors, tool libraries, and templates will be synched across devices and users at a company.
Double Click the CAMPosts Folder and then Press the Upload Button

Once you have uploaded your post(s) to the Cloud Library you can access these from Fusion 360. You do this by pressing the Setup button in the Post Process dialog and selecting your post from the dropdown menu.

Selecting Your Post from the Cloud Library
In all cases you will want to avoid placing posts in the production install folder as these can be overwritten when HSM is updated. Downloading your posts to a separate folder means that you can reduce your list of post processors that show up in the Post Process dialog to those that you use in your shop.

1.4.1 Automatically Updating Your Post Processors

It is possible to have Fusion 360 automatically search for the latest versions and additions of post processors and machines when they become available. This is accomplished by enabling *Automatically get latest Posts, Machines and Print Settings* in the Manufacture/Optional Features section of the User Preferences.

![Automatic Update of Post Processors](image)

1.5 Running the Post Processor

The post processor can be run from the Post Process dialog or from an NC Program in Fusion 360. You can either select the Post Process button or right click on an Operation/NC program and select Post Process from the menu. Multiple operations can be selected and post processed in a single operation.
1.5.1 Post Process Dialog

Fusion 360 uses the NC Programs dialog as its interface to the post processor, while Inventor CAM and HSMWorks use the legacy Post Process dialog. The display of the Post properties in the NC Programs dialog is more advanced, as it respects the group names from the property table and displays them in collapsible tabs.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use machine configuration</td>
<td>Check this box to assign a Machine Definition to the post processor. Typically, you would assign a Machine Definition to the Manufacturing Setup in Fusion 360. If a machine is assigned to the Manufacturing Setup, then this box will be checked and the Machine Definition will be displayed below this field.</td>
</tr>
<tr>
<td>Field</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Post</td>
<td>Specifies the post processor you want to run. The dropdown arrow in this field will display a list of recently used post processors. Pressing the ☉ button will open a popup dialog that includes a list of linked folders and available posts that you can select from. The ☉ button allows you to edit the post processor.</td>
</tr>
<tr>
<td>Use cascading post</td>
<td>Used to select a cascading post. A cascading post is usually a 3rd party post processor or verification program that is run after the Fusion 360 post processor.</td>
</tr>
<tr>
<td>Name or number</td>
<td>The name/number of the program. This name/number will usually be output as the first line of the NC file, usually as an Oxxxx code when a number is required or as a comment (xxxx) if a name is allowed. The post processor controls whether an alphanumeric name is allowed in this field or if a number must be entered. This is defined by the programNameIsInteger = true; statement in the post processor and can be set to either true (number required) or false (alphanumeric name allowed).</td>
</tr>
<tr>
<td>File name</td>
<td>The output NC file name. This will default to the program name/number.</td>
</tr>
<tr>
<td>Comment</td>
<td>The program comment, which is usually output as a comment at the top of the NC file.</td>
</tr>
<tr>
<td>Output folder</td>
<td>Specifies the folder for the output NC file. Pressing the ☉ button will open this folder in a File Explorer window. Pressing the ☉ button opens a folder browser window to select the folder for the NC file.</td>
</tr>
<tr>
<td>Post to Fusion Team</td>
<td>Saves the output file to the cloud. The Fusion Team output folder field will be displayed if this box is checked, allowing you to select the cloud folder to post to.</td>
</tr>
<tr>
<td>NC extension</td>
<td>Contains the default file extension for the output NC file as defined in the post processor. You cannot override the file extension.</td>
</tr>
<tr>
<td>Unit</td>
<td>Controls the output units of the NC file. This is usually set to use the same units as the model, but can be overridden to output in either Inch or Millimeters.</td>
</tr>
<tr>
<td>Open NC file in editor</td>
<td>Check this box if you want to open the output NC file in an editor after post processing is finished. The editor used is defined in your Fusion 360 Preferences dialog in the General-&gt;Manufacture-&gt; External editor field.</td>
</tr>
<tr>
<td>Create in browser</td>
<td>Check this box if you want an NC Program automatically created with the operations you are posting against. Be forewarned, if this box remains checked each time you post process outside of an NC Program, then you will continue to get new NC Programs added to the list.</td>
</tr>
<tr>
<td>Property Table</td>
<td>Displays the properties defined in the post processor and allows you to modify these properties. Please see the Property Table.</td>
</tr>
</tbody>
</table>
Field | Description
--- | ---

section in this manual for a full description of post processor properties.

Fusion 360 Post Process Dialog Fields

Selecting a Post Processor in Fusion 360

You select the folder for the post processor and the post processor itself by pressing the button next to the Post field. You can right click on the Linked menu in the Post Library dialog to add a new folder to select post processors from. The new folder will be displayed in the Linked menu.

Selecting a New Folder for Post Processors

Introduction to Post Processors

AUTODESK | CAM Post Processor Guide | 11/7/23
Introduction to Post Processors

**Inventor CAM and HSMWorks Legacy Post Process Dialog**

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration Folder</td>
<td>Specifies the folder location of the post processor you want to run. You can press the button to open a folder browser window to select the post processor. This field is only displayed in the legacy dialog, but you can select the folder in the NC Programs dialog by pressing the button next to the Post field.</td>
</tr>
<tr>
<td>Setup</td>
<td>Used to select preinstalled post processor libraries or to select a cascading post. A cascading post is usually a 3rd party post processor or verification program that is run after the HSM post processor. This field is only displayed in the legacy dialog.</td>
</tr>
<tr>
<td>Post Configuration</td>
<td>Defines the post processor you want to run. The available posts are listed in a dropdown menu. There are filters that will limit the post processors listed, including a Search Text field, Capabilities (milling, turning, etc.), and Vendors.</td>
</tr>
<tr>
<td>Output folder</td>
<td>Specifies the folder for the output NC file. Pressing the button opens a folder browser window to select the folder for the NC file. The Open folder button opens a file browser in this folder.</td>
</tr>
<tr>
<td>NC extension</td>
<td>Contains the default file extension for the output NC file as defined in the post processor. You can override the file extension in this field.</td>
</tr>
</tbody>
</table>
1.5.2 NC Programs

NC Programs are supported in Fusion 360 and allow you to group operations together and assign a post processor that is used for these operations. You create an NC Program by pressing the NC Program menu or right clicking on a (group of) operation(s) and selecting Create NC Program from the list. Pressing the Post Process button will bring up the NC Program dialog where you can create an NC Program from the selected operations when the Post or OK button are pressed. It is important to note that pressing the OK button will NOT post process the NC Program but will only save it.
The NC Program dialog contains two tabs, **Settings** and **Operations**. This is the same dialog that is displayed when Post Processing from the menus.

You will also notice that when you post process against an NC Program that the NC Program dialog is displayed. If you want to change any settings for post processing when using an NC Program, you must edit the NC Program to make changes.
1.5.3 Machine Definitions

Machine Definitions can be used to define the kinematics and multi-axis capabilities of the machine for both the post processor and machine simulation. A Machine Definition is assigned to a Setup in the CAM system. The usage of a Machine Definition has distinct advantages.

1. Allows a single generic post processor to be used for multiple machines with different kinematics.
2. The post processor is assigned directly to the Machine Definition.
3. The NC output folder is defined in the Machine Definition.
4. Defines the unique multi-axis features for the machine.
5. Required for Machine Simulation.
6. Required for Operation Properties.

You can determine if a post processor supports a Machine Definition by checking for the `activateMachine` function inside of the post processor. If this function is not present, then the post processor will most likely not accept or fully support a Machine Definition. There are a number of post processors that support Machine Definitions, such as the Fanuc, Haas Next Generation, Heidenhain, Hurco, Siemens, and Tormach posts.

You assign a Machine Definition to a CAM Setup when creating or editing the Setup and pressing the `Select...` button. This will bring up the Machine Library dialog that allows you to select a machine from the available configurations.

The Machine Library dialog consists of the following areas.
<table>
<thead>
<tr>
<th>Area</th>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location of Machine Definitions</td>
<td></td>
<td>Specifies the area you want to select a Machine Definition from.</td>
</tr>
<tr>
<td>Recent</td>
<td></td>
<td>Displays recently selected Machine Definitions.</td>
</tr>
<tr>
<td>Document</td>
<td></td>
<td>Displays Machine Definitions used in the active model.</td>
</tr>
<tr>
<td>My machines</td>
<td></td>
<td>Displays Machine Definitions stored locally on your computer or in selected (linked) folders. You can add folders to the linked area by right clicking on the Linked menu and selecting Link folder.</td>
</tr>
<tr>
<td>Fusion 360 Library</td>
<td></td>
<td>Displays all Machine Definitions included with Fusion 360.</td>
</tr>
<tr>
<td>Machine Definitions</td>
<td></td>
<td>Lists the Machine Definitions stored in the selected location.</td>
</tr>
<tr>
<td>Filters and Machine Definition Description</td>
<td></td>
<td>The Filter tab allows you to filter the Machine Definitions based on Capabilities, Machine Simulation Ready, and Vendor. The Info tab displays information about the selected Machine Definition.</td>
</tr>
<tr>
<td>Editing Menu</td>
<td></td>
<td>Contains buttons for creating, editing, copying, and deleting Machine Definitions. Right clicking on a Machine Definition will also display this menu.</td>
</tr>
<tr>
<td></td>
<td>+</td>
<td>Creates a new Machine Definition.</td>
</tr>
<tr>
<td></td>
<td>🖍️</td>
<td>Edits an existing Machine Definition. The Machine Definition must reside in one of the My machines folders.</td>
</tr>
<tr>
<td></td>
<td>📖</td>
<td>Copies the selected Machine Definition.</td>
</tr>
<tr>
<td></td>
<td>📕</td>
<td>Pastes the selected Machine Definition into the selected folder.</td>
</tr>
<tr>
<td></td>
<td>🍀</td>
<td>Imports an external Machine Definition file.</td>
</tr>
<tr>
<td></td>
<td>🕒</td>
<td>Exports the selected Machine Definition to an external file.</td>
</tr>
<tr>
<td></td>
<td>❗️</td>
<td>Deletes the selected Machine Definition.</td>
</tr>
</tbody>
</table>

**Machine Library Dialog**

Once you find the Machine Definition you want to use you can copy it into your Local folder or a Linked Folder. You can do this by dragging the definition onto the desired My machines folder or by
copying and pasting it into the desired folder. You can only edit Machine Definitions stored in one of the My machines folders.

The latest versions of Machine Definitions are available on our online Post Library. From here you can search for the machine by the machine type, the manufacturer of the machine, or by machine name.

Once a Machine Definition is selected, you can edit it by pressing the Edit... button in the Setup dialog.
The areas of the Machine Definition that are important for post processing are the General, Kinematics, Post Processing, and Multi-Axis settings. The information in the other areas can be accessed by the post processor, but not all are used by the library post processors as of this writing.

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Describes the manufacture, machine model, and description of the configuration.</td>
</tr>
<tr>
<td>Kinematics</td>
<td>Defines the machine kinematics of the moving axes. You can define up to 3 linear axes, 2 rotary axes, a single spindle, and a table. You can add and axis by pressing the icon. When you add an axis, it will be added after the highlighted component. An axis can be deleted by highlighting it and pressing the icon. The definition of the selected axis is displayed in the right pane of the dialog, including the name, home position, feedrates, preference, and TCP setting. The rotation vector (orientation) and range of the axis is defined below the kinematics diagram.</td>
</tr>
</tbody>
</table>
The rotary axis pivot location (Offset) and initial location at the start of an operation (Reset) are located under the Advanced settings tab.

These fields apply directly to the parameters of the `createAxis` function as described in the Multi-Axis Post Processors chapter.

<table>
<thead>
<tr>
<th>Post Processing</th>
<th>Multi-Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>This is where you will select the location of the post processor, the post processor itself, and the output folder for the NC file. These will become the defaults when post processing and for NC Programs.</td>
<td>Defines the multi-axis capabilities of the control, along with how retract/reconfigure operations are handled, and singularity settings. These capabilities are described in the Multi-Axis Post Processors chapter.</td>
</tr>
</tbody>
</table>

### 1.6 Creating/Modifying a Post Processor

Once you find a post processor that is close, but not exact to the requirements of your machine you will need to make modifications to it. The good news is, all of posts are open source and can be modified without limitation to create the post you need. You have a few options for making the modifications.

1. Make the modifications yourself using this manual as a guide and by asking for assistance from the HSM community on the HSM Post Processor Forum.
2. Visit HSM Post Processor Ideas and create a request for a post processor for your machine. Other users can vote for your request for Autodesk to create and add your post to our library.
3. Contact one of our CAM partners who offer post customization services. These partners can be found on the HSM Post Processor Forum at the top of the page.

---

**Machine Definition Post Processor Settings**

**Area** | **Description**
---|---
Orientation | CUSTOM 1 0 0
Range | LIMITED -120 deg 120 deg
Offset | 0 in 0 in 0 in
Resolution | 0 deg
Reset | Remember the position from previous section

---

**Introduction to Post Processors 1-17**
Finding HSM CAM Partners

No matter which method you decide to use to create your post processor, you should have enough information available to define the requirements, which includes as much of the following as you can gather.

1. A post processor (.cps) that will be used as the seed post.
2. Sample NC code that has run on your machine.
3. The machine/control make and model.
4. The type of machine (mill, lathe, mill/turn, waterjet, etc.).
5. The machine configuration, including linear axes, rotary axes setup, etc.
6. A programming manual for your machine/control.

1.7 Testing your Post Processor – Benchmark Parts

When testing your post processor, you will need a part with cutting operations to post against. We have created standard benchmark parts for this specific purpose. These parts cover the most common scenarios you will come across when testing a post processor and are available for HSMWorks, Inventor CAM, and Fusion 360 CAM. They are available in both metric and inch format for all three CAM systems. There are five different benchmark parts.

- Milling
- Turning and Mill/Turn
- Stock Transfers
- Waterjet-Laser-Plasma
- Probing

HSM Post Processor Forum

Finding HSM CAM Partners

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- Milling
- Turning and Mill/Turn
- Stock Transfers
- Waterjet-Laser-Plasma
- Probing
1.7.1 Locating the Benchmark Parts

The benchmark parts are available to all users of Autodesk CAM and can be accessed in the Samples folder for each product.
1.7.2 **Milling Benchmark Part**

The milling benchmark parts include the following strategies.

- 2D
• Drilling
• Coolant codes
• Manual NC commands
• 3+2 5-axis
• 5-axis simultaneous

Mill Benchmark Part

1.7.3 Mill/Turn Benchmark Part
The mill/turn benchmark parts contain the following strategies.

• Primary and Secondary spindle operations
• Turning
• Axial milling
• Radial milling
• 5-axis milling
1.7.4 **Stock Transfer Benchmark Part**

The stock transfer benchmark part contains the following strategies.

- Primary and Secondary spindle operations
- Simple part transfer
- Part transfer with cutoff
The Waterjet-Laser-Plasma benchmark part contains the following strategies.

- Waterjet
- Laser
- Plasma
- Lead in/out
- Radius compensation

1.7.5 Probing Benchmark Part
The Probing benchmark part contains the following strategies.

- Various probing cycles
2 Autodesk Post Processor Editor

Since Fusion 360, Inventor CAM, and HSMWorks post processors are text-based JavaScript code, they can be edited with any text editor that you are familiar with. There are various editors in the marketplace that have been optimized for working with programming code such as JavaScript. We recommend Visual Studio Code with the Autodesk Fusion 360 Post Processor Utility extension. Using this editor provides the following benefits when working with Autodesk post processors.

- Color coding
- Automatic closing and matching of parenthesis and brackets
- Automatic indentation
- Intelligent code completion
- Automatic syntax checking
- Function List
- Run the post processor directly from editor
- Match the output NC file line to the post processor command that created it

2.1 Installing the Autodesk Post Processor Editor

Before you can use the VSC editor you will need to install it. The easiest way is to visit the Autodesk Fusion 360 Post Processor Utility page in the Visual Studio Marketplace, where you can download VSC and then the Autodesk Fusion 360 Post Processor Utility extension. Please note that the Visual Studio Code site changes quite frequently, so the directions/pictures in this section might not be exactly what you see on the screen, but the installation steps should still be similar.
Installing Visual Studio Code

This link will take you to the Visual Studio Code installation page. Select the correct version for your operating system.

Installing the Windows Version of Visual Studio Code

This will download an installation program that you can run to do the actual install. Left click on the installation program to execute it.
Follow the instructions displayed on the screen to finish the installation. You should select the defaults for all questions, though you may want to make this the default code editor and add it to the Windows Explorer file context menu.

Selecting Installation Options
You can choose to startup the Visual Studio Code editor automatically after it is installed. Once the editor is opened you can install the Autodesk Fusion 360 Post Processor Utility by opening the Extensions view in the left pane and searching for Autodesk. Select the Autodesk Fusion 360 Post Processor Utility to install it.
After installing the Autodesk Fusion 360 Post Processor Utility extension you will want to exit the VSC editor and then restart it so that the extension is initialized. You are now ready to start editing Autodesk post processors.

### 2.2 Autodesk Post Processor Settings

After installing the Autodesk Post Processor editor you will want to setup the editor to match your preferences. Open the settings file by selecting `File->Preferences->Settings`. This section will describe some of the most popular settings, but feel free to explore other settings at your leisure to find any that you may want to change. The User Settings can also be displayed by using the `Ctrl+Comma` shortcut.
Displaying the Editor Settings

The settings will be displayed in a separate tab. You can now search for individual settings using the Search bar. To display the Autodesk Fusion 360 Post Processor Utility settings type in `hsm` in the search bar.

Modifying the Editor Settings

There is a description that explains the setting making it easy for you to make the changes.

The following table provides a list of some of the more common settings and their descriptions.
<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Editor &gt; Minimap</td>
<td>Controls if the minimap is shown. The minimap is a small representation of the entire file displayed on the right side of the window and allows you to easily scroll through the file.</td>
</tr>
<tr>
<td>Editor: Font Size</td>
<td>Size of the editor font.</td>
</tr>
<tr>
<td>Editor: Font Weight</td>
<td>Weight (thickness) of the editor font.</td>
</tr>
<tr>
<td>Editor: Detect Indentation</td>
<td>Automatically detects the <code>editor.tabSize</code> and <code>editor.insertSpaces</code> settings when opening a file.</td>
</tr>
<tr>
<td>Editor: Insert Spaces</td>
<td>When checked, spaces will be inserted into the file when the <code>tab</code> key is pressed.</td>
</tr>
<tr>
<td>Editor: Tab Size</td>
<td>Sets the number of spaces a tab is equal to. The standard setting for Autodesk post processors is 2.</td>
</tr>
<tr>
<td>Editor &gt; Parameter Hints</td>
<td>Enables a pop-up that shows parameter documentation and style information as you type.</td>
</tr>
<tr>
<td>Editor: Auto Closing Brackets</td>
<td>Controls if the editor should automatically close brackets after opening them.</td>
</tr>
<tr>
<td>Extensions: Auto Check Update or Auto Updates</td>
<td>Automatically (check for) update extensions.</td>
</tr>
<tr>
<td>Files: Associations</td>
<td>Associates file types with a programming language. This must have &quot;*.cps&quot;: &quot;javascript&quot; set in it to enable the automatic features of the editor in Autodesk post processors.</td>
</tr>
<tr>
<td>Workbench: Color Theme</td>
<td>Defines the color theme for the editor. This setting can be changed using the <code>File &gt; Preferences &gt; Color</code> theme menu.</td>
</tr>
<tr>
<td>HSMPost Utility: Auto Update Function List</td>
<td>Updates the function list automatically, without the need for refreshing.</td>
</tr>
<tr>
<td>HSMPost Utility: Sort Function List Alphabetically</td>
<td>When checked the function list will be sorted. Unchecked will display the function names in the order that they are defined.</td>
</tr>
<tr>
<td>HSMPost Utility: Color Output</td>
<td>When checked, rapid, feedrate, and circular blocks will be displayed in color.</td>
</tr>
<tr>
<td>HSMPost Utility: Rapid Color</td>
<td>Color for rapid move blocks.</td>
</tr>
<tr>
<td>HSMPost Utility: Linear Color</td>
<td>Color for feedrate move blocks.</td>
</tr>
<tr>
<td>HSMPost Utility: Circular Color</td>
<td>Color for circular move blocks.</td>
</tr>
<tr>
<td>HSMPost Utility: Enable Auto Line Selection</td>
<td>Enables the automatic selection of the line in the post processor that generated the selected line in the output NC file.</td>
</tr>
<tr>
<td>HSMPost Utility: Output Units</td>
<td>Sets the desired output units when post processing</td>
</tr>
<tr>
<td>HSMPost Utility: Shorten Output Code</td>
<td>Limits the number of blocks output when posting, making it easier to navigate.</td>
</tr>
</tbody>
</table>
### Setting | Description
--- | ---
HSMPH Utility: Post On CNCSelection | When checked, post processing will occur as soon as a CNC file is selected.
HSMPH Utility: Post On Save | Automatically run the post processor when it is saved, only if the NC output file window is open.

**Commonly Changed User Settings**

#### 2.3 Left Side Flyout

On the left side of the editor window is a tab that will open different flyout dialogs. The features contained in the flyout dialogs are quite beneficial while editing a post processor and are explained in this section. The Source Control flyout is not used when editing post processors and will not be discussed.

![Left Side Flyout Dialog]

**2.3.1 Explorer Flyout**

The Explorer flyout contains expandable lists that are used to display the open editors, folders, variables, functions, and CNC selector. The arrow ▶ at the left of each entry is used to expand or collapse the list.

<table>
<thead>
<tr>
<th>List</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPEN EDITORS</td>
<td>Lists the files that are open in this instance of the VSC editor. Any files that have been changed, but not been saved will be marked with a bullet (•). The number of changed files that have not been saved is displayed in the Explorer icon.</td>
</tr>
<tr>
<td>List</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>NO FOLDERS OPEN</td>
<td>You can open a folder for quick access to all of the post processors in the folder. Expanding the folders will display the Open Folder button that can be used to open a folder. Clicking on a file in the open folder will automatically open it in the editor. Take note that if a folder is opened, then all opened files in the editor will first be closed and you will be prompted to save any that have been changed.</td>
</tr>
<tr>
<td>OUTLINE</td>
<td>Lists the functions defined in the post processor and the variables defined in each function. Expanding the function by pressing the arrow ► to the left of the function name will display the variables defined in the function. You can select any of the variables to go to the line where it is defined.</td>
</tr>
<tr>
<td>CNC SELECTOR</td>
<td>Contains the Autodesk intermediate files (*.cnc) that are available to the post processor from the VSC editor. This list is further explained in the Running/Debugging the Post section of this chapter.</td>
</tr>
<tr>
<td>FUNCTION LIST</td>
<td>Expanding the function list will display the functions defined in the active post processor. The functions will either be listed in alphabetical order or by the order they appear in the post processor depending on the HSMPost Utility: Sort Function List Alphabetically setting. You can select on a function in this list and the cursor will be placed at the beginning of this function in the editor window and while traversing through the post processor the function that the cursor is in will be marked with an arrow ►, making it easy for you to determine what function the active line is in.</td>
</tr>
<tr>
<td>POST PROPERTIES</td>
<td>Contains the Property Table for the post processor, similar to the Property Table displayed when running the post from CAM. This list is further explained in the Running/Debugging the Post section of this chapter.</td>
</tr>
<tr>
<td>VARIABLE LIST</td>
<td>Lists the variable types supported by the post processor, such as Array, Format, Vector, etc. It does not contain a list of variables defined in the post processor. Expanding the variable type by</td>
</tr>
</tbody>
</table>
2.3.2 Search Flyout

You can search for a text string in the current file or in all of the opened files. To search for the text string in the current file you should use the Find popup window accessed by pressing the Ctrl+F keys.
Ctrl+F Find Popup – Search for a Text String in the Current File

As you type in a text string the editor will automatically display and highlight the next occurrence of the text in the file. The number of occurrences of the text string in the file will be displayed to the right of the text field. You can use the *Enter* key to search for the next occurrence of the string or press the arrow keys to search forwards → and backwards ← through the file. If you use the *Enter* key, then the keyboard focus must be in the *Find* field.

Using the Find Popup to Search for Text Strings

The *Search* flyout searches for a file in the opened files and in the files located in an open folder (refer to the *Explorer* flyout to see how to open a folder). The *Search* dialog will be displayed when you press the *Search* button.

Search Flyout – Search for a Text String in Multiple Files

Entering a text string to search for and then pressing the *Enter* key will display the files that contain the text string and the number of instances of the text string in each file. You can expand the file in the list by pressing the arrow key ► and each instance of the text string found in the selected file will be displayed. Clicking on one of the instances causes the editor to go to that line in the file and automatically open the file if it is not already opened. If you don't make any changes to the file and then select the text string in another file, then the first file will be closed before opening the next file. An unchanged file opened from the *Search* flyout will have its name italicized in the editor window.
Searching for a Text String in the Opened Files

There are options that are available when searching for text strings. These options are controlled using the icons in the *Search* dialog and *Find* popup.

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Aa" /></td>
<td>When enabled, the case of the search string must be the same as the matching text string in the file.</td>
</tr>
<tr>
<td><img src="image" alt="Alt" /></td>
<td>When enabled, the entire word of the matching text string in the file must be the same as search string. When disabled, it will search for the occurrence of the search string within words.</td>
</tr>
<tr>
<td><img src="image" alt="Search forward" /></td>
<td>When enabled, the '.' character can be used as a single character wildcard and the '*' character can be used as a multi-character wildcard in the search string.</td>
</tr>
<tr>
<td><img src="image" alt="Search backward" /></td>
<td>Search forward in the file. In the <em>Find</em> popup only.</td>
</tr>
<tr>
<td><img src="image" alt="Search forward" /></td>
<td>Search backward in the file. In the <em>Find</em> popup only.</td>
</tr>
<tr>
<td><img src="image" alt="Search forward" /></td>
<td>Searches for the text string only in the selected text in the file. In the <em>Find</em> popup window only.</td>
</tr>
<tr>
<td><img src="image" alt="Close" /></td>
<td>Closes the <em>Find</em> popup window.</td>
</tr>
<tr>
<td><img src="image" alt="Refresh" /></td>
<td>Refresh the results window. In the <em>Search</em> flyout only.</td>
</tr>
<tr>
<td><img src="image" alt="Collapse" /></td>
<td>Collapse all expanded files in the results window. In the <em>Search</em> flyout only.</td>
</tr>
<tr>
<td><img src="image" alt="Set Include and Exclude" /></td>
<td>Displays fields that allow you to include or exclude certain files from searches. In the <em>Search</em> flyout only.</td>
</tr>
<tr>
<td><img src="image" alt="Replace" /></td>
<td>Displays the <em>Replace</em> field, allowing you to replace the <em>Search</em> text with the <em>Replace</em> field text.</td>
</tr>
<tr>
<td><img src="image" alt="Replace" /></td>
<td>Replaces the current (highlighted) occurrence of the <em>Search</em> text with the <em>Replace</em> field text. Hitting the <em>Enter</em> key while in the <em>Replace</em> field performs the same replacement. In the <em>Find</em> popup window only.</td>
</tr>
<tr>
<td><img src="image" alt="Replace" /></td>
<td>Replaces all occurrences of the <em>Search</em> text with the <em>Replace</em> field text. When initiated from the <em>Search</em> flyout, all occurrences of the text in all files listed in the <em>Results</em> window will be replaced.</td>
</tr>
</tbody>
</table>

**Search and Replace Options**

Autodesk Post Processor Editor 2-34
2.3.3 Bookmarks Flyout

Okay, so the Bookmarks flyout is actually a Breakpoints flyout, but since JavaScript does not have an interactive debugger we are going to use it for adding bookmarks to the opened files. Placing the cursor to the left of the line number where you want to set a bookmark will display a red circle and then clicking at this position will add the bookmark.

To see the active bookmarks you can open the Bookmarks flyout and expand the BreakPoints window. You can then go directly to a line that is bookmarked by selecting that line in the Bookmarks flyout. Bookmarks set in all opened files will be displayed in the flyout and the file that the bookmark is set in will automatically be made the active window when the bookmark is selected.

2.3.4 Extensions Flyout

Visual Studio Code is an open source editor and there are many extensions that have been added to it by the community. For example, the Autodesk Fusion 360 Post Processor Utility is an extension to this editor. By opening the Extensions flyout you can see what extensions you have installed and what extensions have updates waiting for them.
If there is an *Update to x.x.x* button displayed with the extension you can press this button to install the latest version of the associated extension.

You can search the Visual Studio Marketplace for extensions that are beneficial for your editing style by typing in a name in the *Search Extensions in Marketplace* field. For example, if you want a more dedicated way to set bookmarks you can type in bookmark in this field and all extensions dealing with adding bookmarks will be displayed. You can press the green *Install* button to install the extension.

You can also search for extensions online at the [Visual Studio Marketplace](https://marketplace.visualstudio.com).

### 2.4 Autodesk Post Processor Editor Features

The Autodesk Post Processor editor has features to enhance the ease of editing of post processor JavaScript files. One example is the color coding of the text, variables are in one color, functions in another, JavaScript reserved words in yet another, and so on. The colors of each entity is based on the *Workbench Color Theme* setting.
This section will go over some of the more commonly used features. You are sure to discover other features as you use the editor.

2.4.1 Auto Completion

As you type the name of a variable or function you will notice a popup window that will show you previously used names that match the text as it is typed in. Selecting one of the suggestions by using the arrow keys to highlight the name and then the tab key to select it will insert that name into the spot where you are typing.

If the Editor: Parameter Hints setting is set to true, then when you type in the name of a function, including the opening parenthesis, you will be supplied the names of the function's arguments for reference.

2.4.2 Syntax Checking

If you have a syntax error while editing a file, the editor is smart enough to flag the error by incrementing the error count at the bottom left of the window footer and marking the problem in the file with a red squiggly line. You can open the Problems window by selecting the X in the window footer to see all lines that have a syntax error. Clicking on the line displaying the error will then take you directly to that line, so that you can resolve the error.

You can close the window by pressing on the X in the window footer or the X at the top right of the Problems window.
2.4.3 Hiding Sections of Code

You can hide code that is enclosed in braces {} by positioning the cursor to the right of the line number on the line with the opening brace and then pressing the [-] icon. The code can be expanded again by pressing the [+]-icon. Note that the icons will not be displayed unless the cursor is placed in the area between the line number and the editing window.

2.4.4 Matching Brackets

If you place the edit cursor at a parenthesis (()), bracket ([[]), or brace ({{{}}}) the editor will highlight the selected enclosure as well as the opening/closing matching enclosure character. If there are multiple enclosure characters right next to each other, then the enclosure following the edit cursor will be selected. If the enclosure character does not highlight, then this means that there is not a matching opening/closing enclosure.
2.4.5 Go to Line Number
You can go to a specific line number in the file by pressing the Ctrl+G keys and then typing in the line number.

2.4.6 Opening a File in a Separate Window
You can open a file in the current window by selecting the File->Open File... menu from the task bar or by pressing the Ctrl+O keys. You can open the active file in a separate VSC window by pressing the Ctrl+K keys and then pressing the O key. The file will be opened in the a new window and remain open in the active window. You can also open a new VSC window by selecting the File->New Window menu or by pressing the Ctrl+Shift+N keys.

2.4.7 Shortcut Keys
You can display the assigned Shortcut Keys by pressing the F1 key and then typing in key to display all commands referencing the key string. Select the Preferences: Open Keyboard Shortcuts menu. You can also press the Ctrl+K Ctrl+S keys in sequence to display the Shortcut Keys window.
Modifications and/or additions to the Shortcut Key assignments can be made by selecting the `keybindings.json` link at the top of the page. This will open a split window display that displays the default Shortcut Keys in the left window and the user defined Shortcut Keys in the right window. Use the same procedure as modifying a setting to modify a Shortcut Key, by copying the binding definition from the left window into the right window and making the desired changes. Be sure to save the `keybindings.json` file after making your changes.

The format of the keystrokes that represent a single Shortcut is defined in the following table.

<table>
<thead>
<tr>
<th>Shortcut</th>
<th>Sample</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>key</td>
<td>F1</td>
<td>Press the single key.</td>
</tr>
<tr>
<td>key+key</td>
<td>Ctrl+Shift+Enter</td>
<td><code>key</code> is the name of the key to press. The <code>+</code> character means that the keys must be pressed at the same time. The <code>+</code> key is not pressed.</td>
</tr>
<tr>
<td>key key</td>
<td>Ctrl+K Ctrl+S</td>
<td>The keys should be pressed in sequence, one after the other. Each key can be a combination of multiple keys that are pressed at the same time as explained above. Unless <code>Shift</code> is part of the key sequence, then lower case letters are being specified.</td>
</tr>
</tbody>
</table>

Shortcut Key Syntax
2.4.8 Running Commands

The commands accessible by shortcut keys or the menus can be found and run from the command popup dialog and are accessed in the editor by pressing the F1 key. Once the command popup is displayed you can search for commands by typing in text in the search line. The commands that match the search will be displayed along with the Shortcut Keys that are assigned to the commands. Select on the command to run it.

Running a Command

2.5 Running/Debugging the Post

The Autodesk Fusion 360 Post Processor Utility extension allows you to run the post processor that you are editing directly from the editor and to debug the post by matching the output lines in the NC file with the code line that generated the output. You can run the post against the provided intermediate files generated from the Benchmark Parts or you can create your own intermediate file to run the post against.

2.5.1 Autodesk Post Processor Commands

There are built-in commands that pertain to running the post processor. These commands are accessed by pressing the F1 key and typing HSM in the search field.

Displaying the Autodesk Post Processor Commands

The following table describes the available commands.
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post Utility</td>
<td>Displays a menu where you can post process the selected intermediate (CNC) file against the open post processor, select a new CNC file, or display the Autodesk Post Help window. You can also use the shortcut Ctrl+Alt+G to run the post processor.</td>
</tr>
<tr>
<td>Change post executable</td>
<td>Sets the location of the post processor engine executable.</td>
</tr>
<tr>
<td>Show debugged code</td>
<td>Displays the entry functions that are called and the line numbers that generated the block in the output NC file. This is the same output that is displayed when you call the setWriteStack(true) and setWriteInvocations(true) functions.</td>
</tr>
<tr>
<td>Delete CNC file</td>
<td>This command cannot be run from the Commands menu. Right clicking on a CNC file in the CNC Selection list and selecting Delete CNC File will delete the file and remove it from the list.</td>
</tr>
<tr>
<td>Disable auto line selection</td>
<td>Disables the feature of automatically displaying the line in the post processor that generated the selected line in the NC output file.</td>
</tr>
<tr>
<td>Download CNC exporting post processor</td>
<td>Downloads the Exporting Post Processor used for generating your own CNC files for testing.</td>
</tr>
<tr>
<td>Post help</td>
<td>Displays the online Autodesk CAM Post Processor Documentation web page.</td>
</tr>
</tbody>
</table>

The Autodesk Post Processor Commands

2.5.2 The Post Processor Properties

You can display the properties associated with the open post processor by opening the Explorer flyout and expanding the Post Properties list. Clicking on a property will prompt you to change the property. The symbol will be displayed next to the property if it has been changed from the default value.

If you add a new property to the post or for some reason the properties don’t display, you can press the yellow refresh symbol in the Post Properties header to refresh the displayed properties.
2.5.3 Running the Post Processor

To run the post processor that is open in the editor you can use the Ctrl+Alt+G shortcut or run the Post Utility from the Command window as described in the previous section. First you will need to select the intermediate CNC file to run the post against. You select the CNC file by opening the Explorer flyout and expanding the CNC Selector list until you find the desired CNC file.

Post the Selected CNC File Against the Active Post

You can also select the CNC file from the Post Utility menu.

Select the required command
Change CNC file
Post process
Help

Select the CNC File or Post Processor Using the Post Utility Command
If running a post processor for the first time in the editor it is possible that the location of the post engine executable (post.exe) is not known. In this case you will see the following message displayed.

You can press the Browse... button to search for post.exe. The executable will be in one of the following locations depending on the version of HSM being run.

<table>
<thead>
<tr>
<th>HSM Version</th>
<th>Post Executable Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusion 360</td>
<td>C:User\username\AppData\Local\Autodesk\webdeploy\production(id)\Applications\CAM360</td>
</tr>
<tr>
<td></td>
<td>\username is your username that you logged in as.  (id) is a unique and long name that</td>
</tr>
<tr>
<td></td>
<td>changes depending on the version of Fusion 360 that you have installed. You will usually</td>
</tr>
<tr>
<td></td>
<td>select the folder with the latest date.</td>
</tr>
<tr>
<td>Inventor</td>
<td>C:\Program Files\Autodesk\Inventor CAM yyyy</td>
</tr>
<tr>
<td></td>
<td>yyyy is the version number (year) of Inventor.</td>
</tr>
<tr>
<td>HSMWorks</td>
<td>C:\Program Files\HSMWorks</td>
</tr>
</tbody>
</table>

Once you have posted against the CNC file, the output NC file or Log file will be displayed in the right panel of the split screen. When the HSMPostUtility: Enable Auto Line Selection setting is true, then clicking twice on a line in the output NC file will highlight the line in the post processor that generated the output. The second click must be on a different character on the same output line to highlight the line. Then, by clicking on a different character in the same line you will be walked through the stack of functions that were called in the generation of the output.
2.5.4 Creating Your Own CNC Intermediate Files

The Autodesk Post Processor extension comes with built-in CNC intermediate files that are generated using the HSM Benchmark Parts. These can be used for testing most aspects of the post processor, but there are times when you will need to test specific scenarios. For these cases you can create your own CNC file to use as input.

The Export CNC file to Visual Studio Code post processor from the Fustion 360 Post Processor Library is used to create external CNC intermediate files that can be used from within the Visual Studio Code editor. You can download this post in the same manner as you download any post processor from within Fusion.

Follow the directions in the Downloading and Installing a Post Processor section for installing a post processor on your system.

Once the post processor is installed you will want to post process the operations you want to use for testing. The CNC exporting post processor is run just like any other Autodesk post processor, except it will not generate NC code, but will rather create a copy of the CNC file from the Autodesk CAM system in a folder within the CNC Selector. The CNC file will be stored in the Custom folder by default, but you can create your own private folder(s) by typing the custom folder name into the CNC output folder field when post processing.
Most posts use a number for the output file name, it is recommended that you give the CNC file a unique name that describes the operations that were used to generate it.

Once you click the yellow refresh button you should see the CNC file in the selected folder of the CNC Selector list and can use it when post processing from the VSC editor. If you decide that you no longer need a custom CNC intermediate file you can delete it by right clicking on the CNC file and select Delete CNC File.
3 JavaScript Overview

3.1 Overview

Autodesk post processors are written using the JavaScript language. It resembles the C, C++, and Java programming languages, is interpreted rather than being a compiled language, and is object-orientated. JavaScript as it is used for developing post processors is fairly simple to learn and understand, but still retains its complex nature for more advanced programmers.

This chapter covers the basics of the JavaScript language and conventions used by Autodesk post processors. There are many web sites that document the JavaScript language. The ELOQUENT JAVASCRIPT site has a nicely laid out format. If you prefer a hard copy JavaScript guide, then the JavaScript the Definitive Guide, Author: David Flanagan, Publisher: O’Reilly is recommended. Whichever manual you use, you will want to focus on the core syntax of JavaScript and ignore the browser and client-side aspects of the language.

The Autodesk post processor documentation is provided as the post.chm file with HSMWorks and Inventor CAM or you can visit the Autodesk CAM Post Processor Documentation web site. You will find that the post.chm version of the documentation is easier to view, since it has a working Index.

3.2 JavaScript Syntax

JavaScript is a case sensitive language, meaning that all functions, variables, and any other identifiers must always be typed exactly the same with regards to lower and uppercase letters.

```javascript
currentCoolant = 7;
currentCoolant = 8;
currentcoolant = 9;
```

*Case Sensitive Definition of 3 Different Variables*

JavaScript ignores spaces and new lines between variables, operators, names, and delimiting characters. Variable and function names cannot have spaces in them, as this would create separate entities. Commands can be continued onto multiple lines and are terminated with a semicolon (;) to mark the end of the logical command. If you are defining a string literal within quotes, then the literal should be defined on a single line and not on multiple lines. If a text string is too long for a single line, then it should be concatenated using an operation.

```javascript
message = "The 3 inch bore needs to be probed prior to starting " +
"the next operation.;"
```

*Breaking Up a Text String onto Multiple Lines*

There are two methods of defining comments in JavaScript. You can either enclose comments between the /* and */ characters, which will treat all text between these delimiters as a comment, or place the // characters prior to the comment text.
The /* comment */ format is typically used as the descriptive header of a function or to block out multiple lines of code. Any characters on the line that follow the // characters are treated as a comment, so you can have a single comment line or add a comment to the end of a JavaScript statement.

```javascript
/**
 * Output a comment.
 */
function writeComment(text) {
    writeln(formatComment(text)); // write out comment line
}
```

```javascript
switch (unit) {
    case IN:
        writeBlock(gUnitModal.format(20));
        break;
    case MM:
        writeBlock(gUnitModal.format(21));
        break;
}
```

Using indentation for function contents, if blocks, loops and continuation lines is recommended as this makes it easier to visualize the code. Tab characters, though supported by JavaScript, are discouraged from being used. It is preferred to use virtual tab stops of two spaces for indenting code in post processor code. Most editors, including the Autodesk Post Processor Editor can be setup to automatically convert tab characters to spaces that will align each indent at two spaces. Please refer to the Post Processor Editor chapter for an explanation on how to setup the Autodesk recommended editor.

```javascript
function test (input) {
    // indent 2 spaces inside of function
    if (input == 1) {
        writeBlock( // indent 2 more spaces in if block or loop
            gAbsIncModal.format(90), // indent 2 more spaces for continuation lines
            gMotionModal.format(0)
        );
    }
}
```

### 3.3 Variables

Variables are simply names associated with a value. The value can be a number, string, boolean, array, or object. Variables in JavaScript are untyped, meaning that they are defined by the value that they have assigned to them and the value type can change throughout the program. For example, you can assign a

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number to a variable and later in the program you can assign the same variable a string value. The `var` keyword is used to define a variable.

If a variable is not assigned a value, then it will be assigned the special value of `undefined`.

```javascript
var a; // define variable 'a', it will have the value of undefined
var b = 1; // assign a value of 1 to the variable 'b'
var c = "text"; // assign a text string to the variable 'c'
c = 2.5; // 'c' now contains a number instead of string
```

### Variable Definitions

While you can include multiple variable declarations on the same `var` line, this is against the standard used for post processors and is not recommended. You can also implicitly create a variable simply by assigning a value to the variable name without using the `var` keyword, but is also not recommended. When declaring a new variable, be sure to not use the same name as a JavaScript or Post Kernel keyword, for example do not name it `var`, `for`, `cycle`, `currentSection`, etc. Refer to the appropriate documentation for a list of keywords/variables allocated in JavaScript or the Post Kernel.

JavaScript supports both global variables and local variables. A global variable is defined outside the scope of a function, for example at the top of the file prior to defining any functions. Global variables are accessible to all functions within the program and will have the same value from function to function. Local variables are only accessible from within the function that they are defined. You can use the same name for local variables in multiple functions and they will each have their own unique value in the separate functions. Unlike the C and C++ languages, local variables defined within an if block or loop are accessible to the entire function and are not local to the block that they are defined in.

### 3.3.1 Numbers

Besides containing a standard numeric value, a variable assigned to a number creates a `Number` object. For this discussion, we will consider an object a variable with associated functions. These functions are specific to numbers and are listed in the following table.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>toExponential(digits)</code></td>
<td>Format a number using exponential notation</td>
<td>String representation of number</td>
</tr>
<tr>
<td><code>toFixed(digits)</code></td>
<td>Format a number with a fixed number of digits</td>
<td>String representation of number</td>
</tr>
<tr>
<td><code>toLocaleString()</code></td>
<td>Format a number according to locale conventions</td>
<td>String representation of number</td>
</tr>
<tr>
<td><code>toPrecision(digits)</code></td>
<td>Format a number using either a fixed number of digits or using exponential notation depending on value of number</td>
<td>String representation of number</td>
</tr>
<tr>
<td><code>toString()</code></td>
<td>Format a number</td>
<td>String representation of number</td>
</tr>
</tbody>
</table>

### Number Object Functions

```javascript
var a = 12.12345;
```
b = a.toExponential(2); // b = "1.21e+1"
b = a.toFixed(3);       // b = "12.123"
b = a.toString();       // b = "12.12345"

Sample Number Output

The JavaScript built-in Math object contains functions and constants that apply to numbers. The following table lists the Math functions and constants that are most likely to be used in a post processor. All Math functions return a value.

<table>
<thead>
<tr>
<th>Function</th>
<th>Return value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math.abs(x)</td>
<td>Absolute value of x</td>
</tr>
<tr>
<td>Math.acos(x)</td>
<td>Arc cosine of x in radians</td>
</tr>
<tr>
<td>Math.asin(x)</td>
<td>Arc sine of x in radians</td>
</tr>
<tr>
<td>Math.atan(x)</td>
<td>Arc tangent of x in radians</td>
</tr>
<tr>
<td>Math.atan2(y, x)</td>
<td>Counterclockwise angle between the positive X-axis and the point x,y in radians</td>
</tr>
<tr>
<td>Math.ceil(x)</td>
<td>Rounds up x to the next integer</td>
</tr>
<tr>
<td>Math.cos(x)</td>
<td>Cosine of x</td>
</tr>
<tr>
<td>Math.floor(x)</td>
<td>Rounds down x to the next integer</td>
</tr>
<tr>
<td>Math.max(args)</td>
<td>The maximum value of the input arguments</td>
</tr>
<tr>
<td>Math.min(args)</td>
<td>The minimum value of the input arguments</td>
</tr>
<tr>
<td>Math.PI</td>
<td>The value of PI, approximately 3.14159</td>
</tr>
<tr>
<td>Math.pow(x, y)</td>
<td>x raised to the power of y</td>
</tr>
<tr>
<td>Math.round(x)</td>
<td>Rounds x to the nearest integer</td>
</tr>
<tr>
<td>Math.sin(x)</td>
<td>Sine of x</td>
</tr>
<tr>
<td>Math.sqrt(x)</td>
<td>Square root of x</td>
</tr>
<tr>
<td>Math.tan(x)</td>
<td>Tangent of x</td>
</tr>
<tr>
<td>Math.NaN</td>
<td>The value corresponding to the not-a-number property</td>
</tr>
</tbody>
</table>

Math Object

a = Math.sqrt(4); // a = 2
a = Math.round(4.59); // a = 5
a = Math.floor(4.59); // a = 4
a = Math.PI; // a = 3.14159
a = Math.cos(toRad(45)); // a = .7071
a = toDeg(Math.acos(.866)); // a = 60

Sample Math Object Output

The Math trigonometric functions all work in radians. As a matter of fact, most functions that pass angles in the post processor work in radians. There are kernel supplied functions that are available for converting between radians and degrees. toDeg(x) returns the degree equivalent of the radian value x and conversely the toRad(x) function returns the radian equivalent of the degree value x.

There are also standalone numeric functions that are not part of the Number of Math objects. These are listed in the following table.
### 3.3.2 Strings

Variables assigned a text string will create a String object, which contain a full complement of functions that can be used to manipulate the string. These functions are specific to strings and are listed in the following table. The table details the basic usage of these functions as you would use them in a post processor. Some of the functions accept a RegExp object which is not covered in this manual, please refer to dedicated JavaScript manual for a description of this object.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>charAt(n)</td>
<td>Returns a single character at position n</td>
<td>The nth character</td>
</tr>
<tr>
<td>indexOf(substring, start)</td>
<td>Finds the substring within the string. start is optional and specifies the starting location within the string to start the search at.</td>
<td>The location of the first occurrence of substring within the string.</td>
</tr>
<tr>
<td>lastIndexOf(substring, start)</td>
<td>Finds the last occurrence of substring within the string. start is optional and specifies the starting location within the string to start the search at.</td>
<td>The location of the last occurrence of substring within the string.</td>
</tr>
<tr>
<td>length</td>
<td>Returns the length of the string. length is not a function, but rather a property of a string and does not use () in its syntax.</td>
<td>The length of the string</td>
</tr>
<tr>
<td>localeCompare(target)</td>
<td>Compares the string with target string.</td>
<td>A negative number if string is less than target, 0 if the strings are identical, and a positive number if string is greater than target</td>
</tr>
</tbody>
</table>

### JavaScript Overview

<table>
<thead>
<tr>
<th>Function</th>
<th>Return value</th>
</tr>
</thead>
<tbody>
<tr>
<td>parseFloat(value)</td>
<td>Parses value as a string argument and returns a real number. Returns NaN if the string does not represent a valid number.</td>
</tr>
<tr>
<td>parseInt(value, radix)</td>
<td>Parses value as a string argument and returns an integer of the specified radix. radix is typically defined as 10, but can be 2, 8, 16, etc. Returns NaN if the string does not represent a valid integer.</td>
</tr>
<tr>
<td>spatial(value, unit)</td>
<td>Returns value converted to MM. unit specifies the units that value is defined in and can be either MM or IN. The unit conversion scale used is 25mm to 1in and not 25.4. This conversion creates a more acceptable scaled value for display, for example 4in scales to 100mm instead of 101.6mm. The spatial function is typically used to define the Built-in properties at the top of the post processor, since they are referenced as MM in the post engine.</td>
</tr>
<tr>
<td>toPreciseUnit(value, unit)</td>
<td>Returns value converted to the output units. unit specifies the units that value is defined in and can be either MM or IN A scale factor of 25.4mm to 1in is used.</td>
</tr>
<tr>
<td>toUnit(value, unit)</td>
<td>Returns value converted to the output units. unit specifies the units that value is defined in and can be either MM or IN. The unit conversion scale used is 25mm to 1in and not 25.4.</td>
</tr>
</tbody>
</table>
### JavaScript Overview

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>replace(pattern, replacement)</td>
<td>Replaces the pattern text within the string with the replacement text.</td>
<td>The updated string.</td>
</tr>
<tr>
<td>slice(start, end)</td>
<td>Creates a substring from the string consisting of the start character up to, but not including the end character of the string.</td>
<td>A substring containing the text from string starting at start and ending at end-1. A negative value for start or end specifies a position from the end of the string; -1 is the last character, -2 is the second to last character, etc.</td>
</tr>
<tr>
<td>split(delimiter, limit)</td>
<td>Splits a string at each occurrence of the delimiter string.</td>
<td>An array of strings created by splitting string into substrings at the delimiter. A maximum of limit substrings will be created.</td>
</tr>
<tr>
<td>toLocaleLowerCase()</td>
<td>Converts the string to all lowercase letters in a locale-specific method.</td>
<td>Lowercase string.</td>
</tr>
<tr>
<td>toLocaleUpperCase()</td>
<td>Converts the string to all uppercase letters in a locale-specific method.</td>
<td>Uppercase string.</td>
</tr>
<tr>
<td>toLowerCase()</td>
<td>Converts the string to all lowercase letters.</td>
<td>Lowercase string.</td>
</tr>
<tr>
<td>toUpperCase()</td>
<td>Converts the string to all uppercase letters.</td>
<td>Uppercase string.</td>
</tr>
</tbody>
</table>

### String Object Functions

```javascript
var a = "First, Second, Third";
b = a.charAt(3);                          // b = "s"
b = a.indexOf("Second");           // b = 7
b = a.length;                                // b = 20
b = a.localeCompare("ABC"); // b = 5;
b = a.replace(/,/g, ".");               // b = "First- Second- Third"
b = a.slice(0, -7);                        // b = "First, Second"
b = a.toLowerCase();                // b = "first, second, third"
b = a.toUpperCase();                 // b = "FIRST, SECOND, THIRD"
```

### 3.3.3 Booleans

Booleans are the simplest of the variable types. They contain a value of either true or false, which are JavaScript keywords.

```javascript
var a = true; // 'a' is defined as a boolean
if (a) {
    // processes the code in this if block since 'a' is 'true'
}
```
3.3.4 Arrays

An array is a composite data type that stores values in consecutive order. Each value stored in the array is considered an element of the array and the position within an array is called an index. Each element of an array can be any variable type and each element can have a different variable type than the other elements in the array.

An array, like numbers and strings, are considered an object with functions associated with it. You can define an array using two different methods, as an empty array using a new Array object, or by creating an array literal with defined values for the array. You can specify the initial size of the array when defining an Array object. The initial size of an array defined with values is the number of values contained in the initialization.

```
var a = new Array();  // creates a blank array, all values are assigned undefined
var a = new Array(10); // creates a blank array with 10 elements
var a = [true, "a", 3.17];  // creates an array with the first 3 elements assigned
var a = [{x:1, y:2}, {x:3, y:4}, {x:5, y:6}];  // creates an array of 3 xy objects
```

**Array Definitions**

You can access an array element by using the [ ] brackets. The name of the array will appear to the left of the brackets and the index to the element within the array inside of the brackets. The index can be a simple number or an equation.

```
var a = [1, 2, "text", false];
b = a[0];        // b = 1
a[5] = "next";  // a = [1, 2, "text", false, "next"]
b = a[2+a[0]];  // b = false;
```

**Accessing Elements Within an Array**

The Array object has the following functions associated with it.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>concat(values)</td>
<td>Appends the values to an array.</td>
<td>Original array with concatenated elements</td>
</tr>
<tr>
<td>join(separator)</td>
<td>Combines all elements of an array into a string. separator is optional and specifies the string used to separate the elements of the array. The default is a comma.</td>
<td>String containing array elements.</td>
</tr>
<tr>
<td>length</td>
<td>Returns the allocated size of the array. length is not a function, but rather a property of an array and does not use () in its syntax.</td>
<td>The size of the array.</td>
</tr>
<tr>
<td>pop()</td>
<td>Pops the last element from the array and decreases the size of the array by 1.</td>
<td>The value of the last element of the array.</td>
</tr>
<tr>
<td>push(values)</td>
<td>Pushes the values onto the array and increases the size of the array by the number of values.</td>
<td>Updated size of array.</td>
</tr>
</tbody>
</table>
### JavaScript Overview

#### 3.3.5 Objects

An **Object** is similar to an array in that it stores multiple values within a single variable. The difference is that objects use a name for each sub-entity rather than relying on an index pointer into an array. The **properties** table in a post processor is an object. You can define an object using two different methods, explicitly using the **Object** keyword, or implicitly by creating an object literal with defined names and values.
values for the object. Each named entity within an object can be any type of variable, number, string, array, boolean, and another object. Objects can also be stored in an array.

Objects can be expanded to include additional named elements at any time and are not limited to the named elements when they are created. You can reference the elements within an object using either the name of the element (object.element) or by using a text string or variable (object["element"]) as the name of the element. The following examples all reference the moveTime element of the status object.

```javascript
var status = {moveDistance:0, moveTime:0, feedrate:0};
...
writeln("Move time = " + status.moveTime);
writeln("Move time = " + status["moveTime"]);
var element = "moveTime";
writeln("Move time = " + status[element]);
```

Referencing Elements Within an Object

```javascript
var a = new Object();                                     // creates a blank object, without named elements
var a = {x:1, y:2, z:3};                                  // creates an object for storing coordinates
a.feed = 10.0;                                                // adds the 'feed' element to the 'a' Object
a["feed"] = 10.0;                                           // an alternate method for referencing the 'feed' element.
var a = [{x:1, y:2}, {x:3, y:4}, {x:5, y:6}];  // creates an array of 3 xy objects
```

Object Definitions

3.3.6 The Vector Object

The Vector object is built-in to the post processor and is used to store and work with vectors. The vector components are stored in the x, y, z elements of the Vector object. Certain post processor variables are stored as vectors and some functions require vectors as input. A Vector object is created in the same manner as any other object. Vector objects are typically used to store and work on vectors, spatial points, and rotary angles.

```javascript
var a = new Vector();                                    // creates a blank Vector object
var a = new Vector(1, 0, 0);                          // creates an X-axis vector {x:1, y:0, z:0}
a.x = -1;                                                         // assigns -1 to the x element of the vector
setWorkPlane(new Vector(0, 0, 0));             // defines a null vector inline
```

Sample Vector Definitions

The following tables describe the attributes and functions contained in the Vector object. Since an attribute is simply a value contained in the Vector object, it does not have an argument.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>abs</td>
<td>Contains the absolute coordinates of the vector</td>
</tr>
<tr>
<td>length</td>
<td>Contains the length of the vector</td>
</tr>
</tbody>
</table>
### Attribute

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>length2</td>
<td>Contains the negated vector</td>
</tr>
<tr>
<td>negated</td>
<td>Contains the normalized/unit vector</td>
</tr>
<tr>
<td>normalized</td>
<td>Contains the X-component</td>
</tr>
<tr>
<td>x</td>
<td>Contains the Y component</td>
</tr>
<tr>
<td>y</td>
<td>Contains the Z component</td>
</tr>
</tbody>
</table>

### Vector Attributes

You can directly modify an attribute of a vector, but if you do then the remaining attributes will not be updated. For example, if you directly store a value in the \( x \) attribute, \( \text{vec}.x = .707 \), the \( \text{length} \) attribute of the vector will not be updated. You should use the \( \text{vec}.setX(.707) \) method instead.

If the \( \text{Returns} \) column in the following table has \( \text{Implicit} \), then there is no return value, rather the \( \text{Vector} \) object associated with the function is modified implicitly. For this reason, if you are going to nest a \( \text{Vector} \) function within an expression, do not use the \( \text{Implicit} \) function, but rather the equivalent function that returns a vector.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>divide(value)</td>
<td>Divides each component of the object vector by the value</td>
<td>Implicit</td>
</tr>
<tr>
<td>getCoordinate(coordinate)</td>
<td>Returns the value of the vector component ( (0=x, 1=y, 2=z) )</td>
<td>Component of vector</td>
</tr>
<tr>
<td>getMaximum()</td>
<td>Determines the largest component value in the vector</td>
<td>Maximum component value</td>
</tr>
<tr>
<td>getMinimum()</td>
<td>Determines the minimum component value in the vector</td>
<td>Minimum component value</td>
</tr>
<tr>
<td>getNegated()</td>
<td>Calculates the negated vector</td>
<td>Vector at 180 degrees to the object vector ((\text{vector} * -1))</td>
</tr>
<tr>
<td>getNormalized()</td>
<td>Calculates the normalized/unit vector</td>
<td>Normalized or unit vector</td>
</tr>
<tr>
<td>getX()</td>
<td>Returns the X-coordinate of the vector</td>
<td>X-coordinate</td>
</tr>
<tr>
<td>getXYAngle()</td>
<td>Calculates the angle of the vector in the XY-plane</td>
<td>Angle of vector in XY-plane</td>
</tr>
<tr>
<td>getY()</td>
<td>Returns the Y-coordinate of the vector</td>
<td>Y-coordinate</td>
</tr>
<tr>
<td>getZ()</td>
<td>Returns the Z-coordinate of the vector</td>
<td>Z-coordinate</td>
</tr>
<tr>
<td>getZAngle()</td>
<td>Calculates the Z-angle of the vector relative to the XY-plane</td>
<td>Z-angle of vector relative to the XY-plane</td>
</tr>
<tr>
<td>isZero()</td>
<td>Determines if the vector is a null vector ((0,0,0))</td>
<td>True if it is a null vector</td>
</tr>
<tr>
<td>multiply(value)</td>
<td>Multiplies each component of the vector by the value</td>
<td>Implicit</td>
</tr>
<tr>
<td>negate()</td>
<td>Multiplies each component of the vector by (-1). Creates a vector at 180 degrees to the object vector</td>
<td>Implicit</td>
</tr>
<tr>
<td>setCoordinate(coordinate, value)</td>
<td>Sets the value of the vector component ((0=x, 1=y, 2=z))</td>
<td>Implicit</td>
</tr>
<tr>
<td>setX()</td>
<td>Sets the X-coordinate of the vector</td>
<td>Implicit</td>
</tr>
<tr>
<td>setY()</td>
<td>Sets the Y-coordinate of the vector</td>
<td>Implicit</td>
</tr>
<tr>
<td>setZ()</td>
<td>Sets the Z-coordinate of the vector</td>
<td>Implicit</td>
</tr>
</tbody>
</table>
### Function Table

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>toDeg()</td>
<td>Converts radians to degrees</td>
<td>Angles in degrees</td>
</tr>
<tr>
<td>toRad()</td>
<td>Converts degrees to radians</td>
<td>Angles in radians</td>
</tr>
<tr>
<td>toString()</td>
<td>Formats the vector as a string, e.g. &quot;(1, 2, 3)&quot;</td>
<td>String representation of vector</td>
</tr>
</tbody>
</table>

### Vector Object Functions

Static functions do not require an associated Vector object.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vector.cross(left, right)</td>
<td>Calculates the cross product of two vectors</td>
<td>Vector perpendicular to the two vectors</td>
</tr>
<tr>
<td>Vector.diff(left, right)</td>
<td>Calculates the difference between two vectors</td>
<td>Left vector minus right vector</td>
</tr>
<tr>
<td>Vector.dot(left, right)</td>
<td>Calculates the dot product of the two vectors</td>
<td>Cosine of angle between the two vectors</td>
</tr>
<tr>
<td>Vector.getAbsolute()</td>
<td>Converts the vector components to absolute values</td>
<td>Vector with absolute coordinates</td>
</tr>
<tr>
<td>Vector.getAngle()</td>
<td>Calculates the angle between two vectors</td>
<td>Angle between the two vectors in radians</td>
</tr>
<tr>
<td>Vector.getDistance(left, right)</td>
<td>Calculates the distance between two vectors. Typically used when the vectors store XYZ spatial coordinates rather than vectors.</td>
<td>Distance between two points</td>
</tr>
<tr>
<td>Vector.getDistance2(left, right)</td>
<td>Calculates the square of the distance between two vectors.</td>
<td>Squared distance between two points.</td>
</tr>
<tr>
<td>Vector.lerp(left, right, u)</td>
<td>Calculates a point at a percentage of the distance between the two coordinates. 'u' specifies the percentage of the distance to create the point at.</td>
<td>Point at a percentage of the line between two points</td>
</tr>
<tr>
<td>Vector.product(vector, value)</td>
<td>Multiplies each component of the vector by the value</td>
<td>Vector * value</td>
</tr>
<tr>
<td>Vector.sum(left, right)</td>
<td>Adds the two vectors</td>
<td>Left vector plus right vector</td>
</tr>
</tbody>
</table>

### Static Vector Functions

```javascript
b = a.length();                            // b = length of Vector a
c = Vector.getAngle(a, b);                // c = angle in radians between vectors a and b
var a = new Vector(1, 2, 1.5);             // a
b = a.getMaximum();                        // d = 2
b = Vector.getDistance(point1, point2).normalized; // b = directional vector from point1 to point2
b = Vector.dot(vector1, vector2);         // b = cosine of angle between vector1 & vector2
b = a.negated;                            // b = vector at 180 degrees to Vector a
```

### Sample Vector Expressions

#### 3.3.7 The Matrix Object

The **Matrix** object is built-in to the post processor and is used to store and work with matrices. Matrices are normally used when working with multi-axis machines, for 3+2 operations and for adjusting the
coordinates for table rotations. Matrices in the post processor contain only the rotations for each axis and do not contain translation values.

Certain post processor variables are stored as matrices, such as the *workPlane* variable, and some functions require matrices as input. A *Matrix* object has functions that can be used when creating the matrix and are not dependent on working with an existing matrix.

<table>
<thead>
<tr>
<th>Assignment Function</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matrix()</td>
<td>Identity matrix (1,0,0, 0,1,0, 0,0,1)</td>
</tr>
<tr>
<td>Matrix(i1, j1, k1, i2, j2, k2, i3, j3, k3)</td>
<td>Canonical matrix</td>
</tr>
<tr>
<td>Matrix(scale)</td>
<td>Scale matrix</td>
</tr>
<tr>
<td>Matrix(right, up, forward)</td>
<td>Matrix using 3 vectors</td>
</tr>
<tr>
<td>Matrix(vector, angle)</td>
<td>Rotation matrix around the vector</td>
</tr>
</tbody>
</table>

**Matrix Assignment Functions**

```javascript
var a = new Matrix(); // creates an identity matrix
var a = new Vector(-1, 0, 0, -1,0, 0,0, 1); // creates a matrix rotated 180 degrees in the XY-plane
var a = new Matrix(.5); // creates a half scale matrix
var a = new Matrix(new Vector(1, 0, 0), 30); // creates an X-rotation matrix of 30 degrees
```

**Sample Matrix Definitions**

The following tables describe the attributes and functions contained in the *Matrix* object. Since an attribute is simply a value contained in the Matrix object, it does not have an argument.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>forward</td>
<td>Contains the forward vector</td>
</tr>
<tr>
<td>n1</td>
<td>Contains the length of the row vectors of this matrix</td>
</tr>
<tr>
<td>n2</td>
<td>Contains the square root of this matrix vector lengths</td>
</tr>
<tr>
<td>Negated</td>
<td>Contains the negated matrix</td>
</tr>
<tr>
<td>right</td>
<td>Contains the right vector</td>
</tr>
<tr>
<td>transposed</td>
<td>Contains the inverse matrix</td>
</tr>
<tr>
<td>up</td>
<td>Contains the up vector</td>
</tr>
</tbody>
</table>

**Matrix Attributes**

You can directly modify an attribute of a matrix, but if you do then the remaining attributes will not be updated. For example, if you directly store a vector in the *forward* attribute, the other attributes will not be updated to reflect this modification. You should use the *matrix.setForward(vector)* method instead.

If the Returns column in the following table has *Implicit*, then there is no return value, rather the *Matrix* object associated with the function is modified implicitly. For this reason, if you are going to nest a *Matrix* function within an expression, do not use the Implicit function, but rather the equivalent function that returns a matrix.
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>add(matrix)</td>
<td>Adds the specified matrix</td>
<td>Implicit</td>
</tr>
<tr>
<td>getColumn(column)</td>
<td>Retrieves the matrix column as a vector</td>
<td>Vector containing the specified column of this matrix</td>
</tr>
<tr>
<td>getElement(row, column)</td>
<td>Retrieves the matrix element as a value</td>
<td>Value of this matrix element</td>
</tr>
<tr>
<td>getEuler2(convention)</td>
<td>Calculates the angles for the specified Euler convention</td>
<td>Vector containing Euler angles of this matrix. Refer to the <em>Work Plane</em> section of the manual for a description of Euler conventions.</td>
</tr>
<tr>
<td>getForward()</td>
<td>Returns the forward vector. This will be 0,0,1 in an identity matrix</td>
<td>Forward vector of this matrix</td>
</tr>
<tr>
<td>getN1()</td>
<td>Returns the length of the row vectors of this matrix</td>
<td>Returns right_vector + up_vector + forward_vector of matrix</td>
</tr>
<tr>
<td>getN2()</td>
<td>Returns the square root of this matrix vector lengths</td>
<td>Math.sqrt(n1)</td>
</tr>
<tr>
<td>getNegated()</td>
<td>Calculates the negated matrix</td>
<td>Matrix * -1.</td>
</tr>
<tr>
<td>getRight()</td>
<td>Returns the right vector. This will be 1,0,0 in an identity matrix</td>
<td>Right vector of matrix</td>
</tr>
<tr>
<td>getRow(row)</td>
<td>Retrieves the matrix row as a vector</td>
<td>Vector containing the specified row of this matrix</td>
</tr>
<tr>
<td>getTiltAndTilt(first, second)</td>
<td>Calculates the X &amp; Y rotations around the fixed frame to match the forward direction. 'first' and 'second' can be 0 or 1 and must be different.</td>
<td>Calculated forward direction of this matrix</td>
</tr>
<tr>
<td>getTransposed()</td>
<td>Returns the transposed (inverse) of the matrix</td>
<td>Inversed matrix</td>
</tr>
<tr>
<td>getTurnAndTilt(first, second)</td>
<td>Calculates the X, Y, Z rotations around the fixed frame to match the forward direction. 'first' and 'second' can be 0, 1, or 2 and must be different.</td>
<td>Calculated forward direction</td>
</tr>
<tr>
<td>getUp()</td>
<td>Returns the up vector. This will be 0,1,0 in an identity matrix</td>
<td>Right vector of matrix</td>
</tr>
<tr>
<td>isIdentity()</td>
<td>Determines if the matrix is an identity matrix (1,0,0, 0,1,0, 0,0,1).</td>
<td>True if it is an identity matrix</td>
</tr>
<tr>
<td>isZero()</td>
<td>Determines if the matrix is a null matrix (0,0,0, 0,0,0, 0,0,0)</td>
<td>True if it is a null matrix</td>
</tr>
<tr>
<td>multiply(value)</td>
<td>Multiplies each component of the matrix by the value</td>
<td>Result of matrix times specified value</td>
</tr>
<tr>
<td>multiply(matrix)</td>
<td>Multiplies the matrix by the specified matrix</td>
<td>Results of matrix times specified matrix</td>
</tr>
<tr>
<td>multiply(vector)</td>
<td>Multiplies the specified vector by the matrix</td>
<td>Vector multiplied by the matrix</td>
</tr>
<tr>
<td>negate()</td>
<td>Calculates the negated matrix</td>
<td>Implicit</td>
</tr>
<tr>
<td>normalize()</td>
<td>Calculates the negated matrix</td>
<td>Implicit</td>
</tr>
<tr>
<td>setColumn(column, vector)</td>
<td>Sets the matrix column as a vector</td>
<td>Implicit</td>
</tr>
<tr>
<td>setElement(row, column, vector)</td>
<td>Sets the matrix element</td>
<td>Implicit</td>
</tr>
<tr>
<td>setForward(vector)</td>
<td>Sets the forward vector</td>
<td>Implicit</td>
</tr>
<tr>
<td>setRight(vector)</td>
<td>Sets the right vector</td>
<td>Implicit</td>
</tr>
</tbody>
</table>
## Function

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>setRow(row, vector)</td>
<td>Sets the matrix row as a vector</td>
<td>Implicit</td>
</tr>
<tr>
<td>setUp(vector)</td>
<td>Sets the up vector</td>
<td>Implicit</td>
</tr>
<tr>
<td>subtract(matrix)</td>
<td>Subtracts the specified matrix from this matrix</td>
<td>Implicit</td>
</tr>
<tr>
<td>toString()</td>
<td>Formats the matrix as a string, e.g. &quot;[[1, 0, 0], [0, 1, 0], [0, 0, 1]]&quot;</td>
<td>String representation of matrix</td>
</tr>
<tr>
<td>transpose()</td>
<td>Creates the transposed/inverse of this matrix</td>
<td>Implicit</td>
</tr>
</tbody>
</table>

### Matrix Functions

Static functions do not require an associated `Matrix` object.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>Matrix.diff(left, right)</code></td>
<td>Calculates the difference between two matrices</td>
<td>Left matrix minus right matrix</td>
</tr>
<tr>
<td><code>Matrix.GetAxisRotation(vector, angle)</code></td>
<td>Calculates a rotation matrix</td>
<td>Rotation matrix of 'angle' radians around the axis 'vector'</td>
</tr>
<tr>
<td><code>Matrix.getXRotation(angle)</code></td>
<td>Calculates a rotation matrix around the X-axis</td>
<td>Rotation matrix of 'angle' radians around the X-axis</td>
</tr>
<tr>
<td><code>Matrix.getYRotation(angle)</code></td>
<td>Calculates a rotation matrix around the Y-axis</td>
<td>Rotation matrix of 'angle' radians around the Y-axis</td>
</tr>
<tr>
<td><code>Matrix.getZRotation(angle)</code></td>
<td>Calculates a rotation matrix around the Z-axis</td>
<td>Rotation matrix of 'angle' radians around the Z-axis</td>
</tr>
<tr>
<td><code>Matrix.sum(left, right)</code></td>
<td>Adds the two matrices</td>
<td>Left matrix plus right matrix</td>
</tr>
</tbody>
</table>

### Static Matrix Functions

```javascript
var abc = m.getEuler2(EULER_ZXZ_R); // abc = ZXZ Euler angles for m
var t = m.getTransposed();          // t = inverse/transposed matrix of m
var fwd = m.getForward();           // fwd = forward (Z) vector of matrix m
var v = new Vector(0, 0, 1);        // v = new Vector(0, 0, 1);
var q = m.multiply(v);              // q = transformation of v though matrix m
var r = Matrix.getZRotation(toDeg(30)); // r = matrix rotated 30 degrees about Z
```

### Sample Matrix Expressions

#### 3.3.8 Deferred Variables

Deferred variables are used to output values to the NC file prior to them being defined. For example, you could calculate the cutting time or travel distance for each tool while processing the intermediate file and then reference these values in the tool list that is output at the header of the NC file. This is accomplished by defining the deferred variables during the normal processing of the intermediate file and using the deferred variables in an output string at a place that is processed prior to the processing of the section of the intermediate file that defines the deferred variables.
The way that deferred variables work is by using text substitution in the output NC file. The initial text string output to the NC file will include the name of the deferred variable enclosed by the defined separator for defined variables, for example ##id##. After all processing is finished, the post engine will scan the output NC file for the deferred variable text and replace it with the value stored in the deferred variable. It is important to know this procedure, since deferred variables cannot be accessed before they are defined in the post processor, the same as any other variable, except for when they are output to the NC file.

Deferred variables are stored in the DeferredVariables object, which has the following properties. The deferred variable properties are referenced as DeferredVariables.property.

<table>
<thead>
<tr>
<th>DeferredVariables Property/Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>separator</td>
<td>Defines the prefix and suffix that will be added to the deferred variable name when the deferred variable is initially output to the NC file. This should be a unique string that is not normally seen in the NC file. The default is &quot;##&quot;.</td>
</tr>
<tr>
<td>get(id, format)</td>
<td>Retrieves the deferred variable named id and formats it for output using the provided format as created by createFormat.</td>
</tr>
<tr>
<td>set(id, value)</td>
<td>Assigns value to the deferred variable named id. value must be numeric, it cannot be a text string, boolean, or an object.</td>
</tr>
<tr>
<td>isDefined(id)</td>
<td>Returns true if the deferred variable named id has been defined or false if it has not. Remember that the deferred variable is defined during the normal processing of the intermediate file, so if you call isDefined where the deferred variable is being output prior to processing the deferred variable definition, it will return false.</td>
</tr>
</tbody>
</table>

The following sample code will calculate the cutting time for each tool for linear, circular, and canned cycle moves. It will output these times in the tool list located in the header of the NC file.

```javascript
// collected state
var toolTime = new Array();  // define an array to store the tool cutting times.

Define the Tool Times Array

function onOpen() {
    DeferredVariables.separator = "^&^";  // define a unique marker for deferred variables
    ...
    var tools = getToolTable();
    if (tools.getNumberOfTools() > 0) {
        for (var i = 0; i < tools.getNumberOfTools(); ++i) {
            var tool = tools.getTool(i);
            var comment = "T" + toolFormat.format(tool.number) + " " +
```

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"D" + xyzFormat.format(tool.diameter) + " " + localize("CR") + "=" + xyzFormat.format(tool.cornerRadius);
if ((tool.taperAngle > 0) && (tool.taperAngle < Math.PI)) {
    comment += " " + localize("TAPER") + "=" + taperFormat.format(tool.taperAngle) + localize("deg");
}
if (zRanges[tool.number]) {
    comment += " - " + localize("ZMIN") + "=" + xyzFormat.format(zRanges[tool.number].getMinimum());
}
comment += " - " + localize("TIME") + "=" + DeferredVariables.get("tool" + tool.number, xyzFormat); // Output cutting time for tool
comment += " - " + getToolTypeName(tool.type);
writeComment(comment);
}

function onSection() {
    
    writeToolBlock("T" + toolFormat.format(tool.number), mFormat.format(6));
    if (tool.comment) {
        writeComment(tool.comment);
    }
    // initialize the cutting time if not previously defined
}

function moveIsCutting() {
    return movement == MOVEMENT_CUTTING || movement == MOVEMENT_FINISH_CUTTING || movement == MOVEMENT_REDUCED;
}

function onCyclePoint(x, y, z) {
    
    // calculate the canned cycle cutting time
    if (!cycleExpanded) {
    }
}

function onLinear(_x, _y, _z, feed) {


// calculate linear cutting time
if (moveIsCutting()) {
    toolTime[tool.number] += Vector.diff(new Vector(_x, _y, _z), getCurrentPosition()).length / feed;
}

Calculate Linear Moves Cutting Time in onLinear

function onCircular (clockwise, cx, cy, cz, x, y, z, feed) {
    ...
    // calculate circular cutting time
    // be sure to return directly after any calls to linearize or time will be calculated twice
    if (moveIsCutting()) {
        toolTime[tool.number] += getCircularChordLength() / feed;
    }
}

Calculate Circular Moves Cutting Time in onCircular

function onSectionEnd() {
    DeferredVariables.set("tool" + tool.number, toolTime[tool.number]);
    Assign the Tool Cutting Time to the Deferred Variable

3.4 Expressions

Variables can be assigned a simple value or text string or can be more complex in nature containing a list of variables or literals and operators that perform operations on the values contained in the expression. The following table lists the common operators supported by JavaScript and provides samples using the operators. The operator precedence is also listed (column P), where the operators with a higher precedence number are performed prior to the operators of a lower precedence number. Operators with the same precedence number will calculate in the order that they appear in the expression.

Unary operators only require a single operand instead of two. For example, \( y = x++ \) will increment the variable \( x \) after it is assigned to the variable \( y \).

<table>
<thead>
<tr>
<th>P</th>
<th>Operator</th>
<th>Operands</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>()</td>
<td>Expression</td>
<td>Overrides the assigned precedence of operators</td>
</tr>
<tr>
<td>12</td>
<td>++</td>
<td>Integer</td>
<td>Unary increment</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>Integer</td>
<td>Unary decrement</td>
</tr>
<tr>
<td></td>
<td>~</td>
<td>Integer</td>
<td>Unary bitwise complement</td>
</tr>
<tr>
<td></td>
<td>!</td>
<td>Boolean</td>
<td>Unary logical complement (not)</td>
</tr>
<tr>
<td>11</td>
<td>*</td>
<td>Number</td>
<td>Multiplication</td>
</tr>
<tr>
<td></td>
<td>/</td>
<td>Number</td>
<td>Division</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>Number</td>
<td>Remainder</td>
</tr>
<tr>
<td>10</td>
<td>+</td>
<td>Number, String</td>
<td>Addition</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Number</td>
<td>Subtraction</td>
</tr>
</tbody>
</table>
### Expression Operators

<table>
<thead>
<tr>
<th>P</th>
<th>Operator</th>
<th>Operands</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>&lt;&lt;</td>
<td>Integer</td>
<td>Bitwise shift left</td>
</tr>
<tr>
<td></td>
<td>&gt;&gt;</td>
<td>Integer</td>
<td>Bitwise shift right</td>
</tr>
<tr>
<td>8</td>
<td>&lt;</td>
<td>Number, String</td>
<td>Less than</td>
</tr>
<tr>
<td></td>
<td>&lt;=</td>
<td>Number, String</td>
<td>Less than or equal to</td>
</tr>
<tr>
<td></td>
<td>&gt;</td>
<td>Number, String</td>
<td>Greater than</td>
</tr>
<tr>
<td></td>
<td>=&gt;</td>
<td>Number, String</td>
<td>Greater than or equal to</td>
</tr>
<tr>
<td>7</td>
<td>==</td>
<td>Any</td>
<td>Equal to</td>
</tr>
<tr>
<td></td>
<td>!=</td>
<td>Any</td>
<td>Not equal to</td>
</tr>
<tr>
<td></td>
<td>===</td>
<td>Any</td>
<td>Equal to and same variable type</td>
</tr>
<tr>
<td></td>
<td>!==</td>
<td>Any</td>
<td>Not equal to and same variable type</td>
</tr>
<tr>
<td>6</td>
<td>&amp;</td>
<td>Integer</td>
<td>Bitwise AND</td>
</tr>
<tr>
<td>5</td>
<td>^</td>
<td>Integer</td>
<td>Bitwise XOR</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>Integer</td>
</tr>
<tr>
<td>3</td>
<td>&amp;&amp;</td>
<td>Boolean</td>
<td>Logical AND</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>=</td>
<td>Any</td>
<td>Assignment</td>
</tr>
<tr>
<td></td>
<td>+=</td>
<td>Number, String</td>
<td>Assignment with addition</td>
</tr>
<tr>
<td></td>
<td>-=</td>
<td>Number</td>
<td>Assignment with subtraction</td>
</tr>
<tr>
<td></td>
<td>*=</td>
<td>Number</td>
<td>Assignment with multiplication</td>
</tr>
<tr>
<td></td>
<td>/=</td>
<td>Number</td>
<td>Assignment with division</td>
</tr>
</tbody>
</table>

### Sample Expressions

<table>
<thead>
<tr>
<th>x</th>
<th>y</th>
<th>Expression</th>
<th>Result</th>
<th>Expression</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5</td>
<td>z = x + y * 3</td>
<td>18</td>
<td>z = (x + y) * 3</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>z = ++x</td>
<td></td>
<td>z = x++</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>x += y</td>
<td>8</td>
<td>x *= y</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>z = y / x</td>
<td>1.667</td>
<td>z = y % x</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>&quot;Start&quot;</td>
<td>z = x + y</td>
<td></td>
<td>&quot;Start-End&quot;</td>
<td>x += y</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>z = x &amp; y</td>
<td>2</td>
<td>z = x</td>
<td>y</td>
</tr>
<tr>
<td>1</td>
<td>&quot;1&quot;</td>
<td>z = x == y</td>
<td>true</td>
<td>x === y</td>
<td>false</td>
</tr>
<tr>
<td>true</td>
<td>false</td>
<td>z = x</td>
<td></td>
<td>y</td>
<td>true</td>
</tr>
</tbody>
</table>

### 3.5 Conditional Statements

Conditional statements are commands or functions that will test the results of an expression and then process statements based on the outcome of the conditional. Conditionals typically check Boolean type expressions, but can also be used to test if a value is `undefined` or a string is blank.

This section describes the conditional statements and functions used when developing a post processor. Some of the conditionals are supported by JavaScript and others are inherent in the post processor kernel.
3.5.1 The if Statement

The if statement is the most common method for testing a conditional and executing statements based on the outcome of the test. It can contain a single body of statements to execute when the expression is true, a second body of statements to execute when the expression is false, or it can contain multiple conditionals that are checked in order using the else if construct.

As with all commands that affect a body of code, if statements can be nested inside of other if bodies and loops.

The syntax of if statements should follow the Autodesk standard of always including the {} brackets around each body of code, specifying the opening bracket ({) on the conditional line, and the closing bracket (}) at the start of the line following the body of code for each section as shown in the following examples.

```javascript
if (conditional1) {
    // execute code if conditional1 is true
}

if (conditional1) {
    // execute code if conditional1 is true
} else {
    // execute code if conditional1 is false
}

if (conditional1) {
    // execute code if conditional1 is true
} else if (conditional2) {
    // execute code if conditional1 is false and conditional2 is true
} else {
    // execute code if all conditionals are false
}
```

If Statement Syntax

```javascript
if (hasParameter("operation-comment")) {
    comment = getParameter("operation-comment");
}

if (isProbeOperation()) {
    var workOffset = probeOutputWorkOffset ? probeOutputWorkOffset : currentWorkOffset;
    if (workOffset > 99) {
        error(localize("Work offset is out of range."));
        return;
    } else if (workOffset > 6) {
        probeWorkOffsetCode = probe100Format.format(workOffset - 6 + 100);
    }
```
3.5.2 The switch Statement

The *switch* statement is similar to an *if* statement in that it causes a branch in the flow of a program's execution based on the outcome of a conditional. *switch* statements are typically used when checking the value of a single variable, whereas *if* conditionals can test complex expressions.

The syntax of *switch* bodies will contain a single *switch* statement with a variable whose value determines the code to be executed. *case* statements will be included in the *switch* body, with each one containing the value that causes its body of code to be executed. The end of each *case* body of code must have a *break* statement so that the next *case* body of code is not executed. A *default* statement can be defined that contains code that will be executed if the *switch* variable does not match any of the *case* values.

*case* statements should follow the Autodesk standard of always including specifying the opening bracket ({) on the *switch* line, and the closing bracket (}) at the start of the line at the end of the body of code for each section. The *case* statements will be aligned with the *switch* statement and all code within each *case* body will be indented.

```javascript
switch (variable) {
    case value1:
        // execute if variable = value1
        break;
    case value2:
        // execute if variable = value2
    case value3:
        // execute if variable = value3
    default:
        // execute if variable does not equal value1, value2, or value3
        break;
}
```

**Switch Block Syntax**

```javascript
switch (coolant) {
    case COOLANT_FLOOD:
        m = 8;
        break;
    case COOLANT_THROUGH_TOOL:
```
m = 88;
break;
case COOLANT_AIR:
  m = 51;
  break;
default:
  onUnsupportedCoolant(coolant);
}
}

### 3.5.3 The Conditional Operator (?)

The `?` conditional operator tests an expression and returns different values based on whether the expression is true or false. It is a compact version of a simple `if` block and is used in an assignment type statement or as part of an expression.

```javascript
var a = conditional ? true_value : false_value;
```

In the above syntax, `a` will be assigned `true_value` if the conditional is true, or `false_value` if it is false.

```javascript
homeGcode = getProperty("useG30") ? 30 : 28;
// could be expanded into this if block
if (getProperty("useG30")) {
  homeGcode = 30;
} else {
  homeGcode = 28;
}
```

### 3.5.4 The typeof Operator

The `typeof` operator is not a conditional operator per the general terminology, but it is always used as a part of a conditional to determine if a function or variable exists. When used in an expression it will return a string that describes the variable type of the operand. This is the only way to test if a function exists prior to calling the function or if a variable exists before referencing it. If you try to reference a non-existent variable or function without testing to see if it exists first, the post processor will terminate with an error.

The `typeof` operator is followed by a single operand name, i.e. "typeof variable". It can return the following string values:

<table>
<thead>
<tr>
<th>Operand Type</th>
<th>Return Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>&quot;number&quot;</td>
</tr>
<tr>
<td>Operand Type</td>
<td>Return Values</td>
</tr>
<tr>
<td>------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>string</td>
<td>&quot;string&quot;</td>
</tr>
<tr>
<td>boolean</td>
<td>&quot;boolean&quot;</td>
</tr>
<tr>
<td>object, array, null</td>
<td>&quot;object&quot;</td>
</tr>
<tr>
<td>function</td>
<td>&quot;function&quot;</td>
</tr>
<tr>
<td>undefined</td>
<td>&quot;undefined&quot;</td>
</tr>
</tbody>
</table>

**typeof Return Values**

```javascript
if ((typeof getHeaderVersion == "function") && getHeaderVersion()) {
    writeComment(localize("post version") + ": " + getHeaderVersion());
}
```

**Sample typeof Usage**

### 3.5.5 The conditional Function

The `conditional` function will test an expression and if it is true will return the specified value. If the expression is false, then a blank string is returned. The `conditional` function is mainly used for determining if a specific code should be output in a block.

```javascript
conditional(expression, true_value)
```

**conditional Syntax**

```javascript
writeBlock(
    gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(82),
    getCommonCycle(x, y, z, cycle.retract),
    conditional(P > 0, "P" + milliFormat.format(P)), //optional
    feedOutput.format(F)
);
```

**conditional Usage**

Since `conditional` is a function, any function calls contained in the arguments will be processed even if the expression equates to false. This means that if a modal is used to format a value, the value will be formatted prior to evaluating the expression and the modal’s current value will be set using this value, even if the value is not output.

```javascript
writeBlock(conditional(isRapid, gMotionModal.format(0)), x, y, z);
```

*Sets the gMotionModal Modal Value to 0 Even when isRapid is false and G00 is not Output*

### 3.5.6 try / catch

The `try/catch` block is an exception handling mechanism. This allows the post processor to control the outcome of an exception. Depending on the exception that is encountered, the JavaScript code could continue processing or terminate with an error. The `try/catch` block is used to override the normal processing of exceptions in JavaScript.
```
try {
    // code that may generate an exception
} catch (e) {
    // e is a local variable that contains the exception object or value that was thrown
    // code to perform if an exception is encountered
}
```

**Try/Catch Syntax**

```
try {
    programId = getInt(programName);
} catch(e) {
    error(localize("Program name must be a number."));
    return;
}
```

**Try/Catch Usage**

### 3.5.7 The validate Function

The `validate` function tests an expression and raises an exception if the expression is false. The post processor will typically output an error if an exception is raised, so in essence, the `validate` function determines if an expression is true or false and outputs an error using the provided message if it is false.

```
validate(expression, error_message)
```

**Validate Syntax**

```
validate(retracted, "Cannot cancel length compensation if the machine is not fully retracted.");
```

**Sample Validate Code**

In the above sample, an error will be generated if `retracted` is set to false.

### 3.5.8 Comparing Real Values

Real values are stored as binary numbers and are not truncated as you see them in an output file, so there are times when the numbers are not equal even if they show as the same value in the output file. For this reason, it is recommended that you either use a tolerance or truncate them when comparing their values. The `format.getResultingValue` function can be used to truncate a number to a fixed number of decimal places.

```
var a = 3.141592654;
var b = 3.141593174;

// simple comparison
if (a == b) {  // false

// comparison using a tolerance
var toler = .0001;
if (Math.abs(a – b) <= toler) {  // true
```

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3.6 Looping Statements

Loops perform repetitive actions. There are various styles of looping statements; `for`, `for/in`, `while`, and `do/while`. You should choose the looping statement that lends itself to the style of loop you are coding.

The syntax of looping statements should follow the Autodesk standard of always including the `{ }` brackets around each body of code, specifying the opening bracket `(` on the looping statement, and the closing bracket `)` at the start of the line following the body of code for the loop. Loops can be nested within other bodies of code, like conditionals or other loops.

3.6.1 The for Loop

The `for` loop is the most common of the looping statements. It includes a counter and an expression on when to end the loop, so it will loop through the body of the loop a fixed number of times, unless interrupted by the `break` command. The `counter variable` is initialized before the loop starts and is tested when the `expression` is evaluated before each iteration of the loop. The `counter variable` is incremented at the end of the loop, just before the `expression` is evaluated again.

Multiple counters can be initialized and incremented in a for loop by separating the counters with a comma (,).

```javascript
for(initialize_counter; test expression ; increment_counter) {
   // body of loop
}
```

### for Loop Syntax

```javascript
for (var i = 0; i < getNumberOfSections(); ++i) { // loop for the number of sections in intermediate file
   if (getSection(i).workOffset > 0) {
      error(localize("Using multiple work offsets is not possible if the initial work offset is 0.");
      return;
   }
}
```

```javascript
for (i = 0, j = ary.length - 1 ; i < ary.length / 2; ++i, --j) { // reverse the order of an array
   var tl = ary[i];
   ary[i] = ary[j];
   ary[j] = tl;
}
```

### Sample for Loops
3.6.2 The for/in Loop

The `for/in` loop allows you to traverse the properties of an *object*. It is not commonly used in post processors (except for the dump.cps post processor), but can be useful for debugging the property names and values in an *object*.

```javascript
for(variable in object) {
    // body of loop
}
```

**for/in Loop Syntax**

```javascript
for(var element in properties) { // write out the property table
    writeln("properties." + element + " = " + properties[element]);
}
```

**Sample for/in Loop**

3.6.3 The while Loop

The `while` loop evaluates an expression and will execute the body of the loop when the expression is true and will end the loop when the expression is false. Since the expression is tested at the top of the loop, the body of code in the loop will not be executed when the expression is initially set to false.

```javascript
while (expression) {
    // body of loop
}
```

**while Loop Syntax**

```javascript
while (c > 2*Math.PI) {
    c -= 2 * Math.PI;
}
```

**Sample while Loop**

3.6.4 The do/while Loop

The `do/while` loop is pretty much the same as the while loop, but the expression is tested at the end of the loop rather than at the start of the loop. This means that the loop will be executed at least once, even if the expression is initially set to false.

```javascript
do {
    // body of loop
} while (expression)
```

**do/while Loop Syntax**
var i = 0;
var found = false;
do {
    if (mtype[i++] == "Start") {
        found = true;
    }
} while (!found && i < mtype.length);

Sample do/while Loop

3.6.5 The break Statement
The break statement is used to interrupt a loop or switch statement prematurely. When the break statement is encountered during a loop or switch body, then the innermost loop/switch will be ended and control will move to the first statement outside of the loop/switch.

break is pretty much mandatory with switch statements. For loops, break can be used to get out of the loop when an error is encountered, or when a defined pattern is found within an array.

```
for (i = 0; i < mtype.length; ++i) {
    if (mtype[i] == "Start") {
        break; // exits the loop
    }
}
```

Sample Usage of break Command

3.6.6 The continue Statement
The continue statement is used to bypass the remainder of the loop body and restarts the loop at the next iteration.

```
for (i = 0; i < mtype.length; ++i) {
    if (mtype[i] < 0) {
        continue; // skips this iteration of the loop and continues with the next iteration
    }
    ...
}
```

Sample Usage of break Command

3.7 Functions
Functions in JavaScript behave in the same manner as functions in other high-level programming languages. In a post processor all code, except for the global settings at the top of the file, is contained in functions, either entry functions (onOpen, onSection, etc.) or helper functions (writeBlock, setWorkPlane, etc.). The code in a function will not be processed until that function is called from within another routine (for the sake of clarity the calling function will be referred to as a ’routine’ in this
JavaScript Overview

Here are the main reasons for placing code in a separate function rather than programming it in the upper level routine that calls the function.

1. The same code is executed in different areas of the code, either from the same function or in multiple functions. Placing the common code in its own function eliminates duplicate code from the file, making it easier to understand and maintain.

2. To logically separate logic and make it easier to understand. Separating code into its own function can keep the calling routine from becoming too large and harder to follow, even if the function is only called one time.

3.7.1 The function Statement

A function consists of the function statement, a list of arguments, the body of the function (JavaScript code), and optional return statement(s).

```javascript
function name([arg1 [,arg2 […, argn]]]) {
    …
    code
    …
}
```

**function Statement Syntax**

The argument list is optional and contains identifiers that are passed into the function by the calling routine. The arguments passed to the function are considered read-only as far as the calling routine is concerned, meaning that any changes to these variables will be kept local to the called function and not propagated to the calling routine. You use the `return` statement to return value(s) to the calling routine.

```javascript
function writeComment(text) {
    writeln(formatComment(text)); // text is accepted as an argument and passed to formatComment
}
```

**Sample function Definition**

Arguments accepted by a function can either be named identifiers as shown in the previous example, or you can use the `arguments` array to reference the function arguments. The `arguments` array is built-in to JavaScript and is treated as any other `Array` object, meaning that it has the length property and access to the `Array` attributes and functions.

```javascript
transferType = parseChoice(getProperty("transferType"),"PHASE","SPEED","STOP");
...
function parseChoice() {
    for (var i = 1; i < arguments.length; ++i) {
        if (String(arguments[0]).toUpperCase() == String(arguments[i]).toUpperCase()) {
            return i - 1;
        }
    }
}
```

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3.7.2 Calling a function

A function call is treated the same as any other expression. It can be standalone, assign a value, and be placed anywhere within an expression. The value returned by the called function is treated as any other variable. You simply type the name of the function with its arguments.

```javascript
setWorkPlane(abc); // function does not return a value
seqno = formatSequenceNumber(); // function returns a value
circumference = getRadius(circle) * 2.0 * Math.PI; // function used in a regular expression
```

3.7.3 The return Statement

As you can see in the previous sections, a function can be treated the same as any other expression and all expressions have values. The *return* statement is used to provide a value back to the calling routine. You will recall that a function does not have to return a value, in this case you do not have to place a return statement in the function, the function will automatically return when the end of the function body is reached. You can place a *return* statement anywhere within the function, the function will be ended whenever a *return* statement is reached.

```javascript
return [expression]
```

**return Statement Syntax**

The return value can be any valid variable type; a number, string, object, or array. If you want to return multiple values from a function, then you must return either an object or an array. You can also propagate the JavaScript *this* object which will be automatically returned to the calling routine when the end of the function is reached or when processing a return statement without an expression. If the *this* object is used, then the function will be used to create a new object and you will need to define the function call as if you were creating any other type of object as shown in the following example.

```javascript
function writeComment(text) {
    writeln(formatComment(text));
} // implicit return

function parseChoice() {
    for (var i = 1; i < arguments.length; ++i) {
        if (String(arguments[0]).toUpperCase() == String(arguments[i]).toUpperCase()) {
            return i - 1; // return the matching choice
        }
    }
}
```
4 Post Processor Settings

Many of Autodesk’s post processors contain common content that is shared between post processors. When a post processor uses common content, you will see the `settings` variable defined in the global section, just after the output variable definitions. These settings control the behavior of the post processor and can be modified to match the requirements of your machine.

```javascript
var settings = {
  coolant: { …
  smoothing: { …
  retract: { …
  parametricFeeds: { …
  unwind: { …
  machineAngles: { …
  workPlaneMethod: { …
  subprograms: { …
  comments: { …
  probing: { …
}
```

The settings are defined in the post processor and usually do not require changing from the interface like Post Properties do, though logic can be added that will modify a setting based on a Post Property as shown in the following sample code.

```javascript
// setup usage of useTiltedWorkplane
settings.workPlaneMethod.useTiltedWorkplane =
getProperty("useTiltedWorkplane") !== undefined ?
getProperty("useTiltedWorkplane");

getSetting("workPlaneMethod.useTiltedWorkplane", false);
```

useTiltedWorkplane Property Can Override workPlaneMethod.useTiltedWorkPlane Setting
### 4.1 Coolant Settings

```json
coolant: {
  // samples:
  // {id: COOLANT_THROUGH_TOOL, on: 88, off: 89}
  // {id: COOLANT_THROUGH_TOOL, on: [8, 88], off: [9, 89]}
  // {id: COOLANT_THROUGH_TOOL, on: "M88 P3 (myComment)", off: "M89"}
  coolants: [
    {id: COOLANT_FLOOD, on: 8},
    {id: COOLANT_MIST},
    {id: COOLANT_THROUGH_TOOL, on: 88, off: 89},
    {id: COOLANT_AIR},
    {id: COOLANT_AIR_THROUGH_TOOL},
    {id: COOLANT_SUCTION},
    {id: COOLANT_FLOOD_MIST},
    {id: COOLANT_FLOOD_THROUGH_TOOL, on: [8, 88], off: [9, 89]},
    {id: COOLANT_OFF, off: 9}
  ],
  singleLineCoolant: false
}
```

<table>
<thead>
<tr>
<th>Coolant Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>coolants</td>
<td>Each entry in the coolants array contains an id and optional on and off code(s). If an on code is not defined for a coolant id, then this coolant is not supported by the post processor and an error will be output if it is used in an operation.</td>
</tr>
<tr>
<td>id</td>
<td>Each coolant type is defined in the id field. All coolant types should be defined here and not removed from this array.</td>
</tr>
<tr>
<td>on</td>
<td>Defines the code(s) that turn on the associated coolant type. A single code (8) or multiple codes ([8, 88]) can be defined. If a number is specified, then this will be output as an M-code (M08). You can also specify a text string that will be output as defined (&quot;M08 (Coolant flood)&quot;).</td>
</tr>
<tr>
<td>off</td>
<td>Defines the code(s) that turn off the associated coolant type. The same rules for defining the on coolant code(s) apply to the off coolant code(s). If an on code is defined and an off code is not defined, then the code defined for COOLANT_OFF is used.</td>
</tr>
<tr>
<td>singleLineCoolant</td>
<td>When enabled, multiple coolant codes will be output in a single block (M08 M88). Disabling this setting will output each coolant code in a separate block.</td>
</tr>
</tbody>
</table>
The coolant settings define the supported coolant modes and associate on/off codes as well as the output style (single/multiple line) for the coolant codes.

4.2 Smoothing Settings

<table>
<thead>
<tr>
<th>Smoothing Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>roughing</td>
<td>The smoothing level for roughing operations when smoothing is in automatic mode.</td>
</tr>
<tr>
<td>semi</td>
<td>The smoothing level for semi-roughing operations when smoothing is in automatic mode.</td>
</tr>
<tr>
<td>semifinishing</td>
<td>The smoothing level for semi-finishing operations when smoothing is in automatic mode.</td>
</tr>
<tr>
<td>finishing</td>
<td>The smoothing level for finishing operations when smoothing is in automatic mode.</td>
</tr>
<tr>
<td>thresholdRoughing</td>
<td>The threshold value used to determine if an operation is a roughing operation when in automatic mode. Operations with stock-to-leave or machining tolerance above this threshold will be considered a roughing operation.</td>
</tr>
<tr>
<td>thresholdFinishing</td>
<td>The threshold value used to determine if an operation is a finishing operation when in automatic mode. Operations with stock-to-leave or a machining tolerance below this threshold will be considered a finishing operation.</td>
</tr>
<tr>
<td>thresholdSemiFinishing</td>
<td>The threshold value used to determine if an operation is a semi-finishing operation when in automatic mode. Operations with stock-to-leave or a machining tolerance above the finishing threshold and below this threshold will be considered a semi-finishing operation.</td>
</tr>
<tr>
<td>differenceCriteria</td>
<td>Criteria used to determine when the smoothing mode changes. Specify “level” when the level is output in the smoothing block (G187 P2), “tolerance” when the tolerance is output in the...</td>
</tr>
</tbody>
</table>
### Post Processor Settings

#### 4.2.1 Smoothing Properties

The `useSmoothing` Post Property must also be defined. It allows you to choose between disabling smoothing, enabling smoothing in automatic mode, or enabling smoothing at a specific level for each operation.

```javascript
// define the useSmoothing property
useSmoothing: {
  title : "Use G187",
  description: "G187 smoothing mode.",
  group : "preferences",
  type : "enum",
  values : [
    {title:"Off", id:"-1"},
    {title:"Automatic", id:"9999"},
    {title:"Rough", id:"1"},
    {title:"Medium", id:"2"},
    {title:"Finish", id:"3"}
  ],
  value: "-1",
  scope: "post"
}
```

Define the useSmoothing Post Property

#### 4.2.2 Implementing Smoothing Control in Your Post Processor

If smoothing is supported, then the `setSmoothing` function must be defined in the post processor, which outputs the smoothing codes to the NC file.

```javascript
function setSmoothing(mode) {
```

Post Processor Settings 4-78

### Definitions

<table>
<thead>
<tr>
<th>Smoothing Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>smoothing block (G187 E0.2), or &quot;both&quot; when both the level and tolerance are output (G187 P2 E0.2).</td>
</tr>
<tr>
<td>autoLevelCriteria</td>
<td>The method used to determine the smoothing level when automatic mode is active. &quot;level&quot; uses the stock-to-leave setting for the operation and &quot;tolerance&quot; uses the machining tolerance.</td>
</tr>
<tr>
<td>cancelCompensation</td>
<td>Set to true if the tool length compensation needs to be canceled prior to changing the smoothing level.</td>
</tr>
</tbody>
</table>
if (mode == smoothing.isActive && (!mode || !smoothing.isDifferent) && !smoothing.force) {
    return; // return if smoothing is already active or is not different
}
if (typeof lengthCompensationActive != "undefined" && smoothingSettings.cancelCompensation) {
    validate(!lengthCompensationActive, "Length compensation is active while trying to update smoothing.");
}
if (mode) { // enable smoothing
    writeBlock(
        gFormat.format(187),
        "P" + smoothing.level,
        conditional((smoothingSettings.differenceCriteria != "level"), "E" +
            xyzFormat.format(smoothing.tolerance))
    );
} else { // disable smoothing
    writeBlock(gFormat.format(187));
}
smoothing.isActive = mode;
smoothing.force = false;
smoothing.isDifferent = false;
}

setSmoothing Function

A call to initializeSmoothing must be made in onSection to define the smoothing control and level for the current operation. A call to setSmoothing must also be added in the proper location in the onSection function.

function onSection() {
    ...
    initializeSmoothing(); // initialize smoothing mode
    ...
    setSmoothing(smoothing.isAllowed); // writes the required smoothing codes
}

4.3 Retract Settings

retract: {
    cancelRotationOnRetracting: false,
    methodXY: undefined,
    methodZ: undefined,
    useZeroValues: ["G28", "G30"]
}

<table>
<thead>
<tr>
<th>Retract Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cancelRotationOnRetraction</td>
<td>Set to true if a control supported rotation (G68) must be canceled prior to moving to the home</td>
</tr>
<tr>
<td>Retract Setting</td>
<td>Description</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>methodXY</td>
<td>Allows you to override the move to the home position method for X &amp; Y moves. It can be set to <code>undefined</code> to use the default method or to any supported method, such as &quot;G28&quot;, &quot;G53&quot;, etc. The supported methods are defined using the <code>safePositionMethod</code> Post Property.</td>
</tr>
<tr>
<td>methodZ</td>
<td>Allows you to override the move to the home position method for Z moves. It accepts the same values as the <code>methodXY</code> setting.</td>
</tr>
<tr>
<td>useZeroValues</td>
<td>An array containing the safe positioning methods that require a value of 0 for the axis instead of using the home position for that axis, such as &quot;G28&quot;, &quot;G30&quot;, etc. These safe positioning moves are typically made in incremental mode (G91).</td>
</tr>
</tbody>
</table>

### 4.3.1 Safe Positioning Properties

The `retract` settings work in conjunction with the `safePositionMethod` property that defines the default method to use when positioning to the home position of each axis. If the `safePositionMethod` property is not defined, then you must enter a value for the `methodXY` and `methodZ` settings.

```javascript
// define the method to use when positioning to the safe/home position
safePositionMethod: {
  title : "Safe Retracts",
  description: "Select your desired retract option",
  group : "homePositions",
  type : "enum",
  values : [
    {title:"G28", id:"G28"},
    {title:"G53", id:"G53"},
    {title:"Clearance Height", id:"clearanceHeight"}
  ],
  value: "G53",
  scope: "post"
}
```

**The safePositionMethod Post Property**

#### 4.4 Parametric Feeds Settings

```javascript
parametricFeeds: {
  firstFeedParameter : 500,
  feedAssignmentVariable: ":#",
  feedOutputVariable : "F#"
}
```

*Post Processor Settings 4-80*
### Parametric Feed Output

Parametric feeds will define parameters for the feedrates representing each movement type at the beginning of an operation. The feedrates for the cutting moves will then reference these parameters on the motion blocks.

N60 G00 X3.1496 Y-0.9596  
N65 G43 Z0.5906 H01  
N70 #500=39.4 (CUTTING)  
N75 #502=39.4 (FINISH)  
N80 #503=39.4 (ENTRY)  
N85 G00 Z0.1969  
N90 G01 Z-0.0394 F#503  
N95 X-3.1496 F#502  
N100 G02 Y0.0374 J0.4985 F#500  
N105 G01 X3.1496 F#502

### 4.4.1 Parametric Feed Properties

The parametric feed settings work in conjunction with the `useParametricFeed` property that is used to enable and disable parametric feeds.

```json
// Enable/disable parametric feeds
useParametricFeed: {  
  title : "Parametric feed",  
  description: "Output parametric feed values based on movement type.",
  group : "preferences",
  type : "boolean",
  value : false,
  scope : "post"
}
```

### 4.5 Unwind Settings

```json
unwind: {  
  method : 2,
  codes : [gFormat.format(92)],
}
```
```javascript
workOffsetCode: "",
useAngle : "true",
anglePrefix   : []
resetG90      : false
```

<table>
<thead>
<tr>
<th>Unwind Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>method</strong></td>
<td>A value of 1 states that the rotary axis reset block will cause machine movement to the closest iteration of 0 degrees (G28). The rotary movement is handled by the control and not by the post processor. A value of 2 states that the rotary axis reset block will define the rotary axis position between 0 and 360 degrees without moving the table (G92).</td>
</tr>
<tr>
<td><strong>codes</strong></td>
<td>Enter the formatted code(s) or text string(s) that define this as a rotary axis reset command, such as <code>[gFormat.format(92)]</code> or <code>[gAbsIncModal(91), gFormat.format(28)]</code>.</td>
</tr>
<tr>
<td><strong>workOffsetCode</strong></td>
<td>Enter a prefix for the active work offset if it needs to be output on the rotary axis reset command. If a prefix is not defined (&quot;&quot;) then the work offset will not be output.</td>
</tr>
<tr>
<td><strong>useAngle</strong></td>
<td>Specifying &quot;true&quot; will output the calculated angle within 0 and 360 degrees using the standard output variable for this rotary axis. &quot;false&quot; does not output the rotary axis angle. Specifying &quot;prefix&quot; will output the calculated angle using the prefix specified by the <code>anglePrefix</code> setting instead of the normal prefix associated with the rotary axis.</td>
</tr>
<tr>
<td><strong>anglePrefix</strong></td>
<td>Defines an array of three text strings that contain the prefix(es) for each of the internal rotary axes (A, B, C). It is only used if &quot;prefix&quot; is specified for the <code>useAngle</code> setting. A blank string should be used for rotary axes that do not require a rewind. For example, [&quot;&quot;, &quot;&quot;, &quot;C1=&quot;&quot;]</td>
</tr>
</tbody>
</table>
The rotary axis will be repositioned within the 0-360 degree range with minimum or no movement depending on the method defined, instead of unwinding the axis the total number of degrees of its current value.

| G00 C13200 |
| G92 C240 (Reposition C-axis to within 0-360 degrees with no movement) |
| G91 G28 C0 (Reposition C-axis to 0 degrees. It will move 120 degrees to get to C0) |

Repositioning the C-axis to within 0-360 degrees

### 4.6 machineAngles Settings

```json
machineAngles: {
  controllingAxis: ABC,
  type : PREFER_PREFERENCE,
  options : ENABLE_ALL
}
```

<table>
<thead>
<tr>
<th>machineAngles Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>controllingAxis</td>
<td>The axis used to determine the preferred solution in conjunction with the type argument. It can be A, B, or C for a single axis, or ABC to consider all defined rotary axes.</td>
</tr>
<tr>
<td>type</td>
<td>The preference type as defined in the getABCByPreference command. It can be PREFER_PREFERENCE, PREFER_CLOSEST, PREFER_POSITIVE, PREFER_NEGATIVE, PREFER_CW, or PREFER_CCW.</td>
</tr>
<tr>
<td>options</td>
<td>Options used to control the solution as defined in the getABCByPreference command. It can be ENABLE_NONE, ENABLE_RESET, ENABLE_WCS, or ENABLE_ALL.</td>
</tr>
</tbody>
</table>

The `machineAngles` settings directly correlate to the parameters supported by the `getABCByPreference` command.

### 4.7 workPlaneMethod Settings

```json
workPlaneMethod: {
  useTiltedWorkplane : true,
  eulerConvention : EULER_ZXZ_R,
  eulerCalculationMethod: "standard",
  cancelTiltFirst : true,
  useABCPrepositioning : false,
  forceMultiAxisIndexing: false,
  prepositionWithTWP : false,
  optimizeType : undefined
}
```

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<table>
<thead>
<tr>
<th>workPlaneMethod Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>useTiltedWorkplane</td>
<td>Set to true if the control supports a tilted work plane block for 3+2 operations. Examples of tilted work planes are G68.2, G254, PLANE SPATIAL, CYCLE800, etc.</td>
</tr>
<tr>
<td></td>
<td>Set to false if the rotary axes position should be used for 3+2 operations. When disabled, the remaining workPlaneMethod settings, except for optimizeType, are not used.</td>
</tr>
<tr>
<td>eulerConvention</td>
<td>Specifies the Euler angle calculation method for tilted work planes as defined in the getEuler2 command. For example, EULER_ZXZ_R, EULER_XYZ_S, etc.</td>
</tr>
<tr>
<td></td>
<td>Set to undefined if the control uses the rotary axes position to define the tilted plane instead of Euler angles, such as Haas controls.</td>
</tr>
<tr>
<td>eulerCalculationMethod</td>
<td>Set to &quot;standard&quot; if a straight Euler angle calculation should be made.</td>
</tr>
<tr>
<td></td>
<td>Set to &quot;machine&quot; if the Euler calculation should take into consideration the calculated machine rotary angles for the 3+2 operation. &quot;machine&quot; will closely match the Euler angles to the rotary axis angles when the Euler convention used matches the rotary axis kinematics, for example EULER_ZXZ_R on a machine with AC-style rotaries, where the A-axis revolves around X and the C-axis around Z.</td>
</tr>
<tr>
<td>cancelTiltFirst</td>
<td>Set to true if the tilted work plane should be canceled prior to a WCS (G54, G59.1, etc.) change.</td>
</tr>
<tr>
<td>useABCPrepositioning</td>
<td>Set to true if the rotary axis angles should be output prior to the tilted work plane block. Set to false to use only the tilted work plane block for 3+2 operations.</td>
</tr>
<tr>
<td>forceMultiAxisIndexing</td>
<td>Set to true to output tilted work plane blocks on programs that are 3-axis in nature, without any 3+2 or multi-axis operations. This setting may be ignored by some post processors if a tilted work plane block for a 3-axis operation is not supported, for example the Fanuc control.</td>
</tr>
</tbody>
</table>
### workPlaneMethod Setting

<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>prepositionWithTWP</td>
<td>Set to <code>true</code> to use a tilted work plane to position the tool at the beginning of a multi-axis operation when TCP is supported. The first XY move of a multi-axis operation is typically output prior to enabling TCP, but HSM provides the TCP position to the post processor, so this position will be in the wrong coordinate system. Enabling this setting will cause the post to calculate the proper tilted work plane and position for this first move so that the machine positions above the entry point in XY as expected. If this setting is set to <code>false</code> and TCP is supported for this machine, then it is expected that the first move will be made with TCP enabled, otherwise the output position will not be correct.</td>
</tr>
<tr>
<td>optimizeType</td>
<td>Enter the method used to adjust the output coordinates for a 3+2 operation when a tilted work plane block is not supported by the machine (<code>useTiltedWorkplane = false</code>). This value matches the <code>optimizeType</code> parameter in the <code>optimize3DPositionsByMachine</code> and can be <code>OPTIMIZE_NONE</code>, <code>OPTIMIZE_BOTH</code>, <code>OPTIMIZE_TABLES</code>, <code>OPTIMIZE_HEADS</code>, or <code>OPTIMIZE_AXIS</code> (preferred method). Set to <code>undefined</code> to use a rotation matrix to adjust the output coordinates. This setting should only be used with a rotary table configuration that has the origin defined to be at the center of the rotary axes.</td>
</tr>
</tbody>
</table>

The `workPlaneMethod` settings control how 3+2 operations are output, including support for a tilted work plane block and how the coordinates are adjusted. The `getWorkPlaneMachineABC` and `setWorkPlane` functions use these settings, along with multi-axis prepositioning.

### 4.7.1 Work Plane Properties

The `useTiltedWorkplane` and `useABCPrepositioning` settings can be overridden by the `useTiltedWorkplane` and `useABCPrepositioning` post properties respectively if defined in the post processor.

```java
// enable/disable tilted work plane blocks
useTiltedWorkPlane: {
    title: "Use G68.2",
```
description: "Enable to output G68.2 blocks for 3+2 operations.
group : "multiAxis",
scope : ["machine", "post"],
type : "boolean",
value : false
}

// Preposition rotaries prior to tilted work plane block
useABCPrepositioning: {
title : "Preposition rotaries",
description: "Enable to preposition rotary axes prior to G68.2.",
group : "multiAxis",
scope : ["machine", "post"],
type : "boolean",
value : true
}

4.8 subprogram Settings

subprograms: {
  initialSubprogramNumber: undefined,
  minimumCyclePoints     : 5,
  format                 : oFormat,
  startBlock             : {files:["%"], embedded:["O"]}
  endBlock               : {files:["%"], embedded:[mFormat.format(99)]},
  callBlock              : {files:[mFormat.format(98) + " P"],
    embedded:[mFormat.format(98) + " P"]}
}

<table>
<thead>
<tr>
<th>subprogram Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>initialSubProgramNumber</td>
<td>Specifies the base number used for subprograms. The first subprogram output will be labeled this number plus one. If undefined is specified, then the main program number is used.</td>
</tr>
<tr>
<td>minimumCyclePoints</td>
<td>Specifies the minimum number of points in a cycle operation that will be considered for creating a subprogram. Cycle subprograms are used when multiple operations (center-drill, drill, tap) are performed on a large number of holes.</td>
</tr>
<tr>
<td>format</td>
<td>The formatNumber used to format the subprogram number. This formatNumber should be created without a prefix as this will be added by the startBlock setting.</td>
</tr>
<tr>
<td>files:{extension, prefix}</td>
<td>The extension parameter defines the file extension when subprograms are saved into external files. Setting it to undefined will use the same file extension as the main program file.</td>
</tr>
<tr>
<td>subprogram Setting</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>prefix</td>
<td><em>prefix</em> is added to the beginning number of the subprogram number to create the filename for external subprogram files. Set <em>prefix</em> to <em>undefined</em> to not have a subprogram filename prefix.</td>
</tr>
<tr>
<td>startBlock:{files, embedded}</td>
<td>The <em>files</em> parameter defines the code(s) that will be output at the start of a subprogram when subprograms are written to external files. The <em>embedded</em> parameter defines the prefix for the subprogram number when subprograms are contained in the same file as the main program. The subprogram number will be output whether external files are used or not.</td>
</tr>
<tr>
<td>endBlock:{files, embedded}</td>
<td>The <em>files</em> parameter defines the code(s) that will be output at the end of a subprogram when subprograms are written to external files. The <em>embedded</em> parameter defines the code(s) output at the end of a subprogram when subprograms are contained in the same file as the main program.</td>
</tr>
<tr>
<td>callBlock:{files, embedded}</td>
<td>The <em>files</em> parameter defines the code(s) that will be output to call a subprogram when subprograms are written to external files. The <em>embedded</em> parameter defines the code(s) to call a subprogram when subprograms are contained in the same file as the main program. The subprogram number will be added to the call block.</td>
</tr>
</tbody>
</table>

### 4.8.1 Subprogram Name Place Holder

The following subprogram settings will output the subprogram number in the output string generated from the setting.

- files.prefix
- startBlock.files
- startBlock.embedded
- endBlock.files
- endBlock.embedded
- callBlock.files
- callBloc.embedded

The subprogram number will either be appended to the end of the generated string or it can be placed anywhere in the string by using the %currentSubprogram placeholder within the string.

```plaintext
startBlock: {files:”; %_N_” + %currentSubprogram + ”_SPF”, embedded:”LABEL” + ”%currentSubprogram” + “.”}
```
// generates the following output for embedded subprograms
LABEL1001:

Using the %currentSubprogram Placeholder

4.8.2 Subprogram Properties
Subprograms can be output for every operation, patterned operations, and/or cycle operations. The output of subprograms is controlled by the useSubroutines post property, which must be defined to support subprograms. This property is usually defined with the common subprogram support functions defined later in this chapter.

```javascript
properties.useSubroutines = {
  title : "Use subroutines",
  description: "Select your desired subroutine option.
  group : "preferences",
  type : "enum",
  values : [
    {title:"No", id:"none"},
    {title:"All Operations", id:"allOperations"},
    {title:"All Operations & Patterns", id:"allPatterns"},
    {title:"Cycles", id:"cycles"},
    {title:"Operations, Patterns, Cycles", id:"all"},
    {title:"Patterns", id:"patterns"}
  ],
  value: "none",
  scope: "post"
};
```

useSubroutines Post Property

The useFilesForSubprograms post property can be defined if external subprogram files are supported.

```javascript
properties.useFilesForSubprograms = {
  title : "Use files for subroutines",
  description: "Subroutines will be saved as individual files.",
  group : "preferences",
  type : "boolean",
  value : false,
  scope : "post"
};
```

useFilesForSubprograms Post Property

4.8.3 Implementing Subprograms in your Post Processor
To implement subprograms in your Post Processor you will need to define the subprogram settings, include the subprogram support functions, and add some specific calls to the post. The subprogram settings are already described in this chapter.
The subprogram support functions and properties can be included into your post by copying the following code from another post that already supports subprograms, such as the fanuc.cps post processor.

```
// >>>>> INCLUDED FROM include_files/subprograms.cpi
...
// <<<<< INCLUDED FROM include_files/subprograms.cpi
```

Implementing Subprogram Functions and Properties by Copying Code

The following modifications to your post will now need to be made to fully support subprograms. In `onSection` add the following codes at the end of the function.

```
function onSection() {
  ...
  if (subprogramsAreSupported()) {
    subprogramDefine(initialPosition, abc); // define subprogram
  }
}
```

Add this Code to the End of onSection

In `onCycleEnd` add the following code where the canned cycle is cancelled.

```
function onCycleEnd() {
  ...
  if (subprogramsAreSupported() && subprogramState.cycleSubprogramIsActive) {
    subprogramEnd();
  }
  if (!cycleExpanded) {
    writeBlock(gCycleModal.format(80));
    zOutput.reset();
  }
}
```

Add this Code to the onCycleEnd

Add the following code to the end of `onSectionEnd`.

```
function onSectionEnd() {
  ...
  if (subprogramsAreSupported()) {
    subprogramEnd();
  }
}
```

Add this Code to the End of onSectionEnd

And finally add the following code to the end of the `onClose` function.
```javascript
function onClose() {
    ...
    if (subprogramsAreSupported()) {
        writeSubprograms();
    }
    writeln("%");
}

Add this Code to the End of onClose

4.9 Optional Settings

<table>
<thead>
<tr>
<th>Optional Setting</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximumSequenceNumber</td>
<td>undefined</td>
<td>Defines the maximum sequence number allowed. When the maximum sequence number is reached, the post will start again with the beginning sequence number. If this setting is set to <code>undefined</code>, then sequence numbers are unlimited.</td>
</tr>
<tr>
<td>supportsToolVectorOutput</td>
<td>false</td>
<td>Set to <code>true</code> to output tool axis vectors with multi-axis moves when the machine configuration does not contain any rotary axes. By default, an error will be output if a multi-axis operation is used with a machine configuration without a rotary axis.</td>
</tr>
<tr>
<td>supportsRadiusCompensation</td>
<td>true</td>
<td>Disable this setting if the controller does not support tool radius compensation (G41/G42). The post will output an error if tool radius compensation is enabled.</td>
</tr>
<tr>
<td>supportsOptionalBlocks</td>
<td>true</td>
<td>Determines if optional blocks (/) are supported by the controller. An error will be output if an optional block/section is programmed and not supported.</td>
</tr>
<tr>
<td>supportsInverseTimeFeed</td>
<td>true</td>
<td>Set to <code>false</code> if the controller does not support inverse time feedrates. In this case, the post will output an error if the machine configuration sets inverse time feedrate output for multi-axis moves.</td>
</tr>
</tbody>
</table>
```
<table>
<thead>
<tr>
<th>Optional Settings</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>supportsTCP</td>
<td>true</td>
<td>When disabled, the post will output an error if the machine configuration enables TCP on any rotary axis.</td>
</tr>
<tr>
<td>outputToolLengthCompensation</td>
<td>true</td>
<td>When enabled, the tool length compensation code (G43) will be output to the NC file. The tool length compensation code is defined in the <code>getOffsetCode</code> function. Set to <code>false</code> to not output the tool length compensation code.</td>
</tr>
<tr>
<td>outputToolLengthOffset</td>
<td>true</td>
<td>When enabled, the tool length offset code (Hxx) will be output to the NC file. The tool length offset code is output using the <code>hFormat</code> format, which must be defined if this setting is enabled. Set to <code>false</code> to not output the tool length offset code.</td>
</tr>
<tr>
<td>outputToolDiameterOffset</td>
<td>true</td>
<td>When enabled, the tool diameter offset code (Dxx) will be output to the NC file when tool radius compensation is enabled for an operation. The tool diameter offset code is output using the <code>diameterOffsetFormat</code> format, which must be defined if this setting is enabled. Set to <code>false</code> to not output the tool diameter offset code.</td>
</tr>
<tr>
<td>maximumSpindleRPM</td>
<td>99999</td>
<td>Defines the maximum spindle speed when an external Machine Definition is not associated with the CAM Setup or the machine configuration maximum spindle speed is set to 0. A warning will be output if a programmed spindle speed exceeds this value.</td>
</tr>
<tr>
<td>maximumToolNumber</td>
<td>99999</td>
<td>Defines the maximum tool number when an external Machine Definition is not associated with the CAM Setup or the machine configuration maximum number of tools is set to 0. A warning will be output if a programmed tool number exceeds this value.</td>
</tr>
<tr>
<td>maximumToolLengthOffset</td>
<td>99999</td>
<td>Defines the maximum tool length offset value. A warning will be output if a programmed tool length offset exceeds this value.</td>
</tr>
<tr>
<td>maximumToolDiameterOffset</td>
<td>99999</td>
<td>Defines the maximum tool diameter offset value. A warning will be output if a programmed tool diameter offset exceeds this value.</td>
</tr>
</tbody>
</table>

Optional settings do not need to be defined in the post processor and will take on their corresponding default value if they are not defined. The `getSetting` function is used to return the value for an optional setting, either returning its defined value or its default value if it is not defined.

```javascript
var hOffset = getSetting("outputToolLengthOffset", true) ? hFormat.format(tool.lengthOffset) : "";
```

Calling `getSetting` to Get the Value of an Optional Setting
5 Entry Functions

The post processor Entry functions are the interface between the kernel and the post processor. An Entry function will be called for each record in the intermediate file. Which Entry function is called is determined by the intermediate file record type. All Entry functions have the ‘on’ prefix, so it is recommended that you do not use this prefix with any functions that you add to the post processor.

Here is a list of the supported Entry functions and when they are called. The following sections in this Chapter provide more detailed documentation for the most common of the Entry functions.

<table>
<thead>
<tr>
<th>Entry Function</th>
<th>Invoked When …</th>
</tr>
</thead>
<tbody>
<tr>
<td>onCircular(clockwise, cx, cy, cz, x, y, z, feed)</td>
<td>Circular move</td>
</tr>
<tr>
<td>onClose()</td>
<td>End of post processing</td>
</tr>
<tr>
<td>onCommand(value)</td>
<td>Manual NC command not handled in its own function</td>
</tr>
<tr>
<td>onComment(string)</td>
<td>Comment Manual NC command</td>
</tr>
<tr>
<td>onCycle()</td>
<td>Start of a cycle</td>
</tr>
<tr>
<td>onCycleEnd()</td>
<td>End of a cycle</td>
</tr>
<tr>
<td>onCyclePoint(x, y, z)</td>
<td>Each cycle point</td>
</tr>
<tr>
<td>onDwell(value)</td>
<td>Dwell Manual NC command</td>
</tr>
<tr>
<td>onLinear(x, y, z, feed)</td>
<td>3-axis cutting move</td>
</tr>
<tr>
<td>onLinear5D(x, y, z, a, b, c, feed)</td>
<td>5-axis cutting move</td>
</tr>
<tr>
<td>onMachine()</td>
<td>Machine configuration changes</td>
</tr>
<tr>
<td>onManualNC()</td>
<td>Manual NC commands</td>
</tr>
<tr>
<td>onMovement(value)</td>
<td>Movement type changes</td>
</tr>
<tr>
<td>onMoveToSafeRetractPosition()</td>
<td>Move to a safe position at a retract/reconfiguration</td>
</tr>
<tr>
<td>onOpen()</td>
<td>Post processor initialization</td>
</tr>
<tr>
<td>onOrientateSpindle(value)</td>
<td>Spindle orientation is requested</td>
</tr>
<tr>
<td>onParameter(string, value)</td>
<td>Each parameter setting</td>
</tr>
<tr>
<td>onPassThrough(string)</td>
<td>Pass through Manual NC command</td>
</tr>
<tr>
<td>onPower(boolean)</td>
<td>Power mode for water/plasma/laser changes</td>
</tr>
<tr>
<td>onRadiusCompensation()</td>
<td>Radius compensation mode changes</td>
</tr>
<tr>
<td>onRapid(x, y, z)</td>
<td>3-axis Rapid move</td>
</tr>
<tr>
<td>onRapid5D(x, y, z, a, b, c)</td>
<td>5-axis Rapid move</td>
</tr>
<tr>
<td>onReturnFromSafeRetractPosition</td>
<td>Reposition after a retract/reconfiguration</td>
</tr>
<tr>
<td>onRewindMachineEntry()</td>
<td>Rotary axes limits are exceeded</td>
</tr>
<tr>
<td>onRotateAxes(x, y, z, a, b, c)</td>
<td>Reposition the rotary axes at a retract/reconfiguration</td>
</tr>
<tr>
<td>onSection()</td>
<td>Start of an operation</td>
</tr>
</tbody>
</table>
### Entry Functions

<table>
<thead>
<tr>
<th>Entry Function</th>
<th>Invoked When …</th>
</tr>
</thead>
<tbody>
<tr>
<td>onSectionEnd()</td>
<td>End of an operation</td>
</tr>
<tr>
<td>onSectionEndSpecialCycle()</td>
<td>End of a special cycle operation</td>
</tr>
<tr>
<td>onSectionSpecialCycle()</td>
<td>Start of a special cycle operation</td>
</tr>
<tr>
<td></td>
<td>(Stock Transfer)</td>
</tr>
<tr>
<td>onSpindleSpeed(value)</td>
<td>Spindle speed changes</td>
</tr>
<tr>
<td>onTerminate()</td>
<td>Post processing has completed, output files are closed</td>
</tr>
<tr>
<td>onToolCompensation(value)</td>
<td>Tool compensation mode changes</td>
</tr>
</tbody>
</table>

#### 5.1 Global Section

The global section is not an Entry function, but rather is called when the post processor is first initialized. It defines settings used by the post processor kernel, the property table displayed with the post processor dialog inside of HSM, definitions for formatting output codes, and global variables used by the post processor.

While the global section is typically located at the top of the post processor, any variables defined outside of a function are in the global section and accessible by all functions, even the functions defined before the variable. You may notice global variables being defined in the middle of the post processor code just before a function. This allows for a group of functions to be easily cut-and-pasted from one post to another post, including the required global variables.

#### 5.1.1 Kernel Settings

Some of the variables defined in the global section are actually defined in and used by the post engine. These variables are usually at the very top of the file and are easily discerned, since they are not preceded by `var`. The following table provides a description of the kernel settings that you will find in most post processors.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>allowedCircularPlanes</td>
<td>Defines the allowed circular planes. This setting is described in the <code>onCircular</code> section.</td>
</tr>
<tr>
<td>allowFeedPerRevolutionDrilling</td>
<td>Set to true if the post processor supports feed-per-revolution (FPR) feed rates in drilling cycles. This setting is described in the <code>onCyclePoint</code> section.</td>
</tr>
<tr>
<td>allowHelicalMoves</td>
<td>Specifies whether helical moves are allowed. This setting is described in the <code>onCircular</code> section.</td>
</tr>
<tr>
<td>allowSpiralMoves</td>
<td>Specifies whether spiral moves are allowed. This setting is described in the <code>onCircular</code> section.</td>
</tr>
<tr>
<td>capabilities</td>
<td>Defines the capabilities of the post processor. The capabilities can be CAPABILITY_MILLING, CAPABILITY_TURNING,</td>
</tr>
<tr>
<td></td>
<td>CAPABILITY_JET, CAPABILITY_SETUP_SHEET, CAPABILITY_INTERMEDIATE, and</td>
</tr>
<tr>
<td>Setting</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CAPABILITY_MACHINE_SIMULATION.</td>
<td>Multiple capabilities can be enabled by using the logical OR operator.</td>
</tr>
<tr>
<td>capabilities = CAPABILITY_MILLING</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>certificationLevel</td>
<td>Certification level of the post configuration used to determine if the post processor is certified to run against the post engine. This value rarely changes.</td>
</tr>
<tr>
<td>circularInputTolerance</td>
<td>The tolerance to use when determining if a spiral or helical move should be converted to a circular record. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>circularMergeTolerance</td>
<td>The tolerance used to determine if consecutive circular records can be merged into a single circular record. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>circularOutputAccuracy</td>
<td>Defines the number of digits to the right of the decimal point to use when adjusting the final point to lie exactly on the circle.</td>
</tr>
<tr>
<td>description</td>
<td>Short description of post processor. This will be displayed along with the post processor name in the Post Process dialog in HSM when selecting a post processor to run.</td>
</tr>
<tr>
<td>extension</td>
<td>The output NC file extension.</td>
</tr>
<tr>
<td>highFeedMapping</td>
<td>Specifies the high feed mapping mode for rapid moves. Valid modes are HIGH_FEED_NO_MAPPING (do not map rapid moves to high feed), HIGH_FEED_MAP_MULTI (map rapid moves along more than one axis at high feed), HIGH_FEED_MAP_XY_Z (map rapid moves not in the XY-plane or along the Z-axis to high feed), and HIGH_FEED_MAP_ANY (map all rapid moves to high feed). This setting can be changed dynamically in the Property table when running the post processor.</td>
</tr>
<tr>
<td>highFeedrate</td>
<td>Specifies the feedrate to use when mapping rapid moves to linear moves.</td>
</tr>
<tr>
<td>legal</td>
<td>Legal notice of company that authored the post processor.</td>
</tr>
<tr>
<td>mapToWCS</td>
<td>Specifies whether the work plane is mapped to the model origin and work plane. When disabled the post is responsible for handling mapping from the model origin to the setup origin. This variable must be defined using the following syntax and can only be defined in the global section. Any deviation from this format, including adding extra spaces, will cause this command to be ignored.</td>
</tr>
<tr>
<td></td>
<td>mapToWCS = true;</td>
</tr>
<tr>
<td></td>
<td>mapToWCS = false;</td>
</tr>
<tr>
<td>mapWorkOrigin</td>
<td>Specifies whether the coordinates are mapped to the work plane origin. When disabled the post is responsible for handling the work plane origin. This variable must be defined using the following syntax and can only be defined in the global section. Any deviation from this format, including adding extra spaces, will cause this command to be ignored.</td>
</tr>
<tr>
<td></td>
<td>mapWorkOrigin = true;</td>
</tr>
<tr>
<td></td>
<td>mapWorkOrigin = false;</td>
</tr>
<tr>
<td>Setting</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>mapWorkOrigin = true;</td>
<td>Specifies whether the program name must be an integer (true) or can be a text string (false).</td>
</tr>
<tr>
<td>mapWorkOrigin = false;</td>
<td>Specifies the maximum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>maximumCircularRadius</td>
<td>Specifies the maximum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>maximumCircularSweep</td>
<td>Specifies the maximum circular sweep of circular moves that can be output as circular interpolation. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>minimumChordLength</td>
<td>Specifies the minimum delta movement allowed for circular interpolation and can be changed dynamically in the Property table when running the post processor. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>minimumCircularRadius</td>
<td>Specifies the minimum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>minimumCircularSweep</td>
<td>Specifies the minimum circular sweep of circular moves that can be output as circular interpolation. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>minimumRevision</td>
<td>The minimum revision of the post kernel that is supported by the post processor. This value will remain the same unless the post processor takes advantage of functionality added to a later version of the post engine that is not available in earlier versions.</td>
</tr>
<tr>
<td>programNameIsInteger</td>
<td>Specifies the tolerance used to linearize circular moves that are expanded into a series of linear moves. This setting is described in the onCircular section.</td>
</tr>
<tr>
<td>tolerance</td>
<td>Contains the output units of the post processor. This is usually the same as the input units, either MM or IN, but can be changed in the onOpen function of the post processor by setting it to the desired units.</td>
</tr>
<tr>
<td>unit</td>
<td>Name of the machine tool manufacturer.</td>
</tr>
<tr>
<td>vendor</td>
<td>URL of the machine tool manufacturer’s web site.</td>
</tr>
</tbody>
</table>

**Post Kernel Settings**

description = "RS-274D Sample Multi-axis Post Processor";
vendor = "Autodesk";
vendorUrl = "http://www.autodesk.com";
5.1.2 Property Table

Library post processors are designed to run the machine without any modifications, but may not create the output exactly as you would like to see it. The Property Table contains settings that can be changed at runtime so that the library post can remain generic in nature, but still be easily customized by various users. The settings in the Property Table will typically be used to control small variations in the output created by the post processor, with major changes handled by settings in the Fixed Settings section.

The properties can be displayed in multiple areas of HSM; when you use the Post Process dialog to run the post processor, in an NC Program, under the Post Processing tab in the Machine Definition, and in the Post Process tab of an operation. When you Post Process from HSM or edit an NC Program you may be presented with a dialog that allows you to select the post processor to execute, the output file path, and other settings. The Property Table will also be displayed in the dialog allowing you to override settings within the post processor each time it is run.

Sample Post Kernel Settings Code

```csharp
legal = "Copyright (C) 2012-2023 by Autodesk, Inc."

setCodePage("ascii")
capabilities = CAPABILITY_MILLING | CAPABILITY_MACHINE_SIMULATION;
tolerance = spatial(0.002, MM);

minimumChordLength = spatial(0.01, MM);
minimumCircularRadius = spatial(0.01, MM);
maximumCircularRadius = spatial(1000, MM);
minimumCircularSweep = toRad(0.01);
maximumCircularSweep = toRad(180);
allowHelicalMoves = true;
allowedCircularPlanes = undefined; // allow any circular motion
```
Property Table in NC Program

Property Table in Machine Definition

Property Table in Operation
The Property Table is defined in the post processor so you have full control over the information displayed in it, with the exception of the Built-in properties, which are displayed with every post processor and define the post kernel variables described previously. The properties object defined in the post processor defines the property names as they are used in the post processor, the titles displayed in the Property Table, the accepted input types, the default values assigned to each property, and settings controlling the display attributes of the property in the property table.

```javascript
// user-defined properties
properties = {
    writeMachine: {
        title: "Write machine",
        description: "Output the machine settings in the header of the code.",
        group: "general",
        type: "boolean",
        value: true,
        scope: "post"
    },
    useSmoothing: {
        title: "SGI / High Precision Mode",
        description: "High-Speed High-Precision Parameter.",
        group: "preferences",
        type: "enum",
        values:{
            {title:"Off", id:"-1"},
            {title:"Automatic", id:"9999"},
            {title:"Standard", id:"0"},
            {title:"High Speed", id:"1"}
        }
    }
};
```
The following table describes the supported members in the `properties` object. It is important that the format of the `properties` object follows the above example, where the name of the variable is first, followed by a colon (:), and the members enclosed in braces ({}). The `values` property is an array and its members must be enclosed in brackets ([]).

<table>
<thead>
<tr>
<th><strong>Property</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><code>title</code></td>
<td>Description of the property displayed in the User Interface within the <code>Property</code> column.</td>
</tr>
<tr>
<td><code>description</code></td>
<td>A description of the property displayed as a tool tip when the mouse is positioned over this property.</td>
</tr>
<tr>
<td><code>group</code></td>
<td>The group name that this property belongs to. All properties with the same group name will be displayed together in the User Interface. The groups are defined by the <code>groupDefinitions</code> object discussed further in this chapter.</td>
</tr>
<tr>
<td><code>type</code></td>
<td>Defines the input type. The input types are described in the following table.</td>
</tr>
<tr>
<td><code>value</code></td>
<td>The default value for this property.</td>
</tr>
<tr>
<td><code>range</code></td>
<td>The minimum and maximum allowable values for a numeric property specified as an array (<code>[-1000, 1000]</code>).</td>
</tr>
<tr>
<td><code>values</code></td>
<td>Contains a list (array) of choices for the <code>enum</code>, <code>integer</code>, or <code>boolean</code> input types. It is not valid with any other input type. For <code>boolean</code> values, it should be an array of 2 strings, with the first entry representing <code>true</code> and the second representing <code>false</code>.</td>
</tr>
<tr>
<td><code>presentation</code></td>
<td>Defines how a boolean will be displayed in the property table. Valid settings are defined as a text string and can be “yesno” (Yes/No), “truefalse” (True/False), “onoff” (On/Off), and “10” (1/0).</td>
</tr>
<tr>
<td><code>scope</code></td>
<td>Tells the post which dialogs will display this property. Supported settings are <code>post</code>, <code>machine</code>, and <code>operation</code>. The setting must be specified as a text string. <code>scope</code> can be a single value or an array of the supported dialogs. Examples: <code>scope: “post”</code>, <code>scope: [“post”, “machine”]</code>. <strong>There are caveats when enabling a property in more than one dialog type as described in the <code>Property Scopes</code> section of this chapter.</strong></td>
</tr>
<tr>
<td><code>enabled</code></td>
<td>Specifies the operation type where this property will be displayed in the HSM operation dialog. This property only applies to <code>operation</code> properties and has no effect on <code>post</code> and <code>machine</code> properties. The setting must be specified as a text string or an array of text strings. Valid settings are “milling”, “turning”, “drilling”, “probing”, “inspection”, and “additive”.</td>
</tr>
</tbody>
</table>

---

**Entry Functions 5-99**
<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>visible</td>
<td>Defines whether a property is visible in the NC Program and Operation dialogs. This setting has no effect on the Machine Definition or legacy Post Process dialogs. It can be set to true or false.</td>
</tr>
</tbody>
</table>

**Properties Settings**

<table>
<thead>
<tr>
<th>Input Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;integer&quot;</td>
<td>Integer value</td>
</tr>
<tr>
<td>&quot;number&quot;</td>
<td>Real value</td>
</tr>
<tr>
<td>&quot;spatial&quot;</td>
<td>Real value</td>
</tr>
<tr>
<td>&quot;angle&quot;</td>
<td>Angular value in degrees</td>
</tr>
<tr>
<td>&quot;boolean&quot;</td>
<td>true or false</td>
</tr>
<tr>
<td>&quot;string&quot;</td>
<td>Text string</td>
</tr>
<tr>
<td>&quot;enum&quot;</td>
<td>The enum input type defines this variable as having fixed choices associated with it. These choices are defined individually in the values property array. An enum input type should be defined using string values.</td>
</tr>
</tbody>
</table>

**Property Table Input Types**

<table>
<thead>
<tr>
<th>Values Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>title</td>
<td>The text of the choice item displayed in the User Interface for this variable.</td>
</tr>
<tr>
<td>id</td>
<td>The value that will be returned in the variable when the post processor is called. All references to this property, e.g. <code>getProperty(&quot;rotaryTableAxis&quot;)</code>, in the post processor should expect only one of these id values as its value. The id must be a text string when associated with an enum input type or an integer value when associated with an integer.</td>
</tr>
</tbody>
</table>

**Enum Choices Properties**

### 5.1.3 Property Scopes

When multiple dialog types are specified for the scope property there is a hierarchy that defines which dialog has final say in the property value passed to the post processor. This hierarchy is as follows.

1. Operation property
2. Post property
3. Machine property

Therefore, if a property is defined as a post and an operation property, then the setting made in the Post Process, and NC Program dialogs will be ignored by the post processor, only the setting made in each separate operation will be used by the post processor. The only place you would be able to query the Post Process property setting is in `onOpen` when using the `getProperty` function. For these reasons it is highly recommended that operation properties are not defined in the post or machine scopes.

When specifying a property as a machine and post property, the setting made to the property in the Machine Definition dialog will become the default setting for the post property displayed in the
corresponding dialogs. If the property setting is changed in the post dialog, then this value will override the machine property setting.

### 5.1.4 Operation Properties

Operation properties are shown in the Post Process tab of the Operation dialog and are defined by including operation in the scope of the property.

```json
gotChipConveyor: {
    title: "Use chip transport",
    description: "Enable to turn on the chip transport for this operation.",
    group: "configuration",
    type: "boolean",
    value: false,
    scope: "operation", // Only displayed in the Operation dialog
    enabled: "milling" // Only displayed for milling operations
},
useHood: {
    title: "Use vacuum hood",
    description: "Enable to turn on the vacuum hood.",
    group: "preferences",
    type: "boolean",
    value: true,
    scope: ["post", "operation"], // Displayed in Post and Operation dialogs
    disabled: "drilling" // Not displayed for drilling operations
}
```

Defining an Operation Property

When the scope is set to "operation" only, then the single property will be displayed in the Operation dialog as shown with the Use chip transport property. When the scope includes another dialog to display the property in, a checkbox with the property name will be displayed in the Operation dialog. If this checkbox remains unchecked, then the post property value defined in either the Post Process or Machine Definition dialog will be used for this operation. You can change the value of post/machine/operation properties on an operation-by-operation basis by checking the box next to the property and then changing the value of the property itself as shown with the useHood property.
To display operation properties in Fusion 360 or Inventor CAM it is required that a Machine Definition be assigned to the Manufacturing Setup. The reason is that the Machine Definition has a post processor assigned to it and the operation properties are obtained from this known post processor.

The enabled parameter in the property definition specifies the operation type where this property will be displayed in the HSM Operation dialog. The disabled parameter will not display the property for the specified operation type(s). These parameters only applies to operation properties and have no effect on post and machine properties. The setting must be specified as a text string or an array of text strings.

<table>
<thead>
<tr>
<th>enabled Setting</th>
<th>Operation type property is displayed with</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;milling&quot;</td>
<td>All milling and drilling operations.</td>
</tr>
<tr>
<td>&quot;turning&quot;</td>
<td>All turning operations.</td>
</tr>
<tr>
<td>&quot;drilling&quot;</td>
<td>All drilling operations.</td>
</tr>
<tr>
<td>&quot;probing&quot;</td>
<td>All probing operations.</td>
</tr>
<tr>
<td>&quot;inspection&quot;</td>
<td>All inspection operations.</td>
</tr>
<tr>
<td>&quot;additive&quot;</td>
<td>All additive operations.</td>
</tr>
<tr>
<td>&quot;operation-strategy&quot;</td>
<td>Only operations of the specified operation strategy, for example &quot;face&quot;, &quot;contour2D&quot;, &quot;adaptive2D&quot;, &quot;turningRoughing&quot;, etc. You can find the strategy for a certain operation type by running the Dumper post processor (dump.cps) and searching for operation-strategy. The operation strategies can be placed in an array to allow multiple strategies to be specified, for example: enabled : [&quot;contour2d&quot;, &quot;chamfer2d&quot;].</td>
</tr>
</tbody>
</table>

Property Table Input Types
5.1.5 Property Groups

The display order of the properties is controlled by the group setting in the property definition and in the `groupDefinitions` object, which defines which group the property belongs to and the order that the groups are displayed in the Property table in each dialog.

The post processor has a number of built-in property groups as defined in the following table. You can reference these groups in the property definition without creating the group in the `groupDefinition` object.

<table>
<thead>
<tr>
<th>Group</th>
<th>Title</th>
<th>Description</th>
<th>Order</th>
<th>Collapsed</th>
</tr>
</thead>
<tbody>
<tr>
<td>configuration</td>
<td>Configuration</td>
<td>Configuration options</td>
<td>10</td>
<td>true</td>
</tr>
<tr>
<td>preferences</td>
<td>Preferences</td>
<td>User preferences</td>
<td>20</td>
<td>false</td>
</tr>
<tr>
<td>homePositions</td>
<td>Safe retracts and home positioning</td>
<td>Settings related to safe retracts and home positioning</td>
<td>30</td>
<td>true</td>
</tr>
<tr>
<td>multiAxis</td>
<td>Multi-axis</td>
<td>Multi-axis settings</td>
<td>40</td>
<td>true</td>
</tr>
<tr>
<td>formats</td>
<td>Formats</td>
<td>NC code format settings</td>
<td>50</td>
<td>true</td>
</tr>
<tr>
<td>probing</td>
<td>Probing and Inspection</td>
<td>Probing and inspection settings</td>
<td>60</td>
<td>true</td>
</tr>
</tbody>
</table>

Built-in Group Definition

If a property does not fit into a predefined group, you can add to the built-in groups by defining these groups within the `groupDefinitions` object. In the following example, the `subSpindle` group will be displayed after the built-in `configuration` group and the `looping` group will be displayed after the built-in `preferences` group. This is determined by the value assigned to the `order` property.

```javascript
// define the custom property groups
groupDefinitions = {
    looping: {title:"Looping", description: "Looping control", collapsed:true, order:25}
};
```

Property Group Definition

The following table describes the supported properties in the `groupDefinitions` object. It is important that the format of the `groupDefinitions` object follows the above example, where the name of the group is first, followed by a colon (:), and the properties enclosed in braces ({ }).

Each group referenced in the `properties` definition and not one of the built-in property groups should be defined in `groupDefinitions`.

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>title</td>
<td>Title of the group displayed in the Post properties table. The title is not displayed in the legacy Post Process dialog.</td>
</tr>
<tr>
<td>Property</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>description</td>
<td>A description of the group displayed as a tool tip when the mouse is positioned over this group name.</td>
</tr>
<tr>
<td>order</td>
<td>A number defining the displayed placement of the group in the Post properties table. For example, a value of less than 10 will be displayed first, 25 will display between the preferences and homePositions groups, and a value of 70 will be displayed after the probing group.</td>
</tr>
<tr>
<td>collapsed</td>
<td>Defines whether the group will be collapsed or expanded by default in the Post properties table. true collapses the group and false expands the group.</td>
</tr>
</tbody>
</table>

**Group Definition Settings**

![Post properties table](image)

**5.1.6 Accessing Properties**

```
getProperty(property [,default-value])
section.getProperty(property [,default-value])
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>property</td>
<td>The property you want to retrieve the value of. It can be specified as a text string (&quot;useSmoothing&quot;) or as a direct reference to the property (properties.useSmoothing). It is recommended to use the text string syntax. The <code>section.getProperty</code> function can be used to obtain the value of a property for a specific section. If the specified property is not an operation property, then the post property value will be returned. The <code>section.getProperty</code> function only needs to be used if you need to know the value of an operation property outside of when the operation is being processed, for example in <code>onOpen</code>.</td>
</tr>
<tr>
<td>default-value</td>
<td>The value to return from <code>getProperty</code> if the specified property does not exist. If a default value is not specified and the property does not exist, then <code>undefined</code> will be returned.</td>
</tr>
</tbody>
</table>
The `getProperty` function is used to obtain the value of a post processor property.

```
showSequenceNumbers = getProperty("showSequenceNumbers");
if (getProperty(properties.showSequenceNumbers)) {
    var smooth = section.getProperty("useSmoothing", false);
}
```

**Sample `getProperty` Calls**

```
function setProperty(property, value)

Arguments | Description
---|---
property | The property you want to set the value of. It can be specified as a text string ("useSmoothing") or as a direct reference to the property (properties.useSmoothing). It is recommended to use the text string syntax.
value | The value to set the property to.

The `setProperty` function is used to set the value of a post processor property.

```
setProperty("showSequenceNumbers", true);
setProperty(properties.showSequenceNumbers, true);
```

**Sample `setProperty` Calls**

### 5.1.7 Unit-Based Properties

Properties that accept a numeric value (number, spatial) are unitless, meaning that no conversion between units is performed. It is possible to allow for unit-based numeric values in properties by implementing the `parseSpatialProperties` function in your post processor.

To mark a property as a unit-based number the `type` parameter must be set to `string` and the `kind` parameter set to `spatial`. The value must be entered as a string containing the number and followed by `in` or `mm`.

```
xHomePosition: {
    title : "X-axis home position",
    description: "Define the X home position.",
    group : "homePositions",
    type : "string",
    value : "200mm",
    scope : "post",
    kind : "spatial"
}
```

**Defining a Unit Based Property**

When entering a value in a unit-based property it is required that the units string be attached to the number, otherwise an error will be generated.
The `parseSpatialProperties` function can be implemented by copying it from another post processor that supports unit-based properties, such as the Creality family (creality.cps) post.

You will need to call `parseSpatialProperties` from the `onOpen` function to convert the unit-based numeric string to a number in the output units.

```
function onOpen() {
  ...
  if (typeof parseSpatialProperties == "function") { // convert unit-based properties
    parseSpatialProperties();
  }
}
```

### 5.1.8 Format Definitions

The format definitions area of the global section is used to define the formatting of codes output to the NC file. It consists of the format definitions (`createFormat`) as well as definitions that determine when the codes will be output or suppressed (`createOutputVariable`).

The `createFormat` command defines how codes are formatted before being output to the NC file. It can be used to create a complete format for an output code, including the letter prefix, or to create a primary format that is referenced with the output definitions. It has the following syntax.

```
createFormat({specifier:value, specifier:value, ...});
```

**createFormat Syntax**
The specifiers must be enclosed in braces ({}), and contain the specifier name followed by a colon (:) and then by a value. Multiple specifiers are separated by commas.

<table>
<thead>
<tr>
<th>Specifier</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>base</td>
<td>The base increment of the output value. For example, a value of .002 will only output values on a .002 increment (.002, .004, .010, etc.). The default is 0.</td>
</tr>
<tr>
<td>decimals</td>
<td>Defines the number digits to the right of the decimal point to output. The default is 6.</td>
</tr>
<tr>
<td>forceSign</td>
<td>When set to true will force the output of a plus (+) sign on positive numbers. The default is false.</td>
</tr>
<tr>
<td>inherit</td>
<td>Inherits all properties from an existing FormatNumber.</td>
</tr>
<tr>
<td>minDigitsLeft</td>
<td>The minimum number of digits to the left of the decimal point to output. The default is 1.</td>
</tr>
<tr>
<td>minDigitsRight</td>
<td>The maximum number of digits to the right of the decimal point to output. The default is 0.</td>
</tr>
<tr>
<td>maximum</td>
<td>The unsigned maximum value that can be output. Formatted positive values will not be greater than this value and formatted negative values will not be less than the negative value. For example, defining a maximum value of 9999.99 will limit the output values to -9999.99 through 9999.99. The default is unlimited.</td>
</tr>
<tr>
<td>minimum</td>
<td>The unsigned minimum value that can be output. Formatted positive values will not be less than this value and formatted negative values will not be greater than the negative value. For example, defining a minimum value of 0.001 will limit the output values to less than -0.001 or greater than 0.001. The default is 0.</td>
</tr>
<tr>
<td>offset</td>
<td>Defines a number to add to the value prior to formatting it for output. The default is 0.</td>
</tr>
<tr>
<td>prefix</td>
<td>Defines the prefix of the output value as a text string. The prefix should only be defined if this is a standalone format and is not used for multiple output definitions. The default is &quot;&quot;.</td>
</tr>
<tr>
<td>scale</td>
<td>Defines a scale factor to multiply the value by prior to formatting it for output. scale can be a number or a number designator, such as DEG. The default is 1.</td>
</tr>
<tr>
<td>separator</td>
<td>Defines the character to use as the decimal point. The default is &quot;.&quot;.</td>
</tr>
<tr>
<td>suffix</td>
<td>Defines the suffix of the output value as a text string. The suffix should only be defined if this is a standalone format and is not used for multiple output definitions. The default is &quot;&quot;.</td>
</tr>
</tbody>
</table>
| type      | Defines the format of the number. Can be one of the following.  
- FORMAT_INTEGER – whole numbers do not contain a decimal point, fractional numbers contain a decimal point.  
- FORMAT_REAL – all numbers contain a decimal point.  
- FORMAT_LZS – Leading Zero Suppression. The decimal point is omitted and leading zeros are removed, including leading zeros in the fractional portion of the number if the value is less than 1. |
Specifier | Value
---|---
• FORMAT_TZS – Trailing Zero Suppression. The decimal point is omitted and trailing zeros are removed, including trailing zeros in the whole number if the fractional part is set to 0.

The default is FORMAT_INTEGER.

**createFormat Specifiers**

The `createFormat` function creates a `FormatNumber` object. Once a `FormatNumber` is created, it can be used to create a formatted text string of a value that matches the properties in the defined `format`. The following table describes the functions defined in the `FormatNumber` object.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>areDifferent(a, b)</td>
<td>Returns <code>true</code> if the input values are different after being formatted.</td>
</tr>
<tr>
<td>format(value)</td>
<td>Returns the formatted text string representation of the number.</td>
</tr>
<tr>
<td>getBase()</td>
<td>Returns the base increment of the format.</td>
</tr>
<tr>
<td>getDecimalSymbol()</td>
<td>Returns the character used as the decimal point symbol.</td>
</tr>
<tr>
<td>getError(value)</td>
<td>Returns the inverse of the remaining portion of the value that is not formatted for the number. For example, if the formatted value of 4.5005 is &quot;4.500&quot;, then the value returned from <code>getError</code> will be -0.0005.</td>
</tr>
<tr>
<td>getForceSign()</td>
<td>Returns true if the + sign is output in the formatted number.</td>
</tr>
<tr>
<td>getMaximum()</td>
<td>Returns the maximum value that can be output.</td>
</tr>
<tr>
<td>getMinDigitsLeft()</td>
<td>Returns the minimum number of digits to output to the left of the decimal point.</td>
</tr>
<tr>
<td>getMinDigitsRight()</td>
<td>Returns the minimum number of digits to output to the right of the decimal point.</td>
</tr>
<tr>
<td>getMinimum()</td>
<td>Returns the minimum value that can be output.</td>
</tr>
<tr>
<td>getMinimumValue()</td>
<td>Returns the minimum value that can be formatted using this <code>format</code>, for example, 1 for <code>decimals:0</code>, .1 for <code>decimals:1</code>, etc.</td>
</tr>
<tr>
<td>getNumberOfDecimals()</td>
<td>Returns the maximum number of digits to output to the right of the decimal point.</td>
</tr>
<tr>
<td>getOffset()</td>
<td>Returns the number to add to the formatted number.</td>
</tr>
<tr>
<td>getPrefix()</td>
<td>Returns the prefix of the formatted number.</td>
</tr>
<tr>
<td>getResultingValue(value)</td>
<td>Returns the real value that the formatted output text string represents.</td>
</tr>
<tr>
<td>getScale()</td>
<td>Returns the scale to apply to the formatted number.</td>
</tr>
<tr>
<td>getSuffix()</td>
<td>Returns the suffix of the formatted number.</td>
</tr>
<tr>
<td>getType()</td>
<td>Returns the formatting type.</td>
</tr>
<tr>
<td>isSignificant(value)</td>
<td>Returns true if the value will be non-zero when formatted.</td>
</tr>
<tr>
<td>setBase(base)</td>
<td>Defines the base increment of the format.</td>
</tr>
<tr>
<td>setDecimalSymbol('symbol')</td>
<td>Defines the character used as the decimal point symbol.</td>
</tr>
<tr>
<td>setForceSign(forceSign)</td>
<td>Determines if the + sign is output in the formatted number.</td>
</tr>
<tr>
<td>setMaximum(max)</td>
<td>Defines the maximum value that can be output.</td>
</tr>
</tbody>
</table>
### FormatNumber Functions

The following table shows how a value of 0 could be formatted depending on the format type and settings for the minimum digits to the left and right of the decimal point.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>setMinDigitsLeft(min)</td>
<td>Defines the minimum number of digits to output to the left of the decimal point.</td>
</tr>
<tr>
<td>setMinDigitsRight(min)</td>
<td>Defines the minimum number of digits to output to the right of the decimal point.</td>
</tr>
<tr>
<td>setMinimum(min)</td>
<td>Defines the minimum value that can be output.</td>
</tr>
<tr>
<td>setNumberOfDecimals(number)</td>
<td>Defines the maximum number of digits to output to the right of the decimal point.</td>
</tr>
<tr>
<td>setOffset(offset)</td>
<td>Defines the number to add to the formatted number.</td>
</tr>
<tr>
<td>setPrefix(prefix)</td>
<td>Defines the prefix of the formatted number.</td>
</tr>
<tr>
<td>setScale(scale)</td>
<td>Defines the scale to apply to the formatted number.</td>
</tr>
<tr>
<td>setSuffix()</td>
<td>Defines the suffix of the formatted number.</td>
</tr>
<tr>
<td>setType()</td>
<td>Sets the formatting type, FORMAT_INTEGER, FORMAT_REAL, FORMAT_LZS, or FORMAT_TZS.</td>
</tr>
</tbody>
</table>

#### Formatting the Number Zero

<table>
<thead>
<tr>
<th>FORMAT_INTEGER</th>
<th>FORMAT_INTEGER</th>
<th>FORMAT_REAL</th>
<th>FORMAT_REAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>minDigitsLeft:0</td>
<td>minDigitsRight:0</td>
<td>minDigitsLeft:1</td>
<td>minDigitsRight:0</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>X0</td>
<td>X.0</td>
</tr>
</tbody>
</table>

```javascript
var xFormat = createFormat({type:FORMAT_REAL, decimals:3, minDigitsRight:3, forceSign:true});
xFormat.format(4.5); // returns "+4.500"
xFormat.areDifferent(9.123, 9.1234); // returns false, both numbers are 9.123
xFormat.getMinimumValue(); // returns 0.001
xFormat.isSignificant(.0006); // returns true (rounded to .001)
xFormat.isSignificant(.0004); // returns false
```

```javascript
var yFormat = createFormat({prefix:"Y", decimals:3, forceSign:true});
yFormat.format(4.5); // returns "Y+4.5"
yFormat.format(6); // returns Y+6
yFormat.getResultingValue(3.1234); // returns 3.123
```

```javascript
var toolFormat = createFormat({prefix:"T", decimals:0, minDigitsLeft:2});
toolFormat.format(7); // returns "T07"
```

```javascript
var aFormat = createFormat({type:FORMAT_REAL, decimals:3, forceSign:true, scale:DEG});
aFormat.format(Math.PI); // returns "+180."
```

```javascript
var peckFormat = createFormat({type:FORMAT_LZS, decimals:4, minDigitsLeft:0});
peckFormat.format(1.23); // returns Q12300
```
peckFormat.format(0.001); // returns Q10

Example createFormat Commands

5.1.9 Deprecated Format Specifiers

In support of existing post processors, the following legacy format definition is still supported. The syntax of the createFormat statement remains the same, but the specifiers are different from those described in the previous section as shown in the following table.

<table>
<thead>
<tr>
<th>Specifier</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>decimals</td>
<td>Defines the number digits to the right of the decimal point to output. The default is 6.</td>
</tr>
<tr>
<td>forceDecimal</td>
<td>When set to true the decimal point will always be included with the formatted number. false will remove the decimal point for integer values.</td>
</tr>
<tr>
<td>forceSign</td>
<td>When set to true will force the output of a plus (+) sign on positive numbers. The default is false.</td>
</tr>
<tr>
<td>inherit</td>
<td>Inherits all properties from an existing FormatNumber.</td>
</tr>
<tr>
<td>offset</td>
<td>Defines a number to add to the value prior to formatting it for output. The default is 0.</td>
</tr>
<tr>
<td>prefix</td>
<td>Defines the prefix of the output value as a text string. The prefix should only be defined if this is a standalone format and is not used for multiple output definitions. The default is &quot;&quot;.</td>
</tr>
<tr>
<td>scale</td>
<td>Defines a scale factor to multiply the value by prior to formatting it for output. scale can be a number or a number designator, such as DEG. The default is 1.</td>
</tr>
<tr>
<td>separator</td>
<td>Defines the character to use as the decimal point. The default is &quot;.&quot;.</td>
</tr>
<tr>
<td>suffix</td>
<td>Defines the suffix of the output value as a text string. The suffix should only be defined if this is a standalone format and is not used for multiple output definitions. The default is &quot;&quot;.</td>
</tr>
<tr>
<td>trim</td>
<td>When set to true the trailing zeros will be trimmed from the right of the decimal point. The default is true.</td>
</tr>
<tr>
<td>trimLeadZero</td>
<td>When set to true will trim the lead zero from a floating-point number if the number is fractional, e.g. .123 instead of 0.123. The default is false.</td>
</tr>
<tr>
<td>width</td>
<td>Specifies the minimum width of the output string. If the formatted value’s width is less than the width value, then the start of the number will either be filled with spaces or zeros depending on the value of zeropad. If the format is used to output a code to the NC file be sure to set zeropad to true, otherwise the prefix and value could be separated by spaces. The width of the output string includes the decimal point when it is included in the number, but not the sign of the number. The default is 0.</td>
</tr>
<tr>
<td>zeropad</td>
<td>When set to true will fill the beginning of the output string with zeros to match the specified width. If width is not specified or the output string is longer than width, then no zeros will be added. The default is false.</td>
</tr>
</tbody>
</table>

Deprecated createFormat Specifiers
5.1.10 Output Variable Definitions

The format object is used to format values but has no connection to the output of the variable, except for formatting a text string that could be output. It does not know what the last output variable is, which is important when you do not want to output a code if the value has not changed from its previous output value.

The `createOutputVariable` function creates `OutputVariable` objects that are used to control the output of a code. The codes can be output only when they are changed, as an absolute value, as an incremental value, or as a directional value where the sign of the number determines a movement direction.

You can use the `FormatNumber` object, created from the `createFormat` function, for codes/registers that should be output whenever they are encountered in the post, just be sure to add the prefix to the definition.

```
createOutputVariable({specifier:value, specifier:value, ...}, format);
```

Output Variable Syntax

The specifiers must be enclosed in braces ({}), and contain the specifier name followed by a colon (:) and then by a value. Multiple specifiers are separated by commas. A `FormatNumber` object is provided as the second parameter. Supported specifiers are listed in the following table.

<table>
<thead>
<tr>
<th>Specifier</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>Determines when a formatted variable will be output. CONTROL_CHANGED will format the number when it has changed from the previously formatted value, CONTROL_FORCE will format the number each time, and CONTROL_NONZERO will format the number only when it is not equal to zero. If the number is not formatted, then a blank string will be returned.</td>
</tr>
<tr>
<td>current</td>
<td>Defines the initial value to store in the output variable.</td>
</tr>
<tr>
<td>cyclicLimit</td>
<td>Specifies the absolute range limit for the formatted value, for example it could be 360 for a rotary axis.</td>
</tr>
<tr>
<td>cyclicSign</td>
<td>Specifies the sign for a cyclic value and can be -1 (formatted numbers will always be negative), 0 (formatted numbers can be both positive and negative), or 1 (formatted numbers will always be positive).</td>
</tr>
<tr>
<td>onchange</td>
<td>Defines the method to be invoked when the formatting of the value results in output.</td>
</tr>
<tr>
<td>prefix</td>
<td>Text string that prepends to the prefix defined in the <code>format</code>.</td>
</tr>
<tr>
<td>suffix</td>
<td>Text string that appends to the suffix defined in the <code>format</code>.</td>
</tr>
<tr>
<td>tolerance</td>
<td>Defines a tolerance used to determine when the number should be formatted. A value must differ from the previous value by greater than this tolerance to be output.</td>
</tr>
<tr>
<td>type</td>
<td>Defines the output type of the variable. Can be one of the following.</td>
</tr>
<tr>
<td></td>
<td>• TYPE_ABSOLUTE – The number will maintain its value when formatted.</td>
</tr>
</tbody>
</table>
Specifier | Value
--- | ---
• TYPE_INCREMENTAL – The formatted number will be an incremental value from the previously formatted value.
• TYPE_DIRECTIONAL – The formatted number will be negative if the value is less than the previously formatted value or will be positive if the value is greater than the previously formatted value. This type is usually used in conjunction with the cyclicLimit and cyclicSign specifiers for rotary axes that are output on a rotary scale.

The default is TYPE_ABSOLUTE.

Output Variable Specifiers

The onchange property defines a function that is called whenever the formatting of the variable results in an output text string, such as when the value changes or is forced out. The following example will force out the gMotionModal code whenever the plane code is changed.

```javascript
var gPlaneModal = createOutputVariable({onchange:function () {gMotionModal.reset();}}, gFormat);
```

onchange Usage

Once an output variable is created, it can be used to create a formatted text string for output. The following table describes the functions assigned to the output variable objects. The functions are properties of the defined OutputVariable object.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>disable()</td>
<td>Disables this variable from being output. Will cause the return value from the format function to always be a blank string (&quot;&quot;).</td>
</tr>
<tr>
<td>enable()</td>
<td>Enables this variable for output. This is the default condition when the variable is created.</td>
</tr>
<tr>
<td>format(value)</td>
<td>Returns the formatted text string representation of the number. A blank string will be returned when the value is the same as the stored value when control is set to CONTROL_CHANGED, or generates a value of 0 when control is set to CONTROL_NONZERO.</td>
</tr>
<tr>
<td>getControl()</td>
<td>Returns the control setting of the output variable.</td>
</tr>
<tr>
<td>getCurrent()</td>
<td>Returns the value currently stored in this variable.</td>
</tr>
<tr>
<td>getCyclicLimit()</td>
<td>Returns the absolute cyclic limit (rollover) of the output variable.</td>
</tr>
<tr>
<td>getCyclicSign()</td>
<td>Returns the cyclic sign setting of the output variable.</td>
</tr>
<tr>
<td>getFormat()</td>
<td>Returns the FormatNumber associated with this output variable.</td>
</tr>
<tr>
<td>getPrefix()</td>
<td>Returns the prefix of the output variable.</td>
</tr>
<tr>
<td>getResutingValue(value)</td>
<td>Returns the real value that the formatted output text string represents.</td>
</tr>
<tr>
<td>getSuffix()</td>
<td>Returns the suffix of the output variable.</td>
</tr>
<tr>
<td>getTolerance()</td>
<td>Returns the output tolerance of the output variable.</td>
</tr>
<tr>
<td>getType()</td>
<td>Returns the output type of the variable.</td>
</tr>
<tr>
<td>get---()</td>
<td>All get functions supported by the FormatNumber object can be called from an OutputVariable object. These calls return the values stored in the FormatNumber, for example getDecimals(), getScale(), etc. The</td>
</tr>
<tr>
<td>Function</td>
<td>Description</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>isEnabled()</td>
<td>Returns true if this variable is enabled for output.</td>
</tr>
<tr>
<td>setControl(control)</td>
<td>Sets the control type, CONTROL_CHANGED, CONTROL_FORCE, or CONTROL_NONZERO.</td>
</tr>
<tr>
<td>setCurrent(value)</td>
<td>Sets the current value.</td>
</tr>
<tr>
<td>setCyclicLimit(value)</td>
<td>Defines the rollover value (cyclic limit).</td>
</tr>
<tr>
<td>setCyclicSign(value)</td>
<td>Defines the cyclic sign, -1 (formatted numbers will always be negative), 0 (formatted numbers can be both positive and negative), or 1 (formatted numbers will always be positive).</td>
</tr>
<tr>
<td>setFormat(format)</td>
<td>Changes the FormatNumber object associated with this output variable.</td>
</tr>
<tr>
<td>setPrefix(prefix-text)</td>
<td>Overrides the prefix of the variable.</td>
</tr>
<tr>
<td>setSuffix(suffix-text)</td>
<td>Overrides the suffix of the variable.</td>
</tr>
<tr>
<td>setTolerance(value)</td>
<td>Defines the output tolerance of the variable.</td>
</tr>
<tr>
<td>setType(type)</td>
<td>Sets the formatting type, TYPE_ABSOLUTE, TYPE_INCREMENTAL, or CONTROL_DIRECTIONAL.</td>
</tr>
<tr>
<td>set---()</td>
<td>All set functions supported by the FormatNumber object can be called from an OutputVariable object. These calls override the properties stored in the FormatNumber associated with this OutputVariable, for example setDecimals(3), setScale(2), etc. The only set functions not supported are those with the same names as OutputVariable functions, such as setPrefix(). When a FormatNumber is assigned to an OutputVariable then a copy of the FormatNumber is placed in the OutputVariable, so setting a FormatNumber property from an OutputVariable does not modify the original FormatNumber used when creating the OutputVariable.</td>
</tr>
<tr>
<td>reset()</td>
<td>Forces the output of the formatted text string on the next call to format, overriding the rules for not outputting a value.</td>
</tr>
</tbody>
</table>

### OutputVariable Functions

```javascript
var xyzFormat = createFormat({ decimals:3, type:FORMAT_REAL });
var xOutput = createVariable({ prefix:"X" }, xyzFormat);
xOutput.format(4.5); // returns "X4.5"
xOutput.format(4.5); // returns "" (4.5 is currently stored in the xOutput variable)
xOutput.reset(); // force xOuput on next formatting
xOutput.format(4.5); // returns "X4.5"
xOutput.disable(); // disable xOutput formatting
xOutput.format(1.2); // returns "" since it is disabled

var gFormat = createFormat({ prefix:"G", decimals:0, minDigitsLeft:2 });
var gMotionModal = createOutputVariable({ control:CONTROL_FORCE }, gFormat);
gMotionModal.format(0); // returns G00
gMotionModal.format(0); // returns G00 (CONTROL_FORCE is set)
```
Example OutputVariable Commands

5.1.11 Deprecated Output Variable Definitions
In support of existing post processors, the following legacy output variable definition are still supported.

```
cREATE VARIABLE({specifier: value, specifier: value, ...}, format);
cREATE MODAL({specifier: value, specifier: value, ...}, format);
cREATE REFERENCE VARIABLE({specifier: value, specifier: value, ...}, format);
cREATE INCREMENTAL VARIABLE({specifier: value, specifier: value, ...}, format);
```

Deprecated Output Variables Syntax

The `CREATE VARIABLE`, `CREATE MODAL`, `CREATE REFERENCE VARIABLE`, and `CREATE INCREMENTAL VARIABLE` functions create output objects that are used to control the output of a code. The `CREATE VARIABLE` and `CREATE MODAL` objects are used to output codes/registers only when they change from the previous output value, the `CREATE REFERENCE VARIABLE` is used to output values when they are different from a specified reference value, and the `CREATE INCREMENTAL VARIABLE` is used for the output of incremental values, i.e. the output value will be an incremental value based on the previous value and the input value.

The following table lists the specifiers supported by the deprecated output variable definitions. Some of the specifiers are common to all three objects and some to a particular object.

<table>
<thead>
<tr>
<th>Specifier</th>
<th>Object</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>prefix</td>
<td>(all)</td>
<td>Text string that overrides the prefix defined in <code>format</code>.</td>
</tr>
<tr>
<td>Specifier</td>
<td>Object</td>
<td>Value</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>force</td>
<td>(all)</td>
<td>When set to true forces the formatting of the value even if it does not change from the previous value. The default is false.</td>
</tr>
<tr>
<td>onchange</td>
<td>createVariable</td>
<td>Defines the method to be invoked when the formatting of the value results in output.</td>
</tr>
<tr>
<td>suffix</td>
<td>createModal</td>
<td>Text string that overrides the suffix defined in format.</td>
</tr>
<tr>
<td>first</td>
<td>createIncrementalVariable</td>
<td>Defines the initial value of an incremental variable. You will also have to call the variable.format(first) function after creating the IncrementalVariable to properly store the initial value.</td>
</tr>
</tbody>
</table>

**Deprecated Output Variable Specifiers**

The following table describes the functions assigned to the deprecated output variable objects. The functions are properties of the Variable object(s) as listed.

<table>
<thead>
<tr>
<th>Function</th>
<th>Object</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>disable()</td>
<td>Variable</td>
<td>Disables this variable from being output. Will cause the return value from the format function to always be a blank string (&quot;&quot;).</td>
</tr>
<tr>
<td></td>
<td>ReferenceVariable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IncrementalVariable</td>
<td></td>
</tr>
<tr>
<td>enable()</td>
<td>Variable</td>
<td>Enables this variable for output. This is the default condition when the variable is created.</td>
</tr>
<tr>
<td></td>
<td>Reference Variable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IncrementalVariable</td>
<td></td>
</tr>
<tr>
<td>format(value [,ref])</td>
<td>(all)</td>
<td>Returns the formatted text string representation of the number. Can return a blank string if the value is the same as the stored value in the Variable and Modal objects, the same as the reference value in the ReferenceVariable object, or generates a value of 0 in the IncrementalVariable object. The call to format for a ReferenceVariable object must contain the second ref parameter, which determines if the value should be formatted for output.</td>
</tr>
<tr>
<td>getCurrent()</td>
<td>Variable</td>
<td>Returns the value currently stored in this variable.</td>
</tr>
<tr>
<td></td>
<td>Modal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IncrementalVariable</td>
<td></td>
</tr>
<tr>
<td>isEnabled()</td>
<td>Variable</td>
<td>Returns true if this variable is enabled for output</td>
</tr>
<tr>
<td></td>
<td>ReferenceVariable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IncrementalVariable</td>
<td></td>
</tr>
<tr>
<td>reset()</td>
<td>Variable</td>
<td>Forces the output of the formatted text string on the next call to format,</td>
</tr>
<tr>
<td></td>
<td>Modal</td>
<td></td>
</tr>
</tbody>
</table>
### Function | Object | Description
--- | --- | ---
IncrementalVariable | IncrementalVariable | overriding the rules for not outputting a value.
setPrefix(prefix-text) | (all) | Overrides the prefix of the variable.
setSuffix(suffix-text) | Modal | Overrides the suffix of the variable.

## 5.1.12 Modal Groups

Modal groups are similar to Modal variables (`createModal`), but are used to define codes that can be grouped together. For example, all G-codes that use the same formatting and output rules can be placed in a modal group. Modal groups can be considered part of the Output Variable definitions but behave in an expanded manner and limit control over the individual codes in a group element as can be done using a modal variable.

```plaintext
createModalGroup({specifier:value, specifier:value, ...}, groups, format);
```

### createModalGroup Syntax

The specifiers must be enclosed in braces ({}) and contain the specifier name followed by a colon (:) and then by a value. Multiple specifiers are separated by commas. A `format` object is provided as the third parameter. The specifiers are listed in the following table.

<table>
<thead>
<tr>
<th>Specifier</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>force</td>
<td>When set to <code>true</code> forces the formatting of the value even if it does not change from the previous value. The default is <code>false</code>.</td>
</tr>
<tr>
<td>strict</td>
<td>When set to <code>true</code> requires that any code output using this modal must be present in one of the defined groups. An error will be output if any code is output that is not in one of the groups. Specifying <code>false</code> allows for codes not belonging to a group to be output. Codes that do not belong to a group will always be output, meaning they belong to a non-modal group.</td>
</tr>
</tbody>
</table>

### Output Variable Properties

The code groups are defined as arrays of codes within an array. Each individual group is treated similar to as if it was defined as a separate Modal variable.

```plaintext
var mClampModal = createModalGroup({strict:false},
  [
    [10, 11], // 4th axis clamp / unclamp
    [12, 13] // 5th axis clamp / unclamp
  ],
  mFormat
);

var gCodeGroup = createModalGroup({strict:true, force:false},
```
Once a modal group is created, it can be used to create a formatted text string for output. The following table describes the functions assigned to the modal group object. Group numbers are based on 0, so the first group is referenced as 0, the second as 1, etc. The functions are properties of the defined ModalGroup object and are prefixed by the name of the group, for example mClampModal.disable().

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>addCode(group, code)</td>
<td>Adds the specified code to the given group.</td>
</tr>
<tr>
<td>createGroup</td>
<td>Adds a group to the end of the groups.</td>
</tr>
<tr>
<td>disable ()</td>
<td>Disables all defined groups in this modal from being output. Will cause the return value from the format function to always be a blank string (&quot;&quot;).</td>
</tr>
<tr>
<td>enable()</td>
<td>Enables all defined groups in this modal for output. This is the default condition when the modal is created.</td>
</tr>
<tr>
<td>format(code)</td>
<td>Returns the formatted text string representation of the number. Can return a blank string if the value is the same as the stored value in the ModalGroup object. If the code does not belong to a defined group, then it will always be output if the ModalGroup was defined with strict: false, or an error will be output if strict mode is enabled.</td>
</tr>
<tr>
<td>getActiveCode (group)</td>
<td>Returns the value currently stored in the specified group.</td>
</tr>
<tr>
<td>getGroup(code)</td>
<td>Returns the group id for the specified code. If the code does not belong to a group returns a very large number.</td>
</tr>
<tr>
<td>getNumberOfCodes()</td>
<td>Returns the combined number of codes in all groups.</td>
</tr>
<tr>
<td>getNumberOfCodesInGroup(group)</td>
<td>Returns the number of codes in the specified group.</td>
</tr>
<tr>
<td>getNumberOfGroups()</td>
<td>Returns the number of defined groups.</td>
</tr>
<tr>
<td>hasActiveCode(group)</td>
<td>Returns true if the specified group has a valid code. Returns false if a code has not been formatted in this group or if the group has been reset.</td>
</tr>
<tr>
<td>inSameGroup(code1, code2)</td>
<td>Returns true if the two codes are in the same group.</td>
</tr>
<tr>
<td>isActiveCode(code)</td>
<td>Returns true if the code is active within its group.</td>
</tr>
<tr>
<td>isCodeDefined(code)</td>
<td>Returns true if the code is defined in any of the groups.</td>
</tr>
<tr>
<td>isEnabled()</td>
<td>Returns true if this modal group is enabled for output.</td>
</tr>
<tr>
<td>isGroup(group)</td>
<td>Returns true if the specified group id is defined.</td>
</tr>
<tr>
<td>makeActiveCode(code)</td>
<td>Marks the specified code as the active code within its group.</td>
</tr>
<tr>
<td>removeCode(code)</td>
<td>Removes the specified code from its group.</td>
</tr>
</tbody>
</table>

Sample createModalGroup Commands

```javascript
[0, 1, 2, 3], // group 0 – motion codes
[17, 18, 19], // group 1 – plane selection codes
[80, 81, 82, 83, 84, 85, 86, 87, 88, 89], // group 2 – cycle codes
],
gFormat
)
```
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>reset ()</td>
<td>Resets all groups and forces the output of the formatted text string on the next call to format, overriding the rules for not outputting a value.</td>
</tr>
<tr>
<td>resetGroup(group)</td>
<td>Resets the specified group and forces the output of the formatted text string on the next call to format, overriding the rules for not outputting a value.</td>
</tr>
<tr>
<td>setAutoReset(flag)</td>
<td>Sets the auto-reset mode. When set to true, all groups are reset when a code that is not defined in any group is output. Strict mode must be disabled to output an undefined code.</td>
</tr>
<tr>
<td>setForce(force)</td>
<td>Forces the output of all group codes when enabled, even if the code value is the same as the active code value.</td>
</tr>
<tr>
<td>setFormatNumber(format)</td>
<td>Overrides the format variable assigned to the modal group.</td>
</tr>
<tr>
<td>setPrefix(prefix-text)</td>
<td>Defines the prefix of all groups. If a prefix is defined in the format assigned to the modal group, then the format prefix will be appended to this prefix.</td>
</tr>
<tr>
<td>setSuffix(suffix-text)</td>
<td>Defines the suffix of all groups. If a suffix is defined in the format assigned to the modal group, then the modal group suffix will be appended to the format suffix.</td>
</tr>
</tbody>
</table>

**ModalGroup Functions**

The following sample code shows how a single Modal Group can be used to define the clamping codes for the rotary axes rather than creating two separate Modal variables to store the 4<sup>th</sup> and 5<sup>th</sup> axes clamping codes.

```java
case COMMAND_LOCK_MULTI_AXIS:
    if (machineConfiguration.isMultiAxisConfiguration() &&
        (machineConfiguration.getNumberOfAxes() >= 4)) {
        writeBlock(mClampModal.format(10)); // unlock 4th-axis motion
        if (machineConfiguration.getNumberOfAxes() == 5) {
            writeBlock(mClampModal.format(12)); // unlock 5th-axis motion
        }
    }
    return;

case COMMAND_UNLOCK_MULTI_AXIS:
    if (machineConfiguration.isMultiAxisConfiguration() &&
        (machineConfiguration.getNumberOfAxes() >= 4)) {
        writeBlock(mClampModal.format(11)); // unlock 4th-axis motion
        if (machineConfiguration.getNumberOfAxes() == 5) {
            writeBlock(mClampModal.format(13)); // unlock 5th-axis motion
        }
    }
```

**Sample Modal Group Code**
5.1.13 Fixed Settings

The fixed settings area of the global section defines settings in the post processor that enable features that may change from machine to machine, but are not common enough to place in the Property Table. These settings are usually not modified by the post processor, but can be modified to enable features on your machine that are disabled in a stock post processor or vice versa.

```javascript
// fixed settings
var firstFeedParameter = 500;
var useMultiAxisFeatures = false;
var forceMultiAxisIndexing = false; // force multi-axis indexing for 3D programs
var maximumLineLength = 80; // the maximum number of characters allowed in a line
var minimumCyclePoints = 5; // min number of points in cycle operation to consider for subprogram

var WARNING_WORK_OFFSET = 0;
var ANGLE_PROBE_NOT_SUPPORTED = 0;
var ANGLE_PROBE_USE_ROTATION = 1;
var ANGLE_PROBE_USE_CAXIS = 2;
```

Sample Fixed Settings Code

5.1.14 Collected State

The collected state area of the global section contains global variables that will be changed during the execution of the post processor and are either referenced in multiple functions or need to maintain their values between calls to the same function.

```javascript
// collected state
var sequenceNumber;
var currentWorkOffset;
```

Sample Collected State Code

5.2 onOpen

```javascript
function onOpen() {
```

The `onOpen` function is called at start of each CAM operation and can be used to define settings used in the post processor and output the startup blocks.

1. Define settings based on properties
2. Define the multi-axis machine configuration
3. Output program name and header
4. Perform checks for duplicate tool numbers and work offsets
5. Output initial startup codes
5.2.1 Define Settings Based on Post Properties

The fixed settings section at the top of the post processor contain settings that are fixed and will not be changed during the processing of the intermediate file. Settings and variables that are dependant on the properties defined in the Property Table are defined in the onOpen function, since this is the function called when the post processor first starts.

Some of the variables that may be defined here are the maximum circular sweep, starting sequence number, formats, properties that can be changed using a Manual NC command, etc.

```plaintext
if (getProperty("useRadius")) {
    maximumCircularSweep = toRad(90); // avoid potential center calculation errors for CNC
}

// define sequence number output
if (getProperty("sequenceNumberOperation")) {
    setProperty("showSequenceNumbers", false);
} else {
    sequenceNumber = getProperty("sequenceNumberStart");
}

// separate codes with a space in output block
if (!getProperty("separateWordsWithSpace")) {
    setWordSeparator(" ");
}

// Manual NC command can change the transfer type
transferType = parseToggle(getProperty("transferType"), "PHASE", "SPEED");
```

Defining Dynamic Variables in the onOpen Function

The majority of machines on the market today accept input in both inches and millimeters. It is possible that your machine must be programmed in only one unit. If this is the case, then you can define the unit variable in the onOpen function to force the output of all relevant information in inches or millimeters.

```plaintext
unit = MM; // set output units to millimeters, use IN for inches
```

Support for Only One Input Unit

5.2.2 Define the Multi-Axis Configuration

The onOpen function contains calls to the functions that will optionally create a hardcode machine configuration and activate the machine configuration, whether it be hardcoded or defined in the CAM system. Following is an example of this code. For a complete description of defining a multi-axis configuration please see the Multi-Axis Post Processors chapter.

```plaintext
// define and enable machine configuration
receivedMachineConfiguration = (typeof machineConfiguration.isReceived == "function") ?
    machineConfiguration.isReceived() :
```

Entry Functions 5-120
((machineConfiguration.getDescription() != "") ||
machineConfiguration.isMultiAxisConfiguration());
if (typeof defineMachine == "function") {
defineMachine(); // hardcoded machine configuration
} activateMachine(); // enable the machine optimizations and settings

5.2.3 Output Program Name and Header

The program name and program comment are defined in the Post Process tab of the CAM setup in HSM. The **programNameIsInteger** variable defined at the top of the program determines if the program name needs to be a number or can be a text string.

```java
writeln("%"); // output start of NC file
if (programName) {
    var programId;
    try {
        programId = getAsInt(programName);
    } catch(e) {
        error(localize("Program name must be a number."));
        return;
    }
    if ( !(programId >= 1) && (programId <= 99999)) {
        error(localize("Program number is out of range."));
        return;
    }
    writeln(  
        "O" + oFormat.format(programId) +
        conditional(programComment, " " + formatComment(programComment.substr(0,
```
maximumLineLength - 2 - ("O" + oFormat.format(programId)).length - 1))
    lastSubprogram = programId;
} else {
    error(localize("Program name has not been specified."));
    return;
}

Output the Program Name as an Integer and Program Comment

Some machines don't use a program number and accept the program name as a comment.

writeln("%"); // output start of NC file
if (programName) {
    writeComment(programName);
} else {
    error(localize("Program name has not been specified.

Output the Program Name as a Comment

The program header can consist of the output filename, version numbers, the run date and time, the
description of the machine, the list of tools used in the program, and setup notes.

// Output current run information
if (hasParameter("generated-by") && getParameter("generated-by")) {
    writeComment("            " + localize("CAM") + ": " + getParameter("generated-by"));
} else {
    writeComment("            " + localize("Post Processor") + ": " + getParameter("generated-by"));
} else {
    writeComment("            " + localize("Document") + ": " + getParameter("document-path"));
} else {
    var eos = longDescription.indexOf(");
    writeComment(localize(" Post Processor: ") + ((eos == -1) ?
        longDescription : longDescription.substr(0, eos + 1)));
    if ((typeof getHeaderVersion == "function") && getHeaderVersion()) {
        writeComment("       " + localize("Post version") + ": " + getHeaderVersion());
    } else {
        writeComment("       " + localize("Post modified") + ": " + getHeaderDate());
    } else {
        var d = new Date(); // output current date and time
        writeComment("            " + localize("Date") + ": " + d.toLocaleDateString() + " " +
            d.toLocaleTimeString());
}

Output the Description of the Current Run

// dump machine configuration
var vendor = machineConfiguration.getVendor();
```javascript
var model = machineConfiguration.getModel();
var description = machineConfiguration.getDescription();

if (getProperty("writeMachine") && (vendor || model || description)) {
    writeComment(localize("Machine"));
    if (vendor) {
        writeComment(" " + localize("vendor") + ": " + vendor);
    }
    if (model) {
        writeComment(" " + localize("model") + ": " + model);
    }
    if (description) {
        writeComment(" " + localize("description") + ": " + description);
    }
}

Output Machine Information

In the above code sample, the machine information is retrieved from the Machine Definition, but a Machine Definition file is not always available to the post processor, so it is possible to hard code the machine description.

```
Output List of Tools Used

The `getToolList` function is used to obtain the list of tools used in the program based on the arguments passed to the function. It returns an array of objects that define the tool, Z-levels, and operations that each individual tool is used in.

```
getToolList(arguments, flag);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>arguments</td>
<td>Any number of string arguments, which are the comparison criteria for determining if a tool is different from a previously found tool. These can be &quot;number&quot;, &quot;description&quot;, &quot;lengthCompensation&quot;, or any other property in the tool object. The tool number is checked if there are no arguments.</td>
</tr>
<tr>
<td>flag</td>
<td>A bitwise of SORT or NOSORT and DUPLICATES or NODUPLICATES. For example, SORT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Return Objects</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>tool</td>
<td>The Tool object.</td>
</tr>
<tr>
<td>range</td>
<td>A Range object defining the minimum and maximum Z-levels reached for this tool.</td>
</tr>
<tr>
<td>operations</td>
<td>An array containing the Section Ids that the tool is used in. You can obtain the Section object from the Id by calling <code>getSection(id)</code>.</td>
</tr>
</tbody>
</table>

The `getToolList` Function

The following code is used to output the notes from the first setup. The property `showNotes` is defined in the properties, see the `Operation Comments and Notes` section to see how to define this property.

```
// output setup notes
if (getProperty("showNotes")) {
    writeSetupNotes();
}
```

Output Notes from First Setup

If your post needs to output the notes from multiple setups, then additional code outside of `onOpen` needs to be added.

First, define the `firstNote` property in the collected state section of the post.

```
// collected state
...
var firstNote; // handles output of notes from multiple setups
```

Define the `firstNote` Global Variable
In the onParameter function define the logic to process the *job-notes* parameter.

```javascript
function onParameter(name, value) {
    switch (name) {
        ...
        case "job-notes":
            if (!firstNote) {
                writeNotes(value, true);
            }
            firstNote = false;
            break;
    }
}
```

Handle the Setup Notes in onParameter

And finally, implement the *writeText* function. It can be placed in front of the *onParameter* function. This function can also be used to output the text from the *Pass through* Manual NC command.

```javascript
// writes out multi-line text either as-is or as a comment
function writeNotes(text, asComment) {
    if (text) {
        var lines = String(text).split("\n");
        var r2 = new RegExp("[\s]+$", "g");
        for (line in lines) {
            var comment = lines[line].replace(r2, "");
            if (comment) {
                if (asComment) {
                    onComment(comment);
                } else {
                    writeln(comment);
                }
            }
        }
    }
}
```

The *writeNotes* function is used to output multi-line text.

### 5.2.4 Performing General Checks

Basic checks for using duplicate tool numbers, undefined work offsets, and other requirements can be done in the *onOpen* function since all operations can be accessed at any time during post processing.

```javascript
if (false) { // set to true to check for duplicate tool numbers w/different cutter geometry
    // check for duplicate tool number
    for (var i = 0; i < getNumberOfSections(); ++i) {
```
var sectioni = getSection(i);
var tooli = sectioni.getTool();
for (var j = i + 1; j < getNumberOfSections(); ++j) {
  var sectionj = getSection(j);
  var toolj = sectionj.getTool();
  if (tooli.number == toolj.number) {
    if (xyzFormat.areDifferent(tooli.diameter, toolj.diameter) ||
        xyzFormat.areDifferent(tooli.cornerRadius, toolj.cornerRadius) ||
        abcFormat.areDifferent(tooli.taperAngle, toolj.taperAngle) ||
        (tooli.numberOfFlutes != toolj.numberOfFlutes)) {
      error(
        subst(
          localize("Using the same tool number for different cutter geometry for operation '%%I' and '%%2'."),
          sectioni.hasParameter("operation-comment") ?
            sectioni.getParameter("operation-comment") : ("#" + (i + 1)),
          sectionj.hasParameter("operation-comment") ?
            sectionj.getParameter("operation-comment") : ("#" + (j + 1))
        );
      return;
    }
  }
}

Check for Duplicate Tool Numbers using Different Cutter Geometry

// don't allow WCS 0 unless it is the only WCS used in the program
if ((getNumberOfSections() > 0) && (getSection(0).workOffset == 0)) {
  for (var i = 0; i < getNumberOfSections(); ++i) {
    if (getSection(i).workOffset > 0) {
      error(localize("Using multiple work offsets is not possible if the initial work offset is 0.")));
      return;
    }
  }
}

Check for Work Offset 0 when Multiple Work Offsets are Used in Program

5.2.5 Output Initial Startup Codes
Codes that set the machine to its default condition are usually output at the beginning of the NC file. These codes could include the units setting, absolute mode, the feedrate mode, etc.

// output default codes
writeBlock(gAbsIncModal.format(90), gFeedModeModal.format(94), gPlaneModal.format(17),
gFormat.format(49), gFormat.format(40), gFormat.format(80));

// output units code
switch (unit) {
  case IN:
    writeBlock(gUnitModal.format(20));
    break;
  case MM:
    writeBlock(gUnitModal.format(21));
    break;
}

Output Initial Startup Codes

5.3 onSection

function onSection() {

The onSection function is called at start of each CAM operation and controls the output of the following blocks.

1. End of previous section
2. Operation comments and notes
3. Tool change
4. Work plane
5. Initial position

![Diagram showing setups and tool configurations]

onSection is Called for Each Operation
The first part of `onSection` determines if there is a change in the tool being used and if the Work Coordinate System offset or Work Plane is different from the previous section. These settings determine the output required between operations.

```javascript
var insertToolCall = isToolChangeNeeded("number");
var newWorkOffset = isFirstSection() ||
  (getPreviousSection().workOffset != currentSection.workOffset); // work offset changes
var newWorkPlane = isNewWorkPlane();
```

### 5.3.1 Ending the Previous Operation

You would expect that the NC blocks output at the end of an operation to be output in the `onSectionEnd` function, but in most posts, this is handled in `onSection` and for the final operation, in the `onClose` function. This code will typically stop the spindle, turn off the coolant, and retract the tool.

```javascript
if (insertToolCall || newWorkOffset || newWorkPlane) {

  // stop spindle before retract during tool change
  if (insertToolCall && !isFirstSection()) {
    onCommand(COMMAND_STOP_SPINDLE);
  }

  // retract to safe plane
  writeRetract(Z);
}

... onCommand(COMMAND_COOLANT_OFF);

... if (!isFirstSection() && getProperty("optionalStop")) {
    onCommand(COMMAND_OPTIONAL_STOP);
}
```

The code to retract the tool can vary from post to post, depending on the controller model and the machine configuration. It can output an absolute move to the machine home position, for example using G53, or move to a clearance plane relevant to the current work offset, for example G00 Z5.0.

The `onSectionEnd` section has an example of ending the operation when not done in the `onSection` function.
5.3.2 Operation Comments and Notes

The operation comment is output in the onSection function and optionally notes that the user attached to the operation.

```javascript
var comment = getParameter("operation-comment", "");
if (comment) {
    writeComment(comment);
}
```

Create Operation Comment

Output Operation Comment

Right Click to Show Menu to Create Operation Notes
The output of the operation notes is normally handled by the post processor property `showNotes`.

```javascript
// user-defined properties
properties = {
    ...
    showNotes: {
        title      : "Show notes",
        description: "Writes setup and operation notes as comments in the output code.",
        type       : "boolean",
        value      : false,
        scope      : "post"
    },
    ...
}
```

**Define the showNotes Property**

```javascript
// output section notes
if (getProperty("showNotes")) {
    writeSectionNotes();
}
```

**Output Operation Notes**

### 5.3.3 Tool Change

Tool change blocks are output whenever a new tool is loaded in the spindle or the tool change is forced, either by a Manual NC Force tool change command or internally, for example when a safe start is forced at each operation. The tool change blocks usually contain the following information.

1. Tool number and tool change code
2. Tool comment
3. Comment containing lower Z-limit for tool (optional)
4. Selection of next tool
5. Spindle speed and direction
6. Coolant codes
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The Length Offset value is usually output with the Initial Position as described further in this chapter. The Diameter Offset value is output with a motion block in onLinear. All other tool parameters are output in the tool change code.

```
if (insertToolCall) {
  ...
  if (tool.number > numberOfToolSlots) {
    warning(localize("Tool number exceeds maximum value."));
  }
  writeBlock("T" + toolFormat.format(tool.number), mFormat.format(6));
  if (tool.comment) {
    writeComment(tool.comment);
  }
  ...
```

Output Tool Change and Tool Comment

You will have to change the setting of showToolZMin to true if you want the lower Z-limit comment output at a tool change.

```
var showToolZMin = true;
if (showToolZMin) {
  if (is3D()) {
    var zRange = toolZRange();
    writeComment(localize("ZMIN") + "=" + zRange.getMinimum());
  }
}
```

Output Lower Limit of Z for This Operation
The selection of the next tool is optional and is controlled by the post processor property `preloadTool`.

```javascript
// user-defined properties
properties = {
    ...
    preloadTool: {
        title: "Preload tool",
        description: "Preloads the next tool at a tool change (if any).",
        type: "boolean",
        value: true,
        scope: "post"
    }
}
```

Define the `preloadTool` Property

The first tool will be loaded on the last operation of the program.

```javascript
// preload next tool
if (getProperty("preloadTool")) {
    var nextTool = getNextTool("number");
    if (nextTool) {
        writeBlock("T" + toolFormat.format(nextTool.number));
    } else {
        // preload first tool
        var firstToolNumber = getFirstTool().number;
        if (tool.number != firstToolNumber) {
            writeBlock("T" + toolFormat.format(firstToolNumber));
        }
    }
}
```

Preload the Next Tool

The spindle codes will be output with a tool change and if the spindle speed changes.

```javascript
if (insertToolCall ||
    isFirstSection() ||
    (rpmFormat.areDifferent(tool.spindleRPM, sOutput.getCurrent()))) ||
    (tool.clockwise != getPreviousSection().getTool().clockwise)) {
    if (tool.spindleRPM < 1) {
        error(localize("Spindle speed out of range."));
        return;
    }
    if (tool.spindleRPM > 99999) {
        warning(localize("Spindle speed exceeds maximum value."));
    }
    writeBlock(
```
Output Spindle Codes

You will find different methods of outputting the coolant codes in the various posts. The latest method uses a table to define the coolant on and off codes. The table is defined just after the properties table at the top of the post processor. You can define a single code for each coolant mode or multiple codes using an array. When adding or changing the coolant codes supported by your machine, this is the only area of the code that needs to be changed.

```javascript
var singleLineCoolant = false; // specifies to output multiple coolant codes in one line rather than in separate lines
// samples:
// {id: COOLANT_THROUGH_TOOL, on: 88, off: 89}
// {id: COOLANT_THROUGH_TOOL, on: [8, 88], off: [9, 89]}
var coolants = [
    {id: COOLANT_FLOOD, on: 8},
    {id: COOLANT_MIST},
    {id: COOLANT_THROUGH_TOOL, on: 88, off: 89},
    {id: COOLANT_AIR},
    {id: COOLANT_AIR_THROUGH_TOOL},
    {id: COOLANT_SUCTION},
    {id: COOLANT_FLOOD_MIST},
    {id: COOLANT_FLOOD_THROUGH_TOOL, on: [8, 88], off: [9, 89]},
    {id: COOLANT_OFF, off: 9}
];
```

Coolant Definition Table

The coolant code is output using the following code in `onSection`.

```javascript
// set coolant after we have positioned at Z
setCoolant(tool.coolant);
```

Output of Coolant Codes

The `setCoolant` function will output each coolant code in separate blocks. It does this by calling the `getCoolantCodes` function to obtain the coolant code(s) and using `writeBlock` to output each individual coolant code. Both of these functions are generic in nature and should not have to be modified.

It may be that you want to output the coolant codes(s) in a block with other codes, such as the initial position or the spindle speed. In this case you can call `getCoolantCodes` directly in the `onSection` function and add the output of the coolant codes to the appropriate block. The following example will output the coolant codes with the initial position of the operation.

```javascript
var coolantCodes = getCoolantCodes(tool.coolant);
var initialPosition = getFramePosition(currentSection.getInitialPosition());
```
5.3.4 Work Coordinate System Offsets

The active Work Coordinate System (WCS) offset is defined in the CAM Setup dialog. You can override the WCS defined in the setup in either a folder or pattern. The wcsDefinitions variable defines the supported WCS codes that can be output and it is recommended that you include this variable definition in your post. All examples in this section assume that wcsDefinitions is defined.

If a CAM Machine Definition is defined the WCS can be selected using the number as expected by the machine control. When a CAM Machine Definition is not defined, then a simple value will be displayed.

WCS Offset with a Machine Definition

WCS Offset without a Machine Definition

WCS codes are output when a new tool is used for the operation or when the WCS offset number used is changed. WCS offsets are typically controlled using the G54 to G59 codes and possibly an extended syntax for handling work offsets past 6.

wcsDefinitions is defined just after the coolants table at the top of the post processor.

```javascript
var wcsDefinitions = {
  useZeroOffset: false, // set to 'true' to allow for workoffset 0, 'false' treats 0 as 1
  wcs : [
    { name:"Standard", format:"G", range:[54, 59]} // standard WCS, output as G54-G59
    { name:"Extended", format:"G59.#", range:[1, 64]} // extended WCS, output as G59.7, etc.
  ]
};
```
// {name:"Extended", format:"G54 P#", range:[1, 64]} // extended WCS, output as G54 P7, etc.
}
);

### Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>useZeroOffset</td>
<td>Set to <code>true</code> to enable a work offset value of 0. Setting it to <code>false</code> will treat a work offset of 0 as 1.</td>
</tr>
<tr>
<td>wcsc</td>
<td>Contains the definitions of the supported WCS formats.</td>
</tr>
<tr>
<td>name</td>
<td>The name of the WCS output format. This will usually be Standard or Extended. The name is displayed in the Format field of the Machine WCS frame.</td>
</tr>
<tr>
<td>format</td>
<td>The output format of the WCS. This is a text string that has an optional # character that defines where the offset value will be placed. If # is not specified, then the offset value will be placed at the end of the string. You can also use multiple consecutive # characters to define the number of digits to output with the WCS value, for example <code>P##</code> will output P01. Specifying <code>$#</code> will place a # character in the output.</td>
</tr>
<tr>
<td>range</td>
<td>Defines the valid range of work offsets for the defined format.</td>
</tr>
</tbody>
</table>

#### The wcsDefinitions Variable

The post processor kernel will format the output WCS code based on the format defined in wcsDefinitions. Both a string and number is available to the post processor in the section object.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section.wcs</td>
<td>The output code of the work offset (G54, G51 P1, etc.).</td>
</tr>
<tr>
<td>section.workOffset</td>
<td>The work offset number.</td>
</tr>
</tbody>
</table>

```javascript
// wcs
if (insertToolCall) { // force work offset when changing tool
    currentWorkOffset = undefined;
}

if (currentSection.workOffset != currentWorkOffset) {
    writeBlock(currentSection.wcs);
    currentWorkOffset = currentSection.workOffset;
}
```

#### Output the Work Coordinate System Offset Number

### 5.3.5 Work Plane – 3+2 Operations

3+2 operations are supported by defining a tool orientation for the operation. This tool orientation is referenced as the Work Plane in the post processor. The tool orientation is defined in the Geometry tab of the operation.
The output for a Work Plane will either be the rotary axes positions or the definition of the Work Plane itself as Euler angles. For machine controls that support both formats the `useMultiAxisFeatures` variable determines the Work Plane method to use. This variable, along with other variables that control 3+2 operations, is defined with the machine configuration settings and functions towards the top of the post processor.

```cpp
// Start of machine configuration logic
...
var useMultiAxisFeatures = false; // enable to use control enabled tilted plane
var useABCPrepositioning = false; // enable to preposition rotary axes prior to tilted plane output
var forceMultiAxisIndexing = false; // force multi-axis indexing for 3D programs
var eulerConvention = EULER_ZXZ_R; // euler angle convention for 3+2 operations
```
Definition of Variables for Tilted Plane Support

<table>
<thead>
<tr>
<th>variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>useMultiAxisFeatures</td>
<td>Enable this setting when the control supports tilted plane codes for 3+2 operations, such as G68.2, CYCLE800, PLANE SPATIAL, DWO, etc. When it is disabled, the rotary axes will be output for 3+2 operations and the output coordinates could be adjusted for the tables/heads based on the TCP setting for each axis.</td>
</tr>
<tr>
<td>useABCPrepositioning</td>
<td>Enable to position the rotary axes prior to the output of the tilted plane. Disable to only output the tilted plane. This variable is only used when useMultiAxisFeatures is set to true.</td>
</tr>
<tr>
<td>forceMultiAxisIndexing</td>
<td>Forces the output of the rotary axes/tilted plane when the program is purely 3-axis. Disabling this variable will not output the rotary axis positions if the entire program is 3-axis.</td>
</tr>
<tr>
<td>eulerConvention</td>
<td>Defines the order of the Euler angle calculations that is required by the machine for tilted plane output. If the post processor does not support Euler angles, then this setting will be ignored.</td>
</tr>
</tbody>
</table>

Variables that Control the Output of 3+2 Operations

The eulerConvention setting is passed to the getEuler2 function and is used to calculate the Euler angles for the Work Plane. It specifies the order of the primary axis rotations that the machine control requires and can be one of the values in the following table.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter</th>
<th>Parameter</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>EULER_XYZ_R</td>
<td>EULER_XYX_R</td>
<td>EULER_XZX_R</td>
<td>EULER_XZY_R</td>
</tr>
<tr>
<td>EULER_YXY_R</td>
<td>EULER_XYZ_R</td>
<td>EULER_YZX_R</td>
<td>EULER_YZY_R</td>
</tr>
<tr>
<td>EULER_ZXY_R</td>
<td>EULER_ZXZ_R</td>
<td>EULER_ZYX_R</td>
<td>EULER_ZYZ_R</td>
</tr>
<tr>
<td>EULER_XYZ_S</td>
<td>EULER_XYX_S</td>
<td>EULER_XZX_S</td>
<td>EULER_XZY_S</td>
</tr>
<tr>
<td>EULER_YXY_S</td>
<td>EULER_XYZ_S</td>
<td>EULER_YZX_S</td>
<td>EULER_YZY_S</td>
</tr>
<tr>
<td>EULER_ZXY_S</td>
<td>EULER_ZXZ_S</td>
<td>EULER_ZYX_S</td>
<td>EULER_ZYZ_S</td>
</tr>
</tbody>
</table>

Euler Angle Order

Check the Programming Manual for your machine to determine if Euler angles are supported and the order of rotations. The _R (rotated) variants of the Euler angles will use the modified orientation after each rotation for each axis. The _S (static) variants will use the original coordinate system for all rotations and is sometimes referred to as pitch, row, yaw.

The useMultiAxisFeatures and useABCPrepositioning variables can be controlled from the post processor properties, simply adding a property with the same name. The activateMachine function automatically checks for this property and will use it if it is defined.

```plaintext
properties = {
  ...
  useMultiAxisFeatures: {
    title: "Use G68.2",
    ...
  }...
```

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### Description

"Enable to output G68.2 blocks for 3+2 operations, disable to output rotary angles."

- **Type:** boolean
- **Value:** true
- **Scope:** ["machine", "post"], 
- **Group:** "multiaxis"

#### Use ABC Prepositioning

- **Title:** "Preposition rotaries"
- **Description:** "Enable to preposition rotary axes prior to G68.2 blocks."
- **Scope:** ["machine", "post"], 
- **Group:** "multiaxis"
- **Type:** boolean
- **Value:** true

---

**Defining useMultiAxisFeatures and useABCPrepositioning as Properties**

The code handling 3+2 operations is usually found in the `defineWorkPlane` function but can also be defined as inline code within the `onSection` function. The preferred method is using the `defineWorkPlane` function, which controls the calculation and output of the rotary angles for multi-axis and 3+2 operations. `defineWorkPlane` will be called from `onSection`.

```javascript
// position rotary axes for multi-axis and 3+2 operations
var abc = defineWorkPlane(currentSection, true);
```

**Calling the defineWorkPlane Function**

The `defineWorkPlane` function is defined as follows and returns the initial rotary positions for multi-axis and 3+2 operations.

```javascript
defineWorkPlane(_section, _setWorkPlane)
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>_section</td>
<td>The operation (section) used to calculate the rotary angles.</td>
</tr>
<tr>
<td>_setWorkPlane</td>
<td><code>true</code> = output the rotary angle positions and adjust the output coordinates for the 3+2 rotation. <code>false</code> = don’t output the rotary angle positions. The rotary angles will still be calculated and the output coordinates will be adjusted for the 3+2 rotation.</td>
</tr>
</tbody>
</table>

**The defineWorkPlane Function**

```javascript
// use Euler angles for Work Plane
if (useMultiAxisFeatures) {
  var abc = _section.workPlane.getEuler2(eulerConvention);
  cancelTransformation();
  // use rotary angles for Work Plane
} else {
  abc = getWorkPlaneMachineABC(_section.workPlane, true);
}
```
// output the work plane
if (_setWorkPlane) {
    setWorkPlane(abc);
}
}

Work Plane Calculations

The function getWorkPlaneMachineABC is used to calculate the rotary axes positions that satisfy the Work Plane. It will return the calculated angles of either the rotary axis or tilted plane positions.

getWorkPlaneMachineABC(workPlane, rotate)

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>workPlane</td>
<td>The work plane matrix used to calculate the rotary-angles. This variable is typically section.workPlane.</td>
</tr>
<tr>
<td>rotate</td>
<td>Enable to adjust the output coordinates for the work plane orientation. Disable to just calculate the rotary angles and not adjust the XYZ coordinates for the axis rotations.</td>
</tr>
</tbody>
</table>

The getWorkPlaneMachineABC Function

This function is standard from post to post, but there are a couple of areas that may need to be modified.

The first step is to calculate the rotary angles based on the work plane orientation by calling the getABCByPreference function.

```javascript
var currentABC = isFirstSection() ? new Vector(0, 0, 0) : getCurrentDirection();
var abc = machineConfiguration.getABCByPreference(W, currentABC, ABC, PREFER_PREFERENCE, ENABLE_ALL);
```

Calculate the Rotary Axis Angles Based on the Work Plane

```javascript
abc = machineConfiguration.getABCByPreference(workPlane, current, controllingAxis, type, options);
abc = section.getABCByPreference(machineConfiguration, workPlane, current, controllingAxis, type, options);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>machineConfiguration</td>
<td>The machine configuration. This parameter is only specified with the section.getABCByPreference version.</td>
</tr>
<tr>
<td>workPlane</td>
<td>The work plane matrix used to calculate the rotary-angles. This variable is typically section.workPlane.</td>
</tr>
<tr>
<td>current</td>
<td>The current rotary angles. This is usually the ABC position returned by getCurrentDirection. In the first operation this value is set to a tool axis, so the current rotary angles are defined as 0,0,0 in this case.</td>
</tr>
<tr>
<td>controllingAxis</td>
<td>The axis used to determine the preferred solution in conjunction with the type argument. It can be A, B, or C for a single axis, or ABC to consider all defined rotary axes.</td>
</tr>
</tbody>
</table>
Arguments | Description |
---|---|
**type** | The preference type as described in the Preference Type table. |
**options** | Options used to control the solution as described in the Controlling Options table. |

The getABCByPreference Function

<table>
<thead>
<tr>
<th>Preference Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREFER_PREFERENCE</td>
<td>Uses the preference specified with the axis, either in the CAM Machine Definition or in the <code>createAxis</code> function for hardcoded kinematics.</td>
</tr>
<tr>
<td>PREFER_CLOSEST</td>
<td>Selects the solution closest to the current rotary axes position. All preference types will choose the closest solution that satisfies the preference type chosen. PREFER_CLOSEST will select the closest solution without regards to any other preference.</td>
</tr>
<tr>
<td>PREFER_POSITIVE</td>
<td>The closest solution with a positive angle for the controlling axis. This preference cannot be used when ABC is the controlling axes.</td>
</tr>
<tr>
<td>PREFER_NEGATIVE</td>
<td>The closest solution with a negative angle for the controlling axis. This preference cannot be used when ABC is the controlling axes.</td>
</tr>
<tr>
<td>PREFER_CLW</td>
<td>The closes solution that moves in a clockwise direction from the current axis position. This preference cannot be used when ABC is the controlling axes.</td>
</tr>
<tr>
<td>PREFER_CCW</td>
<td>The closes solution that moves in a counterclockwise direction from the current axis position. This preference cannot be used when ABC is the controlling axes.</td>
</tr>
</tbody>
</table>

The Preferred Solution Types

<table>
<thead>
<tr>
<th>Controlling Options</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENABLE_NONE</td>
<td>Disables all controlling options.</td>
</tr>
<tr>
<td>ENABLE_RESET</td>
<td>Respects the <code>reset</code> parameter in the axis definitions. The <code>reset</code> parameter resets the axis to 0 degrees before calculating the closest solution.</td>
</tr>
<tr>
<td>ENABLE_WCS</td>
<td>Solves for a rotary axis perpendicular to the spindle vector as defined by the tool orientation of the operation. For example, if the tool orientation is facing up in Z and has an XY-rotation, then the C-axis will use the X-axis orientation of the rotation to determine the C-axis position.</td>
</tr>
<tr>
<td>ENABLE_LIMITS</td>
<td>Solves for a rotary axis perpendicular to the spindle vector to keep the linear axes within their defined limits. The limits (range) of the linear axes must be defined in the machine configuration. This option is only valid for the <code>section.getABCByPreference</code> version.</td>
</tr>
<tr>
<td>ENABLE_ALL</td>
<td>Enables all controlling options.</td>
</tr>
</tbody>
</table>

The Controlling Options for the Rotary Axes Solution
There are two variations of the `getABCByPreference` function, one in the `machineConfiguration` object and the other in the `section` object. The only difference between the two is that the `section` function supports the ENABLE_LIMITS option, while the `machineConfiguration` function does not. The ENABLE_LIMITS works with rotary tables that are perpendicular to the spindle vector and will adjust the rotary table position to bring the linear XYZ coordinates within their defined limits if possible. If it is not possible to bring the machine within its limits, then the calculated rotary axis positions will be the same as if ENABLE_LIMITS was not specified.

You must define the limits of the linear axes in the machine configuration when using ENABLE_LIMITS. The limits can be defined as part of an external Machine Definition or hardcoded within the post processor if a Machine Definition is not used.
// define linear axes limits
var xAxis = createAxis({actuator: "linear", coordinate: 0, table: true, axis: [1, 0, 0], range: [xAxisMinimum, xAxisMaximum]});
var yAxis = createAxis({actuator: "linear", coordinate: 1, table: true, axis: [0, 1, 0], range: [yAxisMinimum, yAxisMaximum]});
var zAxis = createAxis({actuator: "linear", coordinate: 2, table: true, axis: [0, 0, 1], range: [-100000, 100000]});
machineConfiguration.setAxisX(xAxis);
machineConfiguration.setAxisY(yAxis);
machineConfiguration.setAxisZ(zAxis);

Defining the Limits of the Linear Axes in the Post Processor

Since the `getABCByPreference` function will return a rotary axis position even if the machine is not within the defined linear limits, you must call the `doesToolPathFitWithinLimits` function to determine if the calculated rotary axis position will keep the machine within limits for this operation.

```javascript
bestABC = section.getABCByPreference(machineConfiguration, section.workPlane, getCurrentDirection(), C, PREFER_CLOSEST, ENABLE_RESET | ENABLE_LIMITS);
bestABC = section.doesToolpathFitWithinLimits(machineConfiguration, bestABC) ?
  bestABC : undefined;
```

Determine if Linear Axes are Within Limits

```javascript
withinLimits = section.doesToolpathFitWithinLimits(machineConfiguration, abc)
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>machineConfig</td>
<td>The machine configuration.</td>
</tr>
<tr>
<td>abc</td>
<td>The rotary angle positions used to determine if the linear XYZ axes are within their defined limits.</td>
</tr>
</tbody>
</table>

The `doesToolpathFitWithinLimits` Function

The 3+2 operation coordinates may need to be adjusted for the rotary axes. This is done by calling `section.optimize3DPositionsByMachine` with the rotary axes and optimization type. Most posts will use the Tool Control Point (TCP) setting for each axis by using the OPTIMIZE_AXIS setting.

```javascript
if (!currentSection.isOptimizedForMachine()) {
  machineConfiguration.setToolLength(addToolLength ? getBodyLength(tool) : null); // define the tool length for head adjustments
  currentSection.optimize3DPositionsByMachine(machineConfiguration, abc, OPTIMIZE_AXIS);
}
```

Adjust the Coordinates for the Rotary Axes

It is important to know that the XYZ coordinates provided to the post processor for 3+2 are in the work plane coordinate system, meaning they are in the XY-plane defined by the work plane. This is fine for machines that support multi-axis features such as G68.2, CYCLE800, etc., but could be incorrect for machines that do not support these features.

Entry Functions 5-142
The `section.optimize3DPositionsByMachine` function is used to calculate the proper coordinates aligned with the defined machine configuration for the specified operation.

```plaintext
section.optimize3DPositionsByMachine(machineConfiguration, abc, optimizeType);
```

Adjust the Coordinates for the Machine Configuration for 3+2 Machining

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>machineConfiguration</td>
<td>The active machine configuration.</td>
</tr>
<tr>
<td>abc</td>
<td>The current rotary axis positions passed as a Vector.</td>
</tr>
<tr>
<td>optimizeType</td>
<td>Optimization type as described in the following table.</td>
</tr>
</tbody>
</table>

**Optimize3DPositionsByMachine Arguments**

<table>
<thead>
<tr>
<th>optimizeType</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIMIZE_NONE</td>
<td>The coordinates will be the tool tip position (TCP).</td>
</tr>
<tr>
<td>OPTIMIZE_BOTH</td>
<td>The coordinates will be adjusted for the table and head rotations. The TCP</td>
</tr>
<tr>
<td></td>
<td>settings for the axes will be ignored</td>
</tr>
<tr>
<td>OPTIMIZE_TABLES</td>
<td>The coordinates will be adjusted for the rotary tables. The TCP settings for</td>
</tr>
<tr>
<td></td>
<td>the axes will be ignored</td>
</tr>
<tr>
<td>OPTIMIZE_HEADS</td>
<td>The coordinates will be adjusted for the rotary heads. The TCP settings for</td>
</tr>
<tr>
<td></td>
<td>the axes will be ignored</td>
</tr>
<tr>
<td>OPTIMIZE_AXIS</td>
<td>The coordinates will be adjusted based on the TCP setting for each axis as</td>
</tr>
<tr>
<td></td>
<td>defined in the Machine Definition or <code>createAxis</code> command.</td>
</tr>
</tbody>
</table>

**Optimization Types for 3+2 Operations**

If TCP positions are output in a 3+2 operation you will have to ensure that the TCP has been enabled for this operation (G43.4, TRAORI, etc.).

The logic that controls the Work Plane calculation is typically located in the `defineWorkPlane` section, but can be in the `onSection` function for legacy post processors.

```plaintext
var abc = new Vector(0, 0, 0);
// use 5-axis indexing for multi-axis mode
if (!is3D() || machineConfiguration.isMultiAxisConfiguration()) {
    if (currentSection.isMultiAxis()) {
        forceWorkPlane();
        cancelTransformation();
    } else {
        // use Euler angles for Work Plane
        if (useMultiAxisFeatures) {
            var eulerXYZ = currentSection.workPlane.getEuler2(EULER_ZXZ_R);
            abc = new Vector(eulerXYZ.x, eulerXYZ.y, eulerXYZ.z);
            cancelTransformation();
        // use rotary axes angles for Work Plane
        } else {
```
abc = getWorkPlaneMachineABC(currentSection.workPlane, true, true);
}

// output the work plane
setWorkPlane(abc);
}
} else { // pure 3D
var remaining = currentSection.workPlane;
if (!isEqualDirection(remaining.forward, new Vector(0, 0, 1))) {
    error(localize("Tool orientation is not supported.");
    return abc;
}
s.setRotation(remaining);
}

Work Plane Calculations

You should be aware that the X-axis direction of the Work Plane does affect the Euler angle calculation. The typical method of defining the Work Plane is to keep the X-axis orientation pointing in the positive direction as you look down the Z-axis, but on some table/table style machines this will cause the machining to be on the back side of the table, so in this case you will want the X-axis pointing in the negative direction.

The setWorkPlane function does the actual output of the Work Plane and can vary from post processor to post processor, depending on the requirements of the machine control. It will output the calculated Euler angles or rotary axes positions, and in some cases, both. In the following code, G68.2 is used to define the Work Plane using Euler angles.

function setWorkPlane(abc) {
    if (is3D() && !machineConfiguration.isMultiAxisConfiguration()) {
        return;
    }

    // the Work Plane does not change, do not output it
    if (!((currentWorkPlaneABC == undefined) ||
          abcFormat.areDifferent(abc.x, currentWorkPlaneABC.x) ||
          abcFormat.areDifferent(abc.y, currentWorkPlaneABC.y) ||
          abcFormat.areDifferent(abc.z, currentWorkPlaneABC.z))) {
        return; // no change
    }

    // unlock rotary axes
    onCommand(COMMAND_UNLOCK_MULTI_AXIS);

    // retract the tool
    if (!retracted) {
        writeRetract(Z);
    }
// output using Euler angles
if (useMultiAxisFeatures) {
    cancelWorkPlane();

    // preposition the rotary axes
    if (machineConfiguration.isMultiAxisConfiguration()) {
        var machineABC = abc.isNonZero() ? getWorkPlaneMachineABC(currentSection.workPlane, false) : abc;
        if (useABCPrepositioning || abc.isZero()) {
            positionABC(machineABC, true);
        }
        setCurrentABC(machineABC); // required for machine simulation
    }
    if (abc.isNonZero()) {
        gRotationModal.reset();
        writeBlock(gRotationModal.format(68.2), "X" + xyzFormat.format(0), "Y" + xyzFormat.format(0), "Z" + xyzFormat.format(0), "I" + abcFormat.format(abc.x), "J" + abcFormat.format(abc.y), "K" + abcFormat.format(abc.z)); // set frame
        writeBlock(gFormat.format(53.1)); // turn machine
    }

    // output rotary axis positions
} else {
    positionABC(abc, true);
}

// lock rotary axes
onCommand(COMMAND_LOCK_MULTI_AXIS);

---

### 5.3.6 Initial Position

The initial position of the operation is available to the onSection function and is output here. Tool length compensation on the control is enabled with the initial position when the tool is changed or if it has been disabled between operations.

// force all axes to be output at start of operation
forceAny();

// get the initial tool position and retract in Z if necessary
var initialPosition = getFramePosition(currentSection.getInitialPosition());
if (!retracted) {
    if (getCurrentPosition().z < initialPosition.z) {
        writeBlock(gMotionModal.format(0), zOutput.format(initialPosition.z));
    }
}
} }

// output tool length offset on tool change or if tool has been retracted
if (insertToolCall || retracted) {
  var lengthOffset = tool.lengthOffset;
  if (lengthOffset > numberOfToolSlots) {
    error(localize("Length offset out of range."));
    return;
  }
  gMotionModal.reset();
  writeBlock(gPlaneModal.format(17));
}

// output XY and then Z with 3-axis or table configuration
if (!machineConfiguration.isHeadConfiguration()) {
  writeBlock(
    gAbsIncModal.format(90),
    gMotionModal.format(0), xOutput.format(initialPosition.x), yOutput.format(initialPosition.y)
  );
  writeBlock(gMotionModal.format(0), gFormat.format(43), zOutput.format(initialPosition.z),
             hFormat.format(lengthOffset));
// output XYZ with head configuration
} else {
  writeBlock(
    gAbsIncModal.format(90),
    gMotionModal.format(0),
    gFormat.format(43), xOutput.format(initialPosition.x),
    yOutput.format(initialPosition.y),
    zOutput.format(initialPosition.z), hFormat.format(lengthOffset)
  );
}

// do not activate tool length compensation if already activated
} else { 
    writeBlock(
        gAbsIncModal.format(90),
        gMotionModal.format(0),
        xOutput.format(initialPosition.x),
        yOutput.format(initialPosition.y)
    );
}
5.4 The section Object

The start of a machining operation defined in CAM is stored in the intermediate file as a separate section. The section object contains the information used to generate the operation. All defined sections are accessible to the post processor at any time in the post processor by accessing the section by its ID. This section provides a description of some of the functions/variables used to access the information stored in a section. You will find a description of various section functions/variables in other sections of this manual where they are used.

5.4.1 currentSection

The currentSection variable refers to the active section/operation. It is unspecified if used outside of the scope of a section, for example in onOpen or onClose. In these functions you will need to access the section directly using the getSection function.

```javascript
var firstSection = getSection(0); // access the first section of the program
var lastSection = getSection(getNumberOfSections() - 1) // access the last section of the program
```

Accessing the First and Last Sections

5.4.2 getSection

```javascript
value = getSection(sectionId)
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>sectionId</td>
<td>The ID of the section to return. sectionId can be in the range of 0 through the number of defined sections (getNumberOfSections).</td>
</tr>
</tbody>
</table>

Returns the section object associated with the specified section ID.

5.4.3 getNumberOfSections

```javascript
value = getNumberOfSections()
```

Returns the number of sections (operations) defined in the program.

```javascript
for (var i = 0; i < getNumberOfSections(); ++i) { // loop through all sections
    var section = getSection(i);
    ...
}
```

Looping Through All Defined Sections

5.4.4 getId

```javascript
value = section.getId()
```

...
The `getId` function returns the ID of the provided section. It will be in the range of 0 through the number of defined sections minus 1 (`getNumberOfSections`).

```javascript
// loop through sections defined after the current section
for (var i = currentSection.getId() + 1; i < numberOfSections; ++i) {
  var section = getSection(i);
}
```

### Looping Through Following Sections

#### 5.4.5 isToolChangeNeeded

```javascript
value = isToolChangeNeeded([section], arguments)
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to test for a tool change. If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
<tr>
<td>arguments</td>
<td>Specifies one or more of the Tool object variables to use as criteria to determine if a tool change is needed. This list of criteria can be <code>number</code>, <code>description</code>, <code>lengthOffset</code>, or any other member of the Tool object.</td>
</tr>
</tbody>
</table>

Returns `true` if a tool change is required for the specified section. The comparison criteria are passed as a list of arguments to the function and can be any valid Tool object variable.

```javascript
var insertToolCall = isToolChangeNeeded("number", "lengthOffset");
```

### Determining if a Tool Change is Required for the Current Section Based on the Tool Number and Length Offset

#### 5.4.6 isNewWorkPlane

```javascript
value = isNewWorkPlane([section])
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to test for a Work Plane change. If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
</tbody>
</table>

Returns `true` if the work plane changes for the specified section as compared to the previous section.

```javascript
var newWorkPlane = isNewWorkPlane();
```

### Determining if the Work Plane Changes Between Sections

#### 5.4.7 isNewWorkOffset

```javascript
value = isNewWorkOffset([section])
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to test for a Work Offset change. If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
</tbody>
</table>

Entry Functions  5-148
Returns *true* if the work offset changes for the specified section as compared to the previous section.

```javascript
var newWorkOffset = isNewWorkOffset();
```

### 5.4.8 isSpindleSpeedDifferent

```javascript
value = isSpindleSpeedDifferent(section)
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to test for a change in the spindle speed or spindle mode.</td>
</tr>
<tr>
<td></td>
<td>If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
</tbody>
</table>

Returns *true* if the spindle speed or spindle mode (RPM, SFM) differs from the previous section, *false* if they are the same.

```javascript
if (isSpindleSpeedDifferent()) {
```

### 5.4.9 isDrillingCycle

```javascript
isDrillingCycle([section], [checkBoringCycles])
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to check for a drilling cycle. If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
<tr>
<td>checkBoringCycles</td>
<td>When set to <em>false</em>, boring cycles with a shift value will not be considered a drilling cycle, otherwise if set to <em>true</em> or not specified shift boring cycles are considered drilling cycles.</td>
</tr>
</tbody>
</table>

Returns *true* if the section is a drilling operation, otherwise returns *false*. Milling cycles are not considered a drilling cycle.

```javascript
if (isDrillingCycle()) { // test if the current section is a drilling operation
if (isDrillingCycle(false)) { // do not include shift boring cycles as a drilling operation
```

### 5.4.10 isTappingCycle

```javascript
isTappingCycle([section])
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to check for a tapping cycle. If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
</tbody>
</table>
Returns `true` if the section is a tapping cycle, otherwise returns `false`.

```java
if (isTappingCycle()) { // test if the current section is a tapping operation
    // test if the section is a tapping operation
}
```

### 5.4.11 isAxialCenterDrilling

`isAxialCenterDrilling([section,] [checkLiveTool])`

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to check for an axial drilling cycle. If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
<tr>
<td>checkLiveTool</td>
<td>When set to <code>false</code>, the live tool setting is ignored and will not be used in testing for an axial center drilling operation, otherwise if set to <code>true</code> or not specified operations using a live tool will not be considered as an axial center drilling operation.</td>
</tr>
</tbody>
</table>

Returns `true` if the section is an axial drilling cycle, otherwise returns `false`. Axial drilling cycles are considered drilling operations that are at X0 Y0 and are usually tested for on lathes.

```java
if (isAxialCenterDrilling()) { // test if the current section is an axial center drilling cycle
    // test if the current section is an axial center drilling cycle
    if (isAxialCenterDrilling(false)) { // ignore the Live Tool setting
        // ignore the Live Tool setting
    }
}
```

### 5.4.12 isMillingCycle

`isMillingCycle([section,] [checkBoringCycles])`

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to check for a milling cycle. If section is not specified, then <code>currentSection</code> is assumed.</td>
</tr>
<tr>
<td>checkBoringCycles</td>
<td>When set to <code>true</code>, boring cycles with a shift value will be considered a milling cycle, otherwise if set to <code>false</code> or not specified shift boring cycles are not considered milling cycles.</td>
</tr>
</tbody>
</table>

Returns `true` if the section is a milling cycle, otherwise returns `false`.

```java
if (isMillingCycle()) { // test if the current section is a milling cycle
    // test if the current section is a milling cycle
    if (isMillingCycle(true)) { // include shift boring cycles as a drilling operation
        // include shift boring cycles as a drilling operation
    }
}
```

### 5.4.13 isProbeOperation

`value = isProbeOperation([section])`

Returns `true` if the section is a tapping cycle, otherwise returns `false` or `null` if the section is not a tapping cycle.

Determining if the Section is a Tapping Operation

Determining if the Section is an Axial Center Drilling Operation

Determining if the Section is a Drilling Operation

Determining if the Section is a Drilling Operation

Entry Functions  5-150
Determining if the Section is a Probing Operation

5.4.14 isInspectionOperation

value = isInspectionOperation([section])

Determining if the Section is an Inspection Operation

5.4.15 isDepositionOperation

value = isDepositionOperation([section])

Determining if the Section is a Deposition Operation

5.4.16 probeWorkOffset

value = section.probeWorkOffset

The probeWorkOffset variable contains the WCS number that is active during the probing operation. It is the same as the probe-output-work-offset parameter.
validate(currentSection.probeWorkOffset <= 6, "Angular Probing supports work offsets 1-6.");

Validating the Range of the Probe Work Offset

5.4.17 getNextTool

tool = getNextTool([section,] [firstTool,] [arguments])

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>section</td>
<td>Specifies the section to use as the base tool. The next tool following the tool used in this section will be returned. If section is not specified, then currentSection is assumed.</td>
</tr>
<tr>
<td>firstTool</td>
<td>Returns the first tool if the end of the program is reached when set to true. Returns undefined if it is not specified or set to false and the end of the program is reached.</td>
</tr>
<tr>
<td>arguments</td>
<td>Specifies one or more of the Tool object variables to use as criteria to determine the next tool. This list of criteria can be number, description, lengthOffset, or any other member of the Tool object.</td>
</tr>
</tbody>
</table>

The getNextTool function returns the next tool used in the program based on the active tool in the current section. You can pass number, description, diameter, or any other member of the tool object as the criteria for determining if the tool is different than the current tool. This function will take any number of text string arguments. If an argument is not passed to this function, then it will choose the next tool based on the tool number.

var nextTool = getNextTool(true); // get next tool based on tool number, can return the first tool
var nextTool = getNextTool("description"); // get next tool based on tool description

Accessing the Next Tool

5.4.18 getFirstTool

tool = getFirstTool()

The getFirstTool function returns the first tool used in the program.

var firstTool = getFirstTool();

Accessing the First Tool

5.4.19 toolZRange

zRange = toolZRange()

The toolZRange function returns the Z-axis range for the active tool for the current and subsequent sections that use this tool. It will return undefined if the tool orientation of the active section is not along the Z-axis.
var zRange = toolZRange();

Calculate the Z-axis Minimum and Maximum for the Active Section(s)

5.4.20 strategy

value = section.strategy;

The strategy variable is part of the section object and contains a string that represents the machining strategy used for the section. It contains the same value as the operation-strategy parameter.

} else { // do not output smoothing for the following operations
  smoothing.isAllowed = !(currentSection.strategy == "drill");
}

Checking for a Drill Operation

5.4.21 checkGroup

value = section.checkGroup(strategy-list)

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>strategy-list</td>
<td>A list of machining strategy groups to check, separated by commas.</td>
</tr>
</tbody>
</table>

The checkGroup function returns true if the section machining strategy belongs to all of the strategy groups specified in the strategy-list. The valid strategy groups are listed in the following table. Each of these variables should be prefixed with STRATEGY_, for example STRATEGY_2D.

<table>
<thead>
<tr>
<th>2D</th>
<th>3D</th>
<th>ADDITIVE</th>
<th>CHECKSURFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FINISHING</td>
<td>HOLEMAKING</td>
<td>INSPECTION</td>
<td>JET</td>
</tr>
<tr>
<td>DRILLING</td>
<td>MILLING</td>
<td>MULTIAXIS</td>
<td>PROBING</td>
</tr>
<tr>
<td>ROTARY</td>
<td>ROUGHING</td>
<td>SAMPLING</td>
<td>SECONDARYSPINDLE</td>
</tr>
<tr>
<td>SURFACE</td>
<td>THREAD</td>
<td>TURNING</td>
<td></td>
</tr>
</tbody>
</table>

Strategy Groups (Prefixed with STRATEGY_)

} else { // do not output smoothing for the following operations
  smoothing.isAllowed = !(currentSection.checkGroup(STRATEGY_DRILLING));
}

Checking for a Drill Operation

5.5 onSectionEnd

function onSectionEnd() {

Entry Functions 5-153
The `onSectionEnd` function can be used to define the end of an operation, but in most post processors this is handled in the `onSection` function. The reason for this is that different output will be generated depending on if there is a tool change, WCS change, or Work Plane change and this logic is handled in the `onSection` function (see the `insertToolCall` variable), though it could be handled in the `onSectionEnd` function if desired by referencing the `getNextSection` and `isLastSection` functions.

```javascript
var insertToolCall = isLastSection() ||
  getNextSection().getForceToolChange && getNextSection().getForceToolChange() ||
  (getNextSection().getTool().number != tool.number);

var retracted = false; // specifies that the tool has been retracted to the safe plane
var newWorkOffset = isLastSection() ||
  (currentSection.workOffset != getNextSection().workOffset); // work offset changes
var newWorkPlane = isLastSection() ||
  !isSameDirection(currentSection.getGlobalFinalToolAxis(),
                   getNextSection().getGlobalInitialToolAxis());

if (insertToolCall || newWorkOffset || newWorkPlane) {
  // stop spindle before retract during tool change
  if (insertToolCall) {
    onCommand(COMMAND_STOP_SPINDLE);
  }

  // retract to safe plane
  retracted = true;
  writeBlock(gFormat.format(28), gAbsIncModal.format(91), "Z" + xyzFormat.format(0)); // retract
  writeBlock(gAbsIncModal.format(90));
  zOutput.reset();
  if (insertToolCall) {
    onCommand(COMMAND_COOLANT_OFF);
  }
  if (getProperty("optionalStop")) {
    onCommand(COMMAND_OPTIONAL_STOP);
  }
}
```

### Ending the Operation in `onSectionEnd`

You will need to remove the similar code from the `onSection` function and probably the `onClose` function, which will duplicate the session ending code if left intact.

One reason for ending the operation in the `onSectionEnd` function is if a Manual NC command is used between operations. The Manual NC command will be processed prior to the `onSection` function and if the previous operation is terminated in `onSection`, then the Manual NC command will be acted upon prior to ending the previous operation.
The `onSectionEnd` function is pretty basic in most posts and will reset codes that may have been changed in the operation and possibly some variables that are operation specific.

```javascript
function onSectionEnd() {
    writeBlock(gPlaneModal.format(17));
    forceAny();
}
```

**Basic onSectionEnd Function**

### 5.6 onClose

```javascript
function onClose() {
    // end previous operation
    writeln('');
    optionalSection = false;

    onCommand(COMMAND_COOLANT_OFF);

    writeRetract(Z); // retract
disableLengthCompensation(true);
setSmoothing(false);
zOutput.reset();
setWorkPlane(new Vector(0, 0, 0)); // reset working plane
writeRetract(X, Y); // return to home

    // output end-of-program codes
    onImpliedCommand(COMMAND_END);
onImpliedCommand(COMMAND_STOP_SPINDLE);
writeBlock(mFormat.format(30)); // stop program, spindle stop, coolant off
writeLn("%");
}
```

**Basic onClose Function**

### 5.7 onTerminate

```javascript
function onTerminate() {
    // output end-of-program codes
    onImpliedCommand(COMMAND_END);
onImpliedCommand(COMMAND_STOP_SPINDLE);
writeBlock(mFormat.format(30)); // stop program, spindle stop, coolant off
writeLn("%");
}
```

**Basic onTerminate Function**

The `onClose` function is called at the end of the last operation, after `onSectionEnd`. It is used to define the end of an operation, if not handled in `onSectionEnd`, and to output the end-of-program codes.

The `onTerminate` function is called at the end of post processing, after `onClose`. It is called after all output to the NC file is finished and the NC file is closed. It may be used to rename the output file(s)
after processing has finished, to automatically create a setup sheet, or to run another program against the output NC file.

```javascript
function onTerminate() {
  var outputPath = getOutputPath();
  var programFilename = FileSystem.getFilename(outputPath);
  var programSize = FileSystem.getFileSize(outputPath);
  var postPath = findFile("setup-sheet-excel-2007.cps");
  var intermediatePath = getIntermediatePath();
  var a = "--property unit " + ((unit == IN) ? "0" : "1"); // use 0 for inch and 1 for mm
  if (programName) {
    a += " --property programName " + programName + "\"
  }
  if (programComment) {
    a += " --property programComment " + programComment + "\"
  }
  a += " --property programFilename " + programFilename + "\"
  a += " --property programSize " + programSize + "\"
  a += " --noeditor --log temp.log " + postPath + "\"
  + intermediatePath + "\"
  FileSystem.replaceExtension(outputPath, "xlsx") + "\"
  execute(getPostProcessorPath(), a, false, "");
  executeNoWait("excel", "\"
  + FileSystem.replaceExtension(outputPath, "xlsx") + "\", false, "");
}
```

**Create and Display Setup Sheet from onTerminate**

### 5.8 onCommand

```javascript
function onCommand(command) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>command</td>
<td>Command to process.</td>
</tr>
</tbody>
</table>

The `onCommand` function can be called by a Manual NC command, directly from HSM, or from the post processor.

<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMAND_ACTIVATE_SPEED_FEED_SYNCHRONIZATION</td>
<td>Activate threading mode</td>
</tr>
<tr>
<td>COMMAND_ALARM</td>
<td>Alarm</td>
</tr>
<tr>
<td>COMMAND_ALERT</td>
<td>Alert</td>
</tr>
<tr>
<td>COMMAND_BREAK_CONTROL</td>
<td>Tool break control</td>
</tr>
<tr>
<td>COMMAND_CALIBRATE</td>
<td>Run calibration cycle</td>
</tr>
<tr>
<td>COMMAND_CHANGE_PALLET</td>
<td>Change pallet</td>
</tr>
<tr>
<td>COMMAND_CLEAN</td>
<td>Run cleaning cycle</td>
</tr>
<tr>
<td>COMMAND_CLOSE_DOOR</td>
<td>Close primary door</td>
</tr>
<tr>
<td>COMMAND_COOLANT_OFF</td>
<td>Coolant off (M09)</td>
</tr>
</tbody>
</table>
```

Entry Functions 5-156
<table>
<thead>
<tr>
<th>Command</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMAND_COOLANT_ON</td>
<td>Coolant on (M08)</td>
</tr>
<tr>
<td>COMMAND_DEACTIVATE_SPEED_FEED_SYNCHRONIZATION</td>
<td>Deactivate threading mode</td>
</tr>
<tr>
<td>COMMAND_END</td>
<td>Program end (M02)</td>
</tr>
<tr>
<td>COMMAND_EXACT_STOP</td>
<td>Exact stop</td>
</tr>
<tr>
<td>COMMAND_LOAD_TOOL</td>
<td>Tool change (M06)</td>
</tr>
<tr>
<td>COMMAND_LOCK_MULTI_AXIS</td>
<td>Locks the rotary axes</td>
</tr>
<tr>
<td>COMMAND_MAIN_CHUCK_CLOSE</td>
<td>Close main chuck</td>
</tr>
<tr>
<td>COMMAND_MAIN_CHUCK_OPEN</td>
<td>Open main chuck</td>
</tr>
<tr>
<td>COMMAND_OPEN_DOOR</td>
<td>Open primary door</td>
</tr>
<tr>
<td>COMMAND_OPTIONAL_STOP</td>
<td>Optional program stop (M01)</td>
</tr>
<tr>
<td>COMMAND_ORIENTATE_SPINDLE</td>
<td>Orientate spindle (M19)</td>
</tr>
<tr>
<td>COMMAND_POWER_OFF</td>
<td>Power off</td>
</tr>
<tr>
<td>COMMAND_POWER_ON</td>
<td>Power on</td>
</tr>
<tr>
<td>COMMAND_SECONDARY_CHUCK_CLOSE</td>
<td>Close secondary chuck</td>
</tr>
<tr>
<td>COMMAND_SECONDARY_CHUCK_OPEN</td>
<td>Open secondary chuck</td>
</tr>
<tr>
<td>COMMAND_SECONDARY_SPINDLE_SYNCHRONIZATION_ACTIVATE</td>
<td>Activate spindle synchronization</td>
</tr>
<tr>
<td>COMMAND_SECONDARY_SPINDLE_SYNCHRONIZATION_DEACTIVATE</td>
<td>Deactivate spindle synchronization</td>
</tr>
<tr>
<td>COMMAND_SPINDLE_CLOCKWISE</td>
<td>Clockwise spindle direction (M03)</td>
</tr>
<tr>
<td>COMMAND_SPINDLE_COUNTERCLOCKWISE</td>
<td>Counter-clockwise spindle direction</td>
</tr>
<tr>
<td>COMMAND_START_CHIP_TRANSPORT</td>
<td>Start chip conveyor</td>
</tr>
<tr>
<td>COMMAND_START_SPINDLE</td>
<td>Start spindle in previous direction</td>
</tr>
<tr>
<td>COMMAND_STOP</td>
<td>Program stop (M00)</td>
</tr>
<tr>
<td>COMMAND_STOP_CHIP_TRANSPORT</td>
<td>Stop chip conveyor</td>
</tr>
<tr>
<td>COMMAND_STOP_SPINDLE</td>
<td>Stop spindle (M05)</td>
</tr>
<tr>
<td>COMMAND_TOOL_MEASURE</td>
<td>Measure tool</td>
</tr>
<tr>
<td>COMMAND_UNLOCK_MULTI_AXIS</td>
<td>Unlocks the rotary axes</td>
</tr>
<tr>
<td>COMMAND_VERIFY</td>
<td>Verify path/tool/machine integrity</td>
</tr>
</tbody>
</table>

**Valid Commands**

The Manual NC commands that call `onCommand` are described in the *Manual NC Commands* chapter. Internal calls to `onCommand` are usually generated when expanding a cycle. The post processor itself will call `onCommand` directly to perform simple functions, such as outputting a program stop, cancelling coolant, opening the main door, turning on the chip conveyor, etc.

```c
// stop spindle and cancel coolant before retract during tool change
if (insertToolCall && !isFirstSection()) {
    onCommand(COMMAND_COOLANT_OFF);
    onCommand(COMMAND_STOP_SPINDLE);
}
```

**Calling onCommand Directly from Post Processor**
The `onImpliedCommand` function changes the state of certain settings in the post engine without calling `onCommand` and outputting the associated codes with the command. The state of certain parameters is important when the post processor engine expands cycles.

```
onImpliedCommand(COMMAND_END);
onImpliedCommand(COMMAND_STOP_SPINDLE);
onImpliedCommand(COMMAND_COOLANT_OFF);
writeBlock(mFormat.format(30)); // stop program, spindle stop, coolant off
```

Using `onImpliedCommand`

### 5.9 onComment

```javascript
function onComment(message) {

Arguments | Description
---|---
message | Text of comment to output.

The `onComment` function is called when the Manual NC command `Comment` is issued. It will format and output the text of the comment to the NC file.

There are two other functions that are used to format and output comments, `formatComment` and `writeComment`. These comment functions are standard in nature and do not typically have to be modified, though the `permittedCommentChars` variable, defined at the top of the post, is used to define the characters that are allowed in a comment and may have to be changed to match the control. The `formatComment` function will remove any characters in the comment that are not specified in this variable. Lowercase letters will be converted to uppercase by the `formatComment` function. If you want to support lowercase letters, then they would have to be added to the `permittedCommentChars` variable and the `formatComment` function would need to have the conversion to uppercase removed.

```javascript
var permittedCommentChars = "ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789.,_=\";
```

Defining the Permitted Characters for Comments

```javascript
/***/ Format a comment */
```
5.10 onDwell

function onDwell(seconds) {

Arguments | Description
---|---
seconds | Dwell time in seconds.

The onDwell function can be called by a Manual NC command, directly from HSM, or from the post processor. The Manual NC command that calls onDwell is described in the Manual NC Commands chapter. Internal calls to onDwell are usually generated when expanding a cycle. The post processor itself will call onDwell directly to output a dwell block.

```javascript
function onDwell(seconds) {
  if (seconds > 99999.999) {
    warning(localize("Dwelling time is out of range."))) ;
  }
  milliseconds = clamp(1, seconds * 1000, 99999999);
  writeBlock(gFeedModeModal.format(94), gFormat.format(4), "P" +
    milliFormat.format(milliseconds));
}
```

Output the Dwell Time in Milliseconds

onCommand(COMMAND_COOLANT_ON);
onDwell(1.0); // dwell 1 second after turning coolant on

Calling onDwell Directly from Post Processor
5.11 **onParameter**

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Parameter name.</td>
</tr>
<tr>
<td>value</td>
<td>Value stored in the parameter.</td>
</tr>
</tbody>
</table>

Almost all parameters used for creating a machining operation in HSM are passed to the post processor. Common parameters are available using built-in post processor variables (currentSection, tool, cycle, etc.) as well as being made available as parameters. Other parameters are passed to the `onParameter` function.

74: `onParameter('operation:context', 'operation')`
75: `onParameter('operation:strategy', 'drill')`
76: `onParameter('operation:operation_description', 'Drill')`
77: `onParameter('operation:tool_type', 'tap right hand')`
78: `onParameter('operation:undercut', 0)`
79: `onParameter('operation:tool_isTurning', 0)`
80: `onParameter('operation:tool_isMill', 0)`
81: `onParameter('operation:tool_isDrill', 1)`
82: `onParameter('operation:tool_taperedType', 'tapered_bull_nose')`
83: `onParameter('operation:tool_unit', 'inches')`
84: `onParameter('operation:tool_number', 4)`
85: `onParameter('operation:tool_diameterOffset', 4)`
86: `onParameter('operation:tool_lengthOffset', 4)`

### Sample Parameters Passed to the onParameter Function from Dump Post Processor

The name of the parameter along with its value is passed to the `onParameter` function. Some Manual NC commands will call the `onParameter` function, these are described in the Manual NC Commands chapter. You can see how to run and analyze the output from the `dump.cps` post processor in the Debugging chapter.

```javascript
function onParameter(name, value) {
    switch (name) {
    case "job-notes":
        if (!firstNote) {
            writeNotes(value, true);
        }
        firstNote = false;
        break;
    }
}
```

### Sample onParameter Function
5.11.1 `getParameter` Function

```plaintext
value = getParameter(name [,default])
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Parameter name.</td>
</tr>
<tr>
<td>default</td>
<td>The value to return if the requested parameter is not defined. If a <code>default</code> value is not specified and the parameter is not defined, then <code>undefined</code> is returned.</td>
</tr>
</tbody>
</table>

You can retrieve operation parameters at any place in the post processor by calling the `getParameter` function. Operation parameters are defined as parameters that are redefined for each machining operation. There is a chance that a parameter does not exist so it is recommended that you check for the parameter either by specifying a default value in the `getParameter` call or by using the `hasParameter` function.

```plaintext
var comment = getParameter("operation-comment", ""); // get the parameter value
if (comment) {
  writeComment(comment);
}
```

**Verify a Parameter Exists Using the `getParameter` Function**

```plaintext
if (hasParameter("operation-comment")) { // verify the parameter exists
  var comment = getParameter("operation-comment"); // get the parameter value
  if (comment) {
    writeComment(comment);
  }
}
```

**Verify a Parameter Exists Using the `hasParameter` Function**

When scanning through the operations in the intermediate file it is possible to access the parameters for that operation by using the section variant of the `hasParameter` and `getParameter` functions.

```plaintext
// write out all operation comments
writeln("List of Operations:");
for (var i = 0; i < getNumberOfSections(); ++i) {
  var section = getSection(i);
  var comment = section.getParameter("operation-comment", "");
  if (comment) {
    writeln(" " + comment);
  }
}
writeln(" ");
```

**Using Section Variant of `getParameter`**
5.11.2 `getGlobalParameter` Function

```javascript
value = getGlobalParameter(name [,default])
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Parameter name.</td>
</tr>
<tr>
<td>default</td>
<td>The value to return if the requested parameter is not defined. If a <code>default</code> value is not specified and the parameter is not defined, then <code>undefined</code> is returned.</td>
</tr>
</tbody>
</table>

Some parameters are defined at the start of the intermediate file prior to the first operation. These parameters are considered global and are accessed using the `hasGlobalParameter` and `getGlobalParameter` functions. The same rules that apply to the operation parameters apply to global parameters.

```
-1: onOpen()
0: onParameter('product-id', 'fusion360')
1: onParameter('generated-by', 'Fusion 360 CAM 2.0.3803')
2: onParameter('generated-at', 'Saturday, March 24, 2018 4:34:36 PM')
3: onParameter('hostname', 'host')
4: onParameter('username', 'user')
5: onParameter('document-path', 'Water-Laser-Plasma v2')
6: onParameter('leads-supported', 1)
7: onParameter('job-description', 'Laser')
9: onParameter('stock', '((0, 0, -5), (300, 200, 0))')
11: onParameter('stock-lower-x', 0)
13: onParameter('stock-lower-y', 0)
15: onParameter('stock-lower-z', -5)
17: onParameter('stock-upper-x', 300)
19: onParameter('stock-upper-y', 200)
21: onParameter('stock-upper-z', 0)
23: onParameter('part-lower-x', 0)
25: onParameter('part-lower-y', 0)
27: onParameter('part-lower-z', -5)
29: onParameter('part-upper-x', 300)
31: onParameter('part-upper-y', 200)
33: onParameter('part-upper-z', 0)
35: onParameter('notes', '')
```

Sample Global Variables

When processing multiple setups at the same time some of the global parameters will change from one setup to the next. The `getGlobalParameter` function though will always reference the parameters of the first setup, so if you want to access the parameters of the active setup then you will need to use the `onParameter` function rather than the `getGlobalParameter` function.

```javascript
function onParameter(name, value) {
    if (name == "job-description") {
```
setupName = value;
}
}

Using onParameter to Store the Active Setup Name

### 5.12 onPassThrough

Function `onPassThrough(value)`

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>Text to be output to the NC file.</td>
</tr>
</tbody>
</table>

The `onPassThrough` function is called by the *Pass through* Manual NC command and is used to pass a text string directly to the NC file without any processing by the post processor. This function is described in the Manual NC Commands chapter.

### 5.13 onSpindleSpeed

```javascript
function onSpindleSpeed(speed) {
  writeBlock(sOutput.format(speed));
}
```

Sample `onSpindleSpeed` Function

The `onSpindleSpeed` function is used to output changes in the spindle speed during an operation, typically from the post processor engine when expanding a cycle.

### 5.14 onOrientateSpindle

```javascript
function onOrientateSpindle(angle) {
  writeBlock(sOutput.format(angle));
}
```

The `onOrientateSpindle` function is not typically called. When a cycle that orientates the spindle is expanded the `onCommand(COMMAND_ORIENTATE_SPINDLE)` function is called.

### 5.15 onRadiusCompensation

```javascript
function onRadiusCompensation() {
}
```

Entry Functions 5-163
The `onRadiusCompensation` function is called when the radius (cutter) compensation mode changes. It will typically set the pending compensation mode, which will be handled in the motion functions (`onRapid`, `onLinear`, `onCircular`, etc.). Radius compensation, when enabled in an operation, will be enabled on the move approaching the part and disabled after moving off the part.

The state of radius compensation is stored in the global `radiusCompensation` variable and is not passed to the `onRadiusCompensation` function. Radius compensation is defined when creating the machining operation in HSM (1). The Sideways Compensation (2) setting determines the side of the part that the tool will be on when cutting. It is based on the forward direction of the tool during the cutting operation.

<table>
<thead>
<tr>
<th>Compensation Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>In computer</td>
<td>The tool is offset from the part based on the tool diameter. The center line of the offset tool is sent to the post processor and the radius compensation mode is OFF (G40).</td>
</tr>
<tr>
<td>In control</td>
<td>The tool is not offset from the part. The centerline of the tool as if it is on the part is sent to the post processor and the radius compensation mode is determined by the Sideways Compensation setting (G41/G42). The control will perform the entire offsetting of the tool.</td>
</tr>
<tr>
<td>Wear</td>
<td>The tool is offset from the part based on the tool diameter. The center line of the offset tool is sent to the post processor and the radius compensation mode is determined by the Sideways Compensation setting (G41/G42). The control will compensate for tool wear.</td>
</tr>
<tr>
<td>Inverse wear</td>
<td>Same as Wear, but the opposite compensation direction will be used (G42/G41).</td>
</tr>
<tr>
<td>Off</td>
<td>The tool is not offset from the part. The centerline of the tool as if it is on the part is sent to the post processor and the radius compensation mode will be disabled (G40).</td>
</tr>
</tbody>
</table>

**Radius Compensation Modes**
var pendingRadiusCompensation = -1;

function onRadiusCompensation() {
    pendingRadiusCompensation = radiusCompensation;
}

Sample onRadiusCompensation Function

5.16 onMovement

function onMovement(movement) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>movement</td>
<td>Movement type for the following motion(s).</td>
</tr>
</tbody>
</table>

`onMovement` is called whenever the movement type changes. It is used to tell the post when there is a positioning, entry, exit, or cutting type move. There is also a `movement` global variable that contains the movement setting. This variable can be referenced directly in other functions, such as `onLinear`, to access the movement type without defining the `onMovement` function.

The supported movement types are listed in the following table.

<table>
<thead>
<tr>
<th>Movement Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOVEMENT_CUTTING</td>
<td>Standard cutting motion.</td>
</tr>
<tr>
<td>MOVEMENT_EXTENDED</td>
<td>Extended movement type. Not common.</td>
</tr>
<tr>
<td>MOVEMENT_FINISH_CUTTING</td>
<td>Finish cutting motion.</td>
</tr>
<tr>
<td>MOVEMENT_HIGH_FEED</td>
<td>Movement at high feedrate. Not typically used. Rapid moves output using a linear move at the high feedrate will use the MOVEMENT_RAPID type.</td>
</tr>
<tr>
<td>MOVEMENT_LEAD_IN</td>
<td>Lead-in motion.</td>
</tr>
<tr>
<td>MOVEMENT_LEAD_OUT</td>
<td>Lead-out motion.</td>
</tr>
<tr>
<td>MOVEMENT_LINK_DIRECT</td>
<td>Direction (non-cutting) linking move.</td>
</tr>
<tr>
<td>MOVEMENT_LINK_TRANSITION</td>
<td>Transition (cutting) linking move.</td>
</tr>
<tr>
<td>MOVEMENT_PLUNGE</td>
<td>Plunging move.</td>
</tr>
<tr>
<td>MOVEMENT_PREDRILL</td>
<td>Predrilling motion.</td>
</tr>
<tr>
<td>MOVEMENT_RAMP</td>
<td>Ramping entry motion.</td>
</tr>
<tr>
<td>MOVEMENT_RAMP_Helix</td>
<td>Helical ramping motion.</td>
</tr>
<tr>
<td>MOVEMENT_RAMP_PROFILE</td>
<td>Profile ramping motion.</td>
</tr>
<tr>
<td>MOVEMENT_RAMP_Zig_Zag</td>
<td>Zig-Zag ramping motion.</td>
</tr>
<tr>
<td>MOVEMENT_RAPID</td>
<td>Rapid movement.</td>
</tr>
<tr>
<td>MOVEMENT_REduced</td>
<td>Reduced cutting motion.</td>
</tr>
</tbody>
</table>

Movement Types

Movement types are used in defining parametric feedrates in some milling posts and for removing all non-cutting moves for waterjet/plasma/laser machines that require only the cutting profile.
5.17 onRapid

```javascript
function onRapid(_x, _y, _z) {

    // format tool position for output
    var x = xOutput.format(_x);
    var y = yOutput.format(_y);
    var z = zOutput.format(_z);

    // ignore if tool does not move
    if (x || y || z) {
        if (pendingRadiusCompensation >= 0) { // handle radius compensation
            error(localize("Radius compensation mode cannot be changed at rapid traversal."));
            return;
        }
    }

    // output move at high feedrate if movement in more than one axis
```

The `onRapid` function handles rapid positioning moves (G00) while in 3-axis mode. The tool position is passed as the `_x, _y, _z` arguments. The format of the `onRapid` function is pretty basic, it will handle a change in radius compensation, may determine if the rapid moves should be output at a high feedrate (due to the machine making dogleg moves while in rapid mode), and output the rapid move to the NC file.

If the `High feedrate mapping` property is set to `Always use high feed`, then the `onLinear` function will be called with the high feedrate passed in as the feedrate and the `onRapid` function will not be called.
if (!getProperty("useG0") && ((x ? 1 : 0) + (y ? 1 : 0) + (z ? 1 : 0)) > 1)) {
    writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), x, y, z,
    getFeed(highFeedrate));

    // output move in rapid mode
    } else {
    writeBlock(gMotionModal.format(0), x, y, z);
    forceFeed();
    }
}

Sample onRapid Function

5.18 invokeOnRapid

invokeOnRapid(x, y, z);

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>x, y, z</td>
<td>The tool position.</td>
</tr>
</tbody>
</table>

It is possible that the post processor will need to generate rapid positioning moves during the processing of the intermediate file. An example would be creating your own expanded drilling cycle. Instead of calling onRapid with the post generated moves, it is recommended that invokeOnRapid be called instead. This will ensure that the post engine is notified of the move and the current position is set. invokeOnRapid will then call onRapid with the provided arguments.

5.19 onLinear

function onLinear(_x, _y, _z, feed) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>_x, _y, _z</td>
<td>The tool position.</td>
</tr>
<tr>
<td>feed</td>
<td>The feedrate.</td>
</tr>
</tbody>
</table>

The onLinear function handles linear moves (G01) at a feedrate while in 3-axis mode. The tool position is passed as the _x, _y, _z arguments. The format of the onLinear function is pretty basic, it will handle a change in radius compensation and outputs the linear move to the NC file.

function onLinear(_x, _y, _z, feed) {
    // force move when radius compensation changes
    if (pendingRadiusCompensation >= 0) {
        xOutput.reset();
        yOutput.reset();
    }
// format tool position for output
var x = xOutput.format(_x);
var y = yOutput.format(_y);
var z = zOutput.format(_z);
var f = getFeed(feed);

// ignore if tool does not move
if (x || y || z) {
    // handle radius compensation changes
    if (pendingRadiusCompensation >= 0) {
        pendingRadiusCompensation = -1;
        var d = tool.diameterOffset;
        if (d > 200) {
            warning(localize("The diameter offset exceeds the maximum value."));
        }
        writeBlock(gPlaneModal.format(17));
        switch (radiusCompensation) {
            case RADIUS_COMPENSATION_LEFT:
                dOutput.reset();
                writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(41), x, y, z,
                        dOutput.format(d), f);
                break;
            case RADIUS_COMPENSATION_RIGHT:
                dOutput.reset();
                writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(42), x, y, z,
                        dOutput.format(d), f);
                break;
            default:
                writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(40), x, y, z,
                        f);
                break;
        }
    } else {
        writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), x, y, z, f);
    }
}

// output non-compensation change move at feedrate
} else if (f) {
    if (getNextRecord().isMotion()) { // try not to output feed without motion
        forceFeed(); // force feed on next line
    } else {
        writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), f);
    }
}

Sample onLinear Function
5.20 invokeOnLinear

```
invokeOnLinear(x, y, z, feed);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>x, y, z</td>
<td>The tool position.</td>
</tr>
<tr>
<td>feed</td>
<td>The feedrate.</td>
</tr>
</tbody>
</table>

It is possible that the post processor will need to generate cutting moves during the processing of the intermediate file. An example would be creating your own expanded drilling cycle. Instead of calling `onLinear` with the post generated moves, it is recommended that `invokeOnLinear` be called instead. This will ensure that the post engine is notified of the move and the current position is set. `invokeOnLinear` will then call `onLinear` with the provided arguments.

5.21 onRapid5D

```
function onRapid5D(_x, _y, _z, _a, _b, _c) {

Arguments

| _x, _y, _z | The tool position. |
| _a, _b, _c | The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed. |

The `onRapid5D` function handles rapid positioning moves (G00) in multi-axis operations. The tool position is passed as the _x, _y, _z arguments and the rotary angles as the _a, _b, _c arguments. If a machine configuration has not been defined, then _a, _b, _c contains the tool axis vector. The `onRapid5D` function will be called for all rapid moves in a multi-axis operation, even if the move is only a 3-axis linear move without rotary movement.

Like the `onRapid` function, the `onRapid5D` function handles a change in radius compensation, may determine if the rapid moves should be output at a high feedrate (due to the machine making dogleg moves while in rapid mode), and outputs the rapid move to the NC file.

```
function onRapid5D(_x, _y, _z, _a, _b, _c) {
   // enable this code if machine does not accept IJK tool axis vector input
   if (false) {
      if (!currentSection.isOptimizedForMachine()) {
         error(localize("This post configuration has not been customized for 5-axis toolpath."));
         return;
      }
   }
   // handle radius compensation changes
   if (pendingRadiusCompensation >= 0) {
      error(localize("Radius compensation mode cannot be changed at rapid traversal."));
      return;
   }

   // other code for rapid5D function...
```

Entry Functions 5-169
// Machine Configuration has been defined, output rotary angles with move
if (currentSection.isOptimizedForMachine()) {
    var x = xOutput.format(_x);
    var y = yOutput.format(_y);
    var z = zOutput.format(_z);
    var a = aOutput.format(_a);
    var b = bOutput.format(_b);
    var c = cOutput.format(_c);
    writeBlock(gMotionModal.format(0), x, y, z, a, b, c);
}

// Machine Configuration has not been defined, output tool axis with move
} else {
    forceXYZ();
    var x = xOutput.format(_x);
    var y = yOutput.format(_y);
    var z = zOutput.format(_z);
    var i = ijkFormat.format(_a);
    var j = ijkFormat.format(_b);
    var k = ijkFormat.format(_c);
    writeBlock(gMotionModal.format(0), x, y, z, "I" + i, "J" + j, "K" + k);
}

forceFeed();

Sample onRapid5D Function

Please refer to the Multi-Axis Post Processors chapter for a detailed explanation on supporting a multi-axis machine.

5.22 invokeOnRapid5D

invokeOnRapid5D(x, y, z, a, b, c);

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>x, y, z</td>
<td>The tool position.</td>
</tr>
<tr>
<td>a, b, c</td>
<td>The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed.</td>
</tr>
</tbody>
</table>

It is possible that the post processor will need to generate multi-axis rapid positioning moves during the processing of the intermediate file. An example would be when handling the retract/reconfigure procedure. Instead of calling onRapid5D with the post generated moves, it is recommended that invokeOnRapid5D be called instead. This will ensure that the post engine is notified of the move and the current position is set. invokeOnRapid5D will then call onRapid5D with the provided arguments.
5.23 onLinear5D

function onLinear5D(_x, _y, _z, _a, _b, _c, feed, feedMode) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>_x, _y, _z</td>
<td>The tool position.</td>
</tr>
<tr>
<td>_a, _b, _c</td>
<td>The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed.</td>
</tr>
<tr>
<td>feed</td>
<td>The feedrate value calculated for the multi-axis feedrate mode.</td>
</tr>
<tr>
<td>feedMode</td>
<td>The active multi-axis feedrate mode. It can be FEED_FPM, FEED_INVERSE_TIME, or FEED_DPM.</td>
</tr>
</tbody>
</table>

The onLinear5D function handles cutting moves (G01) in multi-axis operations. The tool position is passed as the _x, _y, _z arguments and the rotary angles as the _a, _b, _c arguments. If a machine configuration has not been defined, then _a, _b, _c contains the tool axis vector. The onLinear5D function will be called for all cutting moves in a multi-axis operation, even if the move is only a 3-axis linear move without rotary movement.

It is important to know that the feedMode argument will not be present if multi-axis feedrates are not defined either in an external Machine Definition or within the post processor using the setMultiAxisFeedrate function. The feed value will always be passed as the programmed feedrate in this case.

Like the onLinear function, the onLinear5D function handles a change in radius compensation, and outputs the cutting move to the NC file.

function onLinear5D(_x, _y, _z, _a, _b, _c, feed, feedMode) {
    // enable this code if machine does not accept IJK tool axis vector input
    if (false) {
        if (!currentSection.isOptimizedForMachine()) {
            error(localize("This post configuration has not been customized for 5-axis toolpath.");
            return;
        }
    }

    // handle radius compensation changes
    if (pendingRadiusCompensation >= 0) {
        error(localize("Radius compensation cannot be activated/deactivated for 5-axis move.");
        return;
    }

    // Machine Configuration has been defined, output rotary angles with move
    if (currentSection.isOptimizedForMachine()) {
        var x = xOutput.format(_x);
        var y = yOutput.format(_y);
        var z = zOutput.format(_z);
    }
var a = aOutput.format(_a);
var b = bOutput.format(_b);
var c = cOutput.format(_c);

// get feedrate number
if (feedMode == FEED_INVERSE_TIME) {
  feedOutput.reset();
}
var fMode = feedMode == FEED_INVERSE_TIME ? 93 : 94;
var f = feedMode == FEED_INVERSE_TIME ? inverseTimeOutput.format(feed) : 
  feedOutput.format(feed);

// ignore if tool does not move
if (x || y || z || a || b || c) {
  writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), x, y, z, a, b, c, f);
} else if (f) {
  if (getNextRecord().isMotion()) { // try not to output feed without motion
    forceFeed(); // force feed on next line
  } else {
    writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), f);
  }
}

// Machine Configuration has not been defined, output tool axis with move
} else {
  forceXYZ();
  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var i = ijkFormat.format(_a);
  var j = ijkFormat.format(_b);
  var k = ijkFormat.format(_c);
  var f = getFeed(feed);

  // ignore if tool does not move
  if (x || y || z || i || j || k) {
    writeBlock(gMotionModal.format(1), x, y, z, "I" + i, "J" + j, "K" + k, f);
  } else if (f) {
    if (getNextRecord().isMotion()) { // try not to output feed without motion
      forceFeed(); // force feed on next line
    } else {
      writeBlock(gMotionModal.format(1), f);
    }
  }
}

Sample onLinear5D Function
Please refer to the *Multi-Axis Post Processors* chapter for a detailed explanation on supporting a multi-axis machine.

### 5.24 invokeOnLinear5D

```javascript
invokeOnLinear5D(x, y, z, a, b, c, feed);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>x, y, z</td>
<td>The tool position.</td>
</tr>
<tr>
<td>a, b, c</td>
<td>The rotary angles if a machine configuration has been defined, otherwise the tool axis vector is passed.</td>
</tr>
<tr>
<td>feed</td>
<td>The feedrate.</td>
</tr>
</tbody>
</table>

It is possible that the post processor will need to generate multi-axis cutting moves during the processing of the intermediate file. An example would be when handling the retract/reconfigure procedure. Instead of calling `onLinear5D` with the post generated moves, it is recommended that `invokeOnLinear5D` be called instead. This will ensure that the post engine is notified of the move and the current position is set. `invokeOnLinear5D` will then call `onLinear5D` with the provided arguments.

The post engine will calculate the proper feedrate value and mode prior to calling `onLinear5D`.

### 5.25 onCircular

```javascript
function onCircular(clockwise, cx, cy, cz, x, y, z, feed) {
}
```

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>clockwise</td>
<td>Set to <code>true</code> if the circular direction is in the clockwise direction, <code>false</code> if counter-clockwise.</td>
</tr>
<tr>
<td>cx, cy, cz</td>
<td>Center coordinates of circle.</td>
</tr>
<tr>
<td>x, y, z</td>
<td>Final point on circle</td>
</tr>
<tr>
<td>feed</td>
<td>The feedrate.</td>
</tr>
</tbody>
</table>

The `onCircular` function is called whenever there is circular, helical, or spiral motion. The circular move can be in any of the 3 standard planes, XY-plane, YZ-plane, or ZX-plane, it is up to the `onCircular` function to determine which types of circular interpolation are valid for the machine and to correctly format the output.

The structure of the `onCircular` function in most posts uses the following layout:

1. Test for radius compensation. Most controls do not allow radius compensation to be started on a circular move.
2. Full circle output.
3. Center point (IJK) output.
4. Radius output.
Each of the different styles of output will individually handle the output of circular interpolation in each of the planes and possibly 3-D circular interpolation if it is supported.

```java
if (pendingRadiusCompensation >= 0) { // Disallow radius compensation
    error(localize("Radius compensation cannot be activated/deactivated for a circular move."));
    return;
}
...
if (isFullCircle()) { // Full 360 degree circles
    if (getProperty("useRadius") || isHelical()) { // radius mode does not support full arcs
        linearize(tolerance);
        return;
    }
    ...
} else if (!getProperty("useRadius")) { // Incremental center point output
    switch (getCircularPlane()) {
        case PLANE_XY:
            ...
        ...
    }
} else { // Use radius mode
    var r = getCircularRadius();
    if (toDeg(getCircularSweep()) > (180 + 1e-9)) {
        r = -r; // allow up to <360 deg arcs
    }
    ...
}
```

```java
switch (getCircularPlane()) {
    case PLANE_XY:
        writeBlock(gPlaneModal.format(17), gMotionModal.format(clockwise ? 2 : 3),
                   xOutput.format(x), yOutput.format(y), zOutput.format(z),
                   iOutput.format(cx - start.x, 0), jOutput.format(cy - start.y, 0), getFeed(feed));
        break;
    case PLANE_ZX:
        writeBlock(gPlaneModal.format(18), gMotionModal.format(clockwise ? 2 : 3),
                   xOutput.format(x), yOutput.format(y), zOutput.format(z),
                   iOutput.format(cx - start.x, 0), kOutput.format(cz - start.z, 0), getFeed(feed));
        break;
    case PLANE_YZ:
        writeBlock(gPlaneModal.format(19), gMotionModal.format(clockwise ? 2 : 3),
                   xOutput.format(x), yOutput.format(y), zOutput.format(z),
                   jOutput.format(cy - start.y, 0), kOutput.format(cz - start.z, 0), getFeed(feed));
        break;
    default: // circular record is not in major plane
        linearize(tolerance);
```

Standard onCircular Structure
Circular Output Based on Plane

5.25.1 Circular Interpolation Settings

There are settings that affect how circular interpolation is handled in the post engine, basically telling the post engine when to call `onCircular` or when to linearize the points by calling `onLinear` multiple times instead. The following table describes the circular interpolation settings.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>allowedCircularPlanes</td>
<td>Defines the standard planes that circular interpolation is allowed in, PLANE_XY, PLANE_YZ, PLANE_ZX. It can be set to <code>undefined</code> to allow circular interpolation in all three planes, 0 to disable circular interpolation, or a bit mask of PLANE_XY, PLANE_YZ, and/or PLANE_YZ to allow only certain planes.</td>
</tr>
<tr>
<td>allowHelicalMoves</td>
<td>Helical interpolation is allowed when this variable is set to <code>true</code>. Helical moves are linearized if set to <code>false</code>.</td>
</tr>
<tr>
<td>allowSpiralMoves</td>
<td>Spiral interpolation is defined as circular moves that have a different starting radius than ending radius and can be enabled by setting this variable to <code>true</code>. Spiral moves are linearized if set to <code>false</code>.</td>
</tr>
<tr>
<td>circularInputTolerance</td>
<td>The tolerance to use when determining if a spiral or helical move should be converted to a circular record. There are times when the CAM system will output a circular record as a very small spiral or helical move, for example a helix with a linear distance of 0.0001 over 180 degrees could be programmed. Setting the <code>circularInputTolerance</code> variable to a nominal value will convert any helical/spiral moves to a pure circular move when the distance that marks the move as helical or spiral is less than this value. A value of 0 will disable this feature.</td>
</tr>
<tr>
<td>circularMergeTolerance</td>
<td>The tolerance used to determine if consecutive circular records can be merged into a single circular record. CAM systems will sometimes break up a single circle into multiple circular records. Setting the <code>circularMergeTolerance</code> variable to a nominal value will combine consecutive circular records into a single circular record whose centers and radii are within this tolerance and the direction remains the same. A value of 0 will disable this feature. Circular moves will still be limited by the <code>maximumCircularSweep</code> value, so if you wish to have 360-degree circular records you must define <code>maximumCircularSweep</code> to be 360 degrees.</td>
</tr>
</tbody>
</table>
| circularOutputAccuracy | Some controls are quite picky on the center/ending position of a circular record and will fail if either of these are off by a single digit. Defining the `circularOutputAccuracy` variable the same as the output number of digits to the right of the decimal point for the linear axes will cause the post to adjust the output center and/or ending positions so that they reflect the real
<table>
<thead>
<tr>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>circularOutputAccuracy</td>
<td>Leave undefined or use a value of 0 to disable the adjustment of the center/final point.</td>
</tr>
<tr>
<td></td>
<td>Example: ( \text{circularOutputAccuracy} = \text{unit} == \text{MM} ? 3 : 4; )</td>
</tr>
<tr>
<td>maximumCircularRadius</td>
<td>Specifies the maximum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. Any circular records whose radius exceeds this value will be linearized. This variable must be set in millimeters (MM).</td>
</tr>
<tr>
<td></td>
<td>( \text{maximumCircularRadius} = \text{spatial}(1000, \text{MM}); // 39.37 \text{ inch} )</td>
</tr>
<tr>
<td>maximumCircularSweep</td>
<td>Specifies the maximum angular sweep of circular moves that can be output as circular interpolation and is specified in radians. Any circular records whose delta angle exceeds this value will be linearized.</td>
</tr>
<tr>
<td>minimumChordLength</td>
<td>Specifies the minimum delta movement allowed for circular interpolation and can be changed dynamically in the Property table when running the post processor. Any circular records whose delta linear movement is less than this value will be linearized. This variable must be set in millimeters (MM).</td>
</tr>
<tr>
<td>minimumCircularRadius</td>
<td>Specifies the minimum radius of circular moves that can be output as circular interpolation and can be changed dynamically in the Property table when running the post processor. Any circular records whose radius is less than this value will be linearized. This variable must be set in millimeters (MM).</td>
</tr>
<tr>
<td>minimumCircularSweep</td>
<td>Specifies the minimum angular sweep of circular moves that can be output as circular interpolation and is specified in radians. Any circular records whose delta angle is less than this value will be linearized.</td>
</tr>
<tr>
<td>tolerance</td>
<td>Specifies the tolerance used to linearize circular moves that are expanded into a series of linear moves. Circular interpolation records can be linearized due to the conditions of the circular interpolation settings not being met or by the \text{linearize} function being called. This variable must be set in millimeters (MM).</td>
</tr>
</tbody>
</table>

**Circular Interpolation Settings**

allowedCircularPlanes = undefined; // **allow all circular planes**
allowedCircularPlanes = 0; // **disable all circular planes**
allowedCircularPlanes = \((1 \ll \text{PLANE_XY}) | (1 \ll \text{PLANE_ZX})\); // **XY, ZX planes**

tolerance = spatial(0.002, MM); // **linearization tolerance of .00008 IN**
minimumChordLength = spatial(0.01, MM); // **minimum linear movement of .0004 IN**
minimumCircularRadius = spatial(0.01, MM); // **minimum circular radius of .0004 IN**
maximumCircularRadius = spatial(1000, MM); // **maximum circular radius of 39.37 IN**
minimumCircularSweep = toRad(0.01); // **minimum angular movement of .01 degrees**
maximumCircularSweep = toRad(180); // **circular interpolation up to 180 degrees**

**Entry Functions 5-176**
allowHelicalMoves = true; // enable helical interpolation
allowSpiralMoves = false; // disallow spiral interpolation

**Example Circular Interpolation Settings**

5.25.2 Circular Interpolation Common Functions/Variables

There are built-in functions that are utilized by the `onCircular` function. These functions return values used in the `onCircular` function, determine if the circular record should be linearized, and control the flow of the `onCircular` function logic. Most circular functions have a corresponding variable that can be referenced instead of calling the function.

```plaintext
var center = getCircularCenter(); // returns the circle center
var center = circularCenter; // references the circle center
```

Referencing the Circle Center Using Either a Function or Variable

<table>
<thead>
<tr>
<th>Function</th>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getCircularArcLength()</td>
<td>circularArcLength</td>
<td>Returns the arc movement length of the circular interpolation record.</td>
</tr>
<tr>
<td>getCircularCenter()</td>
<td>circularCenter</td>
<td>Returns the center point of the circle as a Vector.</td>
</tr>
<tr>
<td>getCircularChordLength()</td>
<td></td>
<td>Returns the delta linear movement of the circular interpolation record.</td>
</tr>
<tr>
<td>getCircularClockwise()</td>
<td>circularClockwise</td>
<td>Set to <code>true</code> if the circular move is in the clockwise direction, <code>false</code> if it is in the counter-clockwise direction.</td>
</tr>
<tr>
<td>getCircularNormal()</td>
<td>circularNormal</td>
<td>Returns the normal of the circular plane as a Vector. The normal is flipped if the circular movement is in the clockwise direction. This follows the righthand plane convention.</td>
</tr>
<tr>
<td>getCircularOffset()</td>
<td>circularOffset</td>
<td>Returns the distances from the start point to the circle plane in X, Y, and Z as a Vector.</td>
</tr>
<tr>
<td>getCircularPlane()</td>
<td>circularPlane</td>
<td>Returns the plane of the circular interpolation record, PLANE_XY, PLANE_ZX, or PLANE_YZ. If the return value is -1, then the circular plane is not a major plane, but is in 3-D space.</td>
</tr>
<tr>
<td>getCircularRadius()</td>
<td>circularRadius</td>
<td>Returns the end radius of the circular motion.</td>
</tr>
<tr>
<td>getCircularStartRadius()</td>
<td>circularStartRadius</td>
<td>Returns the start radius of the circular motion. This will be different than the end radius for spiral moves.</td>
</tr>
<tr>
<td>getCircularSweep()</td>
<td>circularSweep</td>
<td>Returns the angular sweep of the circular interpolation record in radians.</td>
</tr>
<tr>
<td>Function</td>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>getCurrentPosition()</td>
<td></td>
<td>Returns the starting point of the circular move as a Vector.</td>
</tr>
<tr>
<td>getHelicalDistance()</td>
<td>circularHelicalDistance</td>
<td>Returns the distance the third axis will move during helical interpolation. Returns 0 for a 2-D circular interpolation record.</td>
</tr>
<tr>
<td>getHelicalOffset()</td>
<td>circularHelicalOffset</td>
<td>Returns the distance along the third axis as a Vector. This function is used when helical interpolation is supported outside one of the three standard circular planes.</td>
</tr>
<tr>
<td>getHelicalPitch()</td>
<td>circularHelicalPitch</td>
<td>Returns the distance that the third axis travels for a full 360-degree sweep, i.e. the pitch value of the thread.</td>
</tr>
<tr>
<td>getPositionU(u)</td>
<td></td>
<td>Returns the point on the circle at u percent along the arc as a Vector.</td>
</tr>
<tr>
<td>isFullCircle()</td>
<td>circularFullCircle</td>
<td>Returns true if the angular sweep of the circular motion is 360 degrees.</td>
</tr>
<tr>
<td>isHelical()</td>
<td>circularHelical</td>
<td>Returns true if the circular interpolation record contains helical movement. The variable allowHelicalMoves must be set to true for helical records to be passed to the onCircular function.</td>
</tr>
<tr>
<td>isSpiral()</td>
<td>circularSpiral</td>
<td>Returns true if the circular interpolation record contains spiral movement (the start and end radii are different). The variable allowSpiralMoves must be set to true for spiral records to be passed to the onCircular function.</td>
</tr>
<tr>
<td>linearize(tolerance)</td>
<td></td>
<td>Linearizes the circular motion by outputting a series of linear moves.</td>
</tr>
</tbody>
</table>

### 5.25.3 Helical Interpolation

Helical interpolation is defined as circular interpolation with movement along the third linear axis. The third linear axis is defined as the axis that is not part of the circular plane, for example, the Z-axis is the third linear axis for circular interpolation in the XY-plane. The variable allowHelicalMoves must be set to true for the post processor to support helical interpolation.

Helical interpolation is typically output using the same format as circular interpolation with the addition of the third axis and optionally a pitch value (incremental distance per 360 degrees) for the third axis. Most stock post processors are already setup to output the third axis with circular interpolation (it won't be output for a 2-D circular move).

```cpp
    case PLANE_XY:
```
5.25.4 Spiral Interpolation

Spiral interpolation is defined as circular interpolation that has a different radius at start of the circular move than the radius at the end of the move. The variable \textit{allowSpiralMoves} must be set to true for the post processor to support helical interpolation.

Spiral interpolation when supported on a control is typically specified with a G-code different than the standard G02/G03 circular interpolation G-codes. Most stock post processors do not support spiral interpolation.

```javascript
if (isSpiral()) {
    var startRadius = getCircularStartRadius();
    var endRadius = getCircularRadius();
    var dr = Math.abs(endRadius - startRadius);
    if (dr > maximumCircularRadiiDifference) { // maximum limit
        if (isHelical()) { // not supported
            linearize(tolerance);
            return;
        }
    }

    switch (getCircularPlane()) {
        case PLANE_XY:
            writeBlock(gPlaneModal.format(17), gMotionModal.format(clockwise ? 2.1 : 3.1),
                        xOutput.format(x), yOutput.format(y), zOutput.format(z),
                        iOutput.format(cx - start.x, 0), jOutput.format(cy - start.y, 0), kOutput.format(getHelicalPitch()),
                        feedOutput.format(feed));
            break;
        case PLANE_ZX:
            writeBlock(gPlaneModal.format(18), gMotionModal.format(clockwise ? 2.1 : 3.1),
                        xOutput.format(x), yOutput.format(y), zOutput.format(z),
                        iOutput.format(cx - start.x, 0), kOutput.format(cz - start.z, 0), getFeed(feed));
            break;
        case PLANE_YZ:
            writeBlock(gPlaneModal.format(19), gMotionModal.format(clockwise ? 2.1 : 3.1),
                        xOutput.format(x), yOutput.format(y), zOutput.format(z),
                        jOutput.format(cy - start.y, 0), kOutput.format(cz - start.z, 0), getFeed(feed));
            break;
        default:
            linearize(tolerance);
    }
}
```
5.25.5 3-D Circular Interpolation

3-D circular interpolation is defined as circular interpolation that is not on a standard circular plane (XY, ZX, YZ).

3-D circular interpolation when supported on a control is typically specified with a G-code different than the standard G02/G03 circular interpolation G-codes and must contain either the mid-point of the circular move and/or the normal vector of the circle. Most stock post processors do not support 3-D circular interpolation.

```java
default:
  if (getProperty("allow3DArcs")) {
    // a post property is used to enable support of 3-D circular
    // make sure maximumCircularSweep is well below 360deg
    var ip = getPositionU(0.5);  // calculate mid-point of circle
    writeBlock(gMotionModal.format(clockwise ? 2.4 : 3.4), // 3-D circular direction G-codes
               xOutput.format(ip.x), yOutput.format(ip.y), zOutput.format(ip.z), // output mid-point of circle
               getFeed(feed));
    writeBlock(xOutput.format(x), yOutput.format(y), zOutput.format(z)); // output end-point
  } else {
    linearize(tolerance);
  }
```

5.26 invokeOnCircular

```java
invokeOnCircular(clockwise, cx, cy, cz, x, y, z, i, j, k, feed);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>clockwise</td>
<td>Set to true if the direction of the circular is in the clockwise direction, false if it is counter-clockwise.</td>
</tr>
<tr>
<td>cx, cy, cz</td>
<td>The center of the circle.</td>
</tr>
<tr>
<td>x, y, z</td>
<td>The tool position.</td>
</tr>
<tr>
<td>i, j, k</td>
<td>The normal vector of the circle.</td>
</tr>
<tr>
<td>feed</td>
<td>The feedrate.</td>
</tr>
</tbody>
</table>

It is possible that the post processor will need to generate circular arcs during the processing of the intermediate file. To do this `invokeOnCircular` can be called. Calling `invokeOnCircular` ensures that
the post engine is notified of the arc move and the current position is set. *invokeOnCircular* will then call *onCircular* with the provided arguments and setting the proper circular variables.

### 5.27 onCycle

```javascript
function onCycle() {
    // Code goes here
}
```

The *onCycle* function is called once at the beginning of an operation that contains a canned cycle and can contain code to prepare the machine for the cycle. Mill post processors will typically set the machining plane here.

```javascript
function onCycle() {
    writeBlock(gPlaneModal.format(17));
}
```

**Sample onCycle Function**

Mill/Turn post processors will usually handle the stock transfer sequence in the *onCycle* function. Logic for the Mill/Turn post processors will be discussed in a dedicated chapter.

### 5.28 onCyclePoint

```javascript
function onCyclePoint(x, y, z) {
    // Code goes here
}
```

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>x, y, z</td>
<td>Hole bottom location.</td>
</tr>
</tbody>
</table>

Canned cycle output is handled in the *onCyclePoint* function, which includes positioning to the clearance plane, formatting of the cycle block, calculating the cycle parameters, discerning if the canned cycle is supported on the machine or should be expanded, and probing cycles which will not be discussed in this chapter.

The location of the hole bottom for the cycle is passed in as the *x, y, z* arguments to the *onCyclePoint* function. All other parameters are available in the *cycle* object or through cycle specific function calls. The flow of outputting canned cycles usually follows the following logic.

1. First hole location in cycle
   a. Position to clearance plane
   b. Canned cycle is supported on machine
      i. Calculate common cycle parameters
      ii. Format and output canned cycle
   c. Canned cycle is not supported on machine
      i. Expand cycle into linear moves
2. 2nd through nth holes
   a. Cycle is not expanded
      i. Output hole location
   b. Cycle is expanded
      i. Expand cycle at new location
The actual output of the cycle blocks is handled in a `switch` block, with a separate `case` for each of the supported cycles.

```java
switch (cycleType) {
    case "drilling":
        writeBlock(
            gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(81),
            getCommonCycle(x, y, z, cycle.retract),
            feedOutput.format(F)
        );
        break;
}
```

**Sample Cycle Formatting Code**

If a cycle is not supported and needs to be expanded by the post engine, then you can either remove the entire case block for this cycle and it will be handled in the default block, or you can specifically expand the cycle. The second method is handy when the canned cycle does not support all of the parameters available in HSM, for example if a dwell is not supported for a deep drilling cycle on the machine, but you want to be able to use a dwell.

```java
case "deep-drilling":
    if (P > 0) { // the machine does not support a dwell code, so expand the cycle
        expandCyclePoint(x, y, z);
    } else {
        writeBlock(
            gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(83),
            getCommonCycle(x, y, z, cycle.retract),
            "Q" + xyzFormat.format(cycle.incrementalDepth),
            feedOutput.format(F)
        );
    }
    break;
```

**Expanding a Cycle When a Feature is not Support on the Machine**

The 2nd through the nth locations in a cycle operation are typically output using simple XY moves without any of the cycle definition codes. Expanded cycles still need to be expanded at these locations.

```java
} else { // end of isFirstCyclePoint() condition
    if (cycleExpanded) {
        expandCyclePoint(x, y, z);
    } else {
        var _x = xOutput.format(x);
        var _y = yOutput.format(y);
        if (!x && !_y) {
            xOutput.reset(); // at least one axis is required
            _x = xOutput.format(x);
        }
```
### 5.28.1 Drilling Cycle Types

The following table contains the drilling (hole making cycles). The cycle type is stored in the `cycleType` variable as a text string. The standard G-code used for the cycle is included in the description, where expanded defines the cycle as usually not being supported on the machine and expanded instead.

<table>
<thead>
<tr>
<th>cycleType</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>drilling</td>
<td>Feed in to depth and rapid out (G81)</td>
</tr>
<tr>
<td>counter-boring</td>
<td>Feed in to depth, dwell, and rapid out (G82)</td>
</tr>
<tr>
<td>chip-breaking</td>
<td>Multiple pecks with periodic partial retract to clear chips (G73)</td>
</tr>
<tr>
<td>deep-drilling</td>
<td>Peck drilling with full retraction at end of each peck (G83)</td>
</tr>
<tr>
<td>break-through-drilling</td>
<td>Allows for reduced speed and feed before breaking through hole (expanded)</td>
</tr>
<tr>
<td>gun-drilling</td>
<td>Guided deep drilling allows for a change in spindle speed for positioning (expanded)</td>
</tr>
<tr>
<td>tapping</td>
<td>Feed in to depth, reverse spindle, optional dwell, and feed out. Automatically determines left or right tapping depending on the tool selected. (G74/G84)</td>
</tr>
<tr>
<td>left-tapping</td>
<td>Left-handed tapping (G74)</td>
</tr>
<tr>
<td>right-tapping</td>
<td>Right-handed tapping (G84)</td>
</tr>
<tr>
<td>tapping-with-chip-breaking</td>
<td>Tapping with multiple pecks. Automatically determines left or right tapping depending on the tool selected. (expanded)</td>
</tr>
<tr>
<td>reaming</td>
<td>Feed in to depth and feed out (G85)</td>
</tr>
<tr>
<td>boring</td>
<td>Feed in to depth, dwell, and feed out (G86)</td>
</tr>
<tr>
<td>stop-boring</td>
<td>Feed to depth, stop the spindle, and feed out (G87)</td>
</tr>
<tr>
<td>fine-boring</td>
<td>Feed to depth, orientate the spindle, shift from wall, and rapid out (G76)</td>
</tr>
<tr>
<td>back-boring</td>
<td>Orientate the spindle, rapid to depth, start spindle, shift the tool to wall, feed up to bore height, orientate spindle, shift from wall, and rapid out (G77)</td>
</tr>
<tr>
<td>circular-pocket-milling</td>
<td>Mills out a hole (expanded)</td>
</tr>
<tr>
<td>thread-milling</td>
<td>Helical thread cutting (expanded)</td>
</tr>
</tbody>
</table>

Types of Drilling Cycles

Any of these cycles can be expanded if the machine control does not support the specific cycle. There are some caveats, where the post (and machine) must support certain capabilities for the expanded cycle to run correctly on the machine. The following table lists the commands that must be defined in the `onCommand` function to support the expansion of these cycles. It is expected that the machine will support these features if they are enabled in the post processor.
<table>
<thead>
<tr>
<th>cycleType</th>
<th>Supported onCommand Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>tapping</td>
<td>COMMAND_SPINDLE_CLOCKWISE</td>
</tr>
<tr>
<td>left-tapping</td>
<td>COMMAND_SPINDLE_COUNTERCLOCKWISE</td>
</tr>
<tr>
<td>right-tapping</td>
<td>COMMAND_ACTIVATE_SPEED_FEED_SYNCHRONIZATION</td>
</tr>
<tr>
<td>tapping-with-chip-breaking</td>
<td>COMMAND_DEACTIVATE_SPEED_FEED_SYNCHRONIZATION</td>
</tr>
<tr>
<td>stop-boring</td>
<td>COMMAND_STOP_SPINDLE</td>
</tr>
<tr>
<td>fine-boring</td>
<td>COMMAND_STOP_SPINDLE</td>
</tr>
<tr>
<td>back-boring</td>
<td>COMMAND_START_SPINDLE</td>
</tr>
<tr>
<td>COMMAND_ORIENTATE_SPINDLE</td>
<td></td>
</tr>
</tbody>
</table>

Required Command Support for Expanded Cycles

Certain cycles will use the following parameters when they are expanded.

<table>
<thead>
<tr>
<th>machineParameters.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>drillingSafeDistance</td>
<td>Specifies the safety distance above the stock when repositioning into the hole for the chip-breaking and deep-drilling cycles.</td>
</tr>
<tr>
<td>spindleOrientation</td>
<td>The spindle orientation angle after orientating the spindle.</td>
</tr>
<tr>
<td>spindleSpeedDwell</td>
<td>Dwell in seconds after the spindle speed changes during a cycle.</td>
</tr>
</tbody>
</table>

Parameters for Expanded Cycles

You define the expanded cycle parameters using the following syntaxes.

```plaintext
machineParameters.drillingSafeDistance = toPreciseUnit(2, MM);
machineParameters.spindleOrientation = 0;
machineParameters.spindleSpeedDwell = 1.5;
```

Defining Expanded Cycles Parameters

5.28.2 Cycle parameters

The parameters defined in the cycle operation are passed to the cycle functions using the `cycle` object. The following variables are available and are referenced as 'cycle.parameter'.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>accumulatedDepth</td>
<td>The depth of the combined cuts before the tool will be fully retracted during a chip-breaking cycle.</td>
</tr>
<tr>
<td>backBoreDistance</td>
<td>The cutting distance of a back-boring cycle.</td>
</tr>
<tr>
<td>bottom</td>
<td>The bottom of the hole.</td>
</tr>
<tr>
<td>breakThroughDistance</td>
<td>The distance above the hole bottom to switch to the break-through feedrate and spindle speed during a break-through-drilling cycle.</td>
</tr>
<tr>
<td>breakThroughFeedRate</td>
<td>The feedrate used when breaking through the hole during a break-through-drilling cycle.</td>
</tr>
<tr>
<td>breakThroughSpindleSpeed</td>
<td>The spindle speed used when breaking through the hole during a break-through-drilling cycle.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>chipBreakDistance</td>
<td>The distance to retract the tool to break the chip during a chip-breaking cycle.</td>
</tr>
<tr>
<td>clearance</td>
<td>Clearance plane where the tool will retract the tool to after drilling a hole and position to the next hole.</td>
</tr>
<tr>
<td>compensation</td>
<td>Radius compensation in effect for circular-pocket-milling and thread-milling cycles. This value can be control, wear, and inverseWear.</td>
</tr>
<tr>
<td>compensationShiftOrientation</td>
<td>Same as shiftOrientation.</td>
</tr>
<tr>
<td>depth</td>
<td>The depth of the hole.</td>
</tr>
<tr>
<td>diameter</td>
<td>The diameter of the hole for circular-pocket-milling and thread-milling cycles.</td>
</tr>
<tr>
<td>direction</td>
<td>Either climb or conventional milling for circular-pocket-milling and thread-milling cycles.</td>
</tr>
<tr>
<td>dwell</td>
<td>The dwell time in seconds.</td>
</tr>
<tr>
<td>dwellDepth</td>
<td>The distance above the cut depth at which to dwell, used for gun-drilling cycles.</td>
</tr>
<tr>
<td>feedrate</td>
<td>The primary cutting feedrate.</td>
</tr>
<tr>
<td>incrementalDepth</td>
<td>The incremental pecking depth of the first cut.</td>
</tr>
<tr>
<td>incrementalDepthReduction</td>
<td>The incremental pecking depth reduction per cut for pecking cycles.</td>
</tr>
<tr>
<td>minimumIncrementalDepth</td>
<td>The minimum pecking depth of cut for pecking cycles.</td>
</tr>
<tr>
<td>numberOfSteps</td>
<td>The number of horizontal passes for the thread-milling cycle.</td>
</tr>
<tr>
<td>plungeFeedrate</td>
<td>The cutting feedrate. The same as feedrate.</td>
</tr>
<tr>
<td>plungesPerRetract</td>
<td>The number of cuts before the tool will be fully retracted during a chip-breaking cycle.</td>
</tr>
<tr>
<td>positioningFeedrate</td>
<td>The feedrate used to position the tool during a gun-drilling cycle.</td>
</tr>
<tr>
<td>positioningSpindleSpeed</td>
<td>The spindle speed used when positioning the tool during a gun-drilling cycle.</td>
</tr>
<tr>
<td>repeatPass</td>
<td>Set to true if the final pass should be repeated for circular-pocket-milling and thread-milling cycles.</td>
</tr>
<tr>
<td>retract</td>
<td>The plane where the tool will position to prior to starting the cycle (feeding into the hole).</td>
</tr>
<tr>
<td>retractFeedrate</td>
<td>The tool retraction feedrate, used when feeding out of the hole.</td>
</tr>
<tr>
<td>shift</td>
<td>The distance to shift the tool away from the wall during a fine-boring and back-boring cycle.</td>
</tr>
<tr>
<td>shiftDirection</td>
<td>The direction in radians to shift the tool away from the wall during a fine-boring and back-boring cycle. The shift direction will be π radians (180 degrees) from the wall plus this amount.</td>
</tr>
<tr>
<td>shiftOrientation</td>
<td>The spindle orientation of the tool in radians when shifting the tool away from the wall during a fine-boring or back-boring cycle.</td>
</tr>
<tr>
<td>stepover</td>
<td>The horizontal stepover distance for circular-pocket-milling and thread-milling cycles.</td>
</tr>
<tr>
<td>stock</td>
<td>The top of the hole.</td>
</tr>
<tr>
<td>stopSpindle</td>
<td>When set to 1, the spindle will be stopped during positioning/retracting in a gun-drilling cycle.</td>
</tr>
<tr>
<td>threading</td>
<td>Either right or left-handed threading for thread-milling cycles.</td>
</tr>
</tbody>
</table>
5.28.3 The Cycle Planes/Heights

The drilling cycles use different heights during the execution of the cycle. These heights are specified in the Heights tab for the Drilling operation. One thing you should keep in mind is that the names given to these heights do not match the cycle parameter names in the post processor. The following table gives the relationship between the HSM height names and the equivalent cycle parameter names.

<table>
<thead>
<tr>
<th>Operation Heights Tab</th>
<th>Cycle Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearance Height</td>
<td>(none)</td>
<td>The plane to position to the first point of the cycle and to retract the tool to after the final point of the cycle.</td>
</tr>
<tr>
<td>Retract Height</td>
<td>cycle.clearance</td>
<td>The tool rapids to this plane from the clearance height and will position between the holes at this height.</td>
</tr>
<tr>
<td>Feed Height</td>
<td>cycle.retract</td>
<td>The tool will feed from this plane into the hole.</td>
</tr>
<tr>
<td>Top Height</td>
<td>cycle.stock</td>
<td>The top of the hole.</td>
</tr>
<tr>
<td>Bottom Height</td>
<td>cycle.bottom</td>
<td>The bottom of the hole. This height is the plane where the tool will drill to and will be different from the actual bottom of the hole if the Drill tip through bottom box is checked.</td>
</tr>
</tbody>
</table>

Correlation Between Cycle Operation Heights and Cycle Parameters

HSM assumes that the tool will always be retracted to the Retract Height (cycle.clearance) between holes, you will notice this in the simulation of the cycle in HSM. This is typically handled in the machine control with a G98 (Retract to clearance plane) code. Of course this code can be different from machine control to machine control and there are controls that will always retract to the Feed Height (cycle.retract) at the end of a drilling operation. In this case it is up to the post processor to retract the tool to the Retract Height.

You can cancel the cycle at the end of the onCyclePoint function and output a tool retract block to take the tool back up to the Retract Height. When this method is used it is also mandatory that the full cycle be output for every hole in the operation and not just the first cycle point. Some machines support a retract plane to be specified with the cancel cycle code, i.e. G80 Rxxx.

```
function onCyclePoint(x, y, z) {
    // if (isFirstCyclePoint()) {
    if (true) { // output a full cycle block for every hole in the operation
        repositionToCycleClearance(cycle, x, y, z);
    }
}
```
5.28.4 Common Cycle Functions

There are functions that are commonly used in the `onCyclePoint` function. The following table lists these functions.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>isFirstCyclePoint()</td>
<td>Returns <code>true</code> if this is the first point in the cycle operation. It is usually called to determine whether to output a full cycle block or just the cycle location.</td>
</tr>
<tr>
<td>isLastCyclePoint()</td>
<td>Returns <code>true</code> if this is the last point in the cycle operation. This function is typically used for a lathe threading operation since HSM sends a single pass to the <code>onCyclePoint</code> function and the full depth of the thread is required to output a single threading block. <code>onCycleEnd</code> is used to terminate a drilling cycle, so this function is not typically used in drilling cycles.</td>
</tr>
<tr>
<td>isProbingCycle()</td>
<td>Returns <code>true</code> if this is a probing cycle.</td>
</tr>
<tr>
<td>repositionToCycleClearance()</td>
<td>Moves the tool to the Retract Height plane (<code>cycle.clearance</code>). This function is typically called prior to outputting a full cycle block.</td>
</tr>
<tr>
<td>getCommonCycle(x, y, z, r)</td>
<td>Formats the common cycle parameters (X, Y, Z, R) for output.</td>
</tr>
</tbody>
</table>

These functions are built into the post engine, except the `getCommonCycle` function, which is contained in the post processor. It takes the cycle location (x, y, z) and the retract plane/distance (r) as arguments. Some machines require that the retract value be programmed as a distance from the current location rather than as an absolute position. There are two ways to accomplish this. You can pass in the distance as the retract value.

```javascript
function getCommonCycle(x, y, z, r) {
    forceXYZ();
    return [xOutput.format(x), yOutput.format(y),
            zOutput.format(z),
            "R" + xyzFormat.format(r)];
}
```
Or you can pass the clearance plane in to the `getCommonCycle` function and have it calculate the distance. This method is typically used in post processors that support subprograms that require a retract plane while in absolute mode and a distance when in incremental mode.

```javascript
function getCommonCycle(x, y, z, r, c) {
  forceXYZ(); // force xyz on first drill hole of any cycle
  if (incrementalMode) {
    zOutput.format(c);
    return [xOutput.format(x), yOutput.format(y),
            "Z" + xyzFormat.format(z - r),
            "R" + xyzFormat.format(r - c)];
  } else {
    return [xOutput.format(x), yOutput.format(y),
            zOutput.format(z),
            "R" + xyzFormat.format(r)];
  }
}

... case "drilling":
    writeBlock(
      gRetractModal.format(98), gAbsIncModal.format(90), gCycleModal.format(81),
      getCommonCycle(x, y, z, cycle.retract – cycle.clearance),
      feedOutput.format(F)
    );
    break;
```

Pass Retract and Clearance Heights to `getCommonCycle` Function

5.28.5 Feed per Revolution Output with Drilling Cycles

It is possible to support feed per revolution (FPR) feedrates with drilling cycles. FPR feedrates can be selected in the Drill operation by enabling the `Use Feed per Revolution` checkbox.
Specify that Feed per Revolution Feedrates are to be used with Drilling Cycles

The post must inform the CAM system that FPR feedrates are supported and have logic in the post to output the proper codes for FPR feedrates. Setting the `allowFeedPerRevolutionDrilling` variable to `true` enables FPR feedrates in the post. If this variable is set to `false`, then drilling cycles that select FPR feedrates will be output in feed per minute (FPM) mode.

```plaintext
allowFeedPerRevolutionDrilling = true; // Enable FPR feedrates for drilling cycles
```

A `formatNumber` must be defined to format FPR feedrate numbers. The format is defined at the top of the post processor with the rest of the format definitions. Refer to the `Format Definitions` section.

```plaintext
var feedPerRevFormat = createFormat({decimals:(unit == MM ? 3 : 4), forceDecimal:true});
```

The feedrate mode for the operation should be checked in the `onSection` function, the appropriate output format assigned, and the code to enable the feedrate mode output.

```plaintext
// Output modal commands here
var fMode;
if (currentSection.feedMode == FEED_PER_REVOLUTION) { // FPR feedrates
    feedOutput.setFormat(feedPerRevFormat);
    fMode = 95;
} else { // FPM feedrates
    feedOutput.setFormat(feedFormat);
    fMode = 94;
}
writeBlock(gPlaneModal.format(17), gAbsIncModal.format(90), gFeedModeModal.format(fMode));
```

Your post should now support FPR feedrates for drilling cycles.

### 5.28.6 Pitch Output with Tapping Cycles

Tapping cycles can sometimes be output with a standard FPM feedrate, sometimes with a thread pitch, and sometimes using the FPR feedrate mode. There are different variables and formats involved
depending on the format used. When using pitch or FPR feedrates you will need to create a format for this style of feedrate. The format is defined at the top of the post processor with the rest of the format definitions. Refer to the Format Definitions and Output Variable Definitions sections.

```javascript
var feedFormat = createFormat({decimals:(unit == MM ? 0 : 1), forceDecimal:true});
var pitchFormat = createFormat({decimals:(unit == MM ? 3 : 4), forceDecimal:true});
...
var feedOutput = createVariable({prefix:"F"}, feedFormat);
var pitchOutput = createVariable({prefix:"F", force:true}, pitchFormat);
```

Create the Pitch Output Format

In the tapping sections of the onCyclePoint function you will need to assign the correct pitch value to the output. The tapping pitch is stored in the tool.threadPitch variable.

```javascript
case "tapping":
    writeBlock(
        gRetractModal.format(98), gCycleModal.format((84),
        getCommonCycle(x, y, z, cycle.retract),
        (conditional(P > 0, "P" + milliFormat.format(P)),
        pitchOutput.format(tool.threadPitch)
    );
    forceFeed(); // force the feedrate to be output after a tapping cycle with pitch output
    break;
```

Output the Thread Pitch on a Tapping Cycle

If the tapping cycle requires that the machine be placed in FPR mode, then you can also calculate the pitch value by dividing the feedrate by the spindle speed. You will also need to output the FPR code (G95) with the tapping cycle and reset it at the end of the tapping operation, usually in the onCycleEnd function.

```javascript
case "tapping":
    var F = cycle.feedrate / spindleSpeed;
    writeBlock(
        gRetractModal.format(98), gFeedModeModal.format(95), gCycleModal.format((84),
        getCommonCycle(x, y, z, cycle.retract),
        (conditional(P > 0, "P" + milliFormat.format(P)),
        pitchOutput.format(F)
    );
    forceFeed(); // force the feedrate to be output after a tapping cycle with pitch output
    break;
```

Output the Feedrate as FPR on a Tapping Cycle

### 5.29 onCycleEnd

```javascript
function onCycleEnd() {
```

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The onCycleEnd function is called after all points in the cycle operation have been processed. The cycle is cancelled in this function and the feedrate mode (FPM) is reset if it is a tapping operation that uses FPR feedrates.

```javascript
function onCycleEnd() {
    if (!cycleExpanded) {
        writeBlock(gCycleModal.format(80));
        // writeBlock(gFeedModeModal.format(94), gCycleModal.format(80)); // reset FPM mode
        zOutput.reset();
    }
}
```

### 5.30 Common Functions

There are functions that are common in most of the generic posts. Some of these functions are used in conjunction with other post processor functions and are described in the appropriate section of this manual, for example the formatComment function is described with the onComment function. This section describes the common functions that are generic in nature and used throughout the post processor.

#### 5.30.1 writeln

```javascript
writeln(text);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>text</td>
<td>Text to output to the NC file</td>
</tr>
</tbody>
</table>

The writeln function is built into the post engine and is not defined in the post processor. It is used to output text to the NC file without formatting it. Text can be a quoted text string or a text expression. writeln is typically used for outputting text strings that don't require formatting, or debug messages.

```javascript
writeln("%"); // outputs '

writeln("Vector = " + new Vector(x, y, z)); // outputs the x, y, z variables in vector format
writeln("\n"); // outputs a blank line
writeln(formatComment("Load tool " + tool.number + " in spindle"));
// outputs 'Load tool n in spindle' as a comment
```

#### 5.30.2 writeBlock

```javascript
function writeBlock(arguments) {
    // code
}
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>arguments</td>
<td>Comma separated list of codes/text to output.</td>
</tr>
</tbody>
</table>
The `writeBlock` function writes a block of codes to the output NC file. It will add a sequence number to the block, if sequence numbers are enabled and add an optional skip character if this is an optional operation. A list of formatted codes and/or text strings are passed to the `writeBlock` function. The code list is separated by commas, so that each code is passed as an individual argument, which allows for the codes to be separated by the word separator defined by the `setWordSeparator` function.

```javascript
/**
   * Writes the specified block.
   */
function writeBlock() {
  var text = formatWords(arguments);
  if (!text) {
    return;
  }
  if (getProperty("showSequenceNumbers")) { // add sequence numbers to output blocks
    if (optionalSection) {
      if (text) {
        writeWords("/", "N" + sequenceNumber, text);
      }
    } else {
      writeWords2("N" + sequenceNumber, text);
    }
    sequenceNumber += getProperty("sequenceNumberIncrement");
  } else { // no sequence numbers
    if (optionalSection) {
      writeWords2("/", text);
    } else {
      writeWords(text);
    }
  }
}
```

**Sample writeBlock Function**

```javascript
writeBlock(gAbsIncModal.format(90), xFormat.format(x), yFormat.format(y));
writeBlock("G28", "X" + xFormat.format(0), "Y" + yFormat.format(0)); // outputs 'G28 X0 Y0'
writeBlock("G28" + "X" + xFormat.format(0) + "Y" + yFormat.format(0)); // outputs 'G28 X0Y0'
```

**Sample writeBlock Calls**

The `writeBlock` function does not usually have to be modified.

### 5.30.3 toPreciseUnit

```javascript
toPreciseUnit(value, units);
```
### Arguments

<table>
<thead>
<tr>
<th><strong>Arguments</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>The input value.</td>
</tr>
<tr>
<td>units</td>
<td>The units that the value is given in, either MM or IN.</td>
</tr>
</tbody>
</table>

The `toPreciseUnit` function allows you to specify a value in a given units and that value will be returned in the active units of the input intermediate CNC file. When developing a post processor, it is highly recommended that any unit based hard coded numbers use the `toPreciseUnit` function when defining the number.

```
yAxisMinimum = toPreciseUnit(gotYAxis ? -50.8 : 0, MM); // minimum range for the Y-axis
yAxisMaximum = toPreciseUnit(gotYAxis ? 50.8 : 0, MM); // maximum range for the Y-axis
xAxisMinimum = toPreciseUnit(0, MM); // maximum range for the X-axis (radius mode)
```

### 5.30.4 force---

The `force` functions are used to force the output of the specified axes and/or feedrate the next time they are supposed to be output, even if it has the same value as the previous value.

<table>
<thead>
<tr>
<th><strong>Function</strong></th>
<th><strong>Description</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>forceXYZ</td>
<td>Forces the output of the linear axes (X, Y, Z) on the next motion block.</td>
</tr>
<tr>
<td>forceABC</td>
<td>Forces the output of the rotary axes (A, B, C) on the next motion block.</td>
</tr>
<tr>
<td>forceFeed</td>
<td>Forces the output of the feedrate on the next motion block.</td>
</tr>
<tr>
<td>forceAny</td>
<td>Forces all axes and the feedrate on the next motion block.</td>
</tr>
</tbody>
</table>

```
/** Force output of X, Y, and Z on next output. */
function forceXYZ() {
    xOutput.reset();
    yOutput.reset();
    zOutput.reset();
}

/** Force output of A, B, and C on next output. */
function forceABC() {
    aOutput.reset();
    bOutput.reset();
    cOutput.reset();
}

/** Force output of F on next output. */
function forceFeed() {
    currentFeedId = undefined;
    feedOutput.reset();
}
```
/** Force output of X, Y, Z, A, B, C, and F on next output. */
function forceAny() {
  forceXYZ();
  forceABC();
  forceFeed();
}

5.30.5 writeRetract

function writeRetract(arguments) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>arguments</td>
<td>X, Y, and/or Z. Separated by commas when multiple axes are specified.</td>
</tr>
</tbody>
</table>

The writeRetract function is used to retract the Z-axis to its clearance plane and move the X and Y axes to their home positions.

The writeRetract function can be called with one or more axes to move to their home position. The axes are specified using their standard names of X, Y, Z, and are separated by commas if multiple axes are specified in the call to writeRetract.

writeRetract(Z); // move the Z-axis to its home position
writeRetract(X, Y); // move the X and Y axes to their home positions

The writeRetract function is not generic in nature and may have to be changed to match your machine's requirements. For example, some machines use a G28 to move an axis to its home position, some will use a G53 with the home position, and some use a standard G00 block.

/** Output block to do safe retract and/or move to home position. */
function writeRetract() {
  // initialize routine
  var _xyzMoved = new Array(false, false, false);
  var _useG28 = getProperty("useG28"); // can be either true or false

  // check syntax of call
  if (arguments.length == 0) {
    error(localize("No axis specified for writeRetract.");
    return;
  }
  for (var i = 0; i < arguments.length; ++i) {
    if ((arguments[i] < 0) || (arguments[i] > 2)) {
      error(localize("Bad axis specified for writeRetract."));
    }
  }
}
return;
}
if (_xyzMoved[arguments[i]]) {
    error(localize("Cannot retract the same axis twice in one line"));
    return;
}
_xxyzMoved[arguments[i]] = true;
}

// special conditions
if (_useG28 && _xyzMoved[2] && (_xyzMoved[0] || _xyzMoved[1])) { // XY don't use G28
    error(localize("You cannot move home in XY & Z in the same block."));
    return;
}
if (_xyzMoved[0] || _xyzMoved[1]) {
    _useG28 = false;
}

// define home positions
var _xHome;
var _yHome;
var _zHome;
if (_useG28) {
    _xHome = 0;
    _yHome = 0;
    _zHome = 0;
} else {
    if (getProperty("homePositionCenter") &&
        hasParameter("part-upper-x") && hasParameter("part-lower-x")) {
        _xHome = (getParameter("part-upper-x") + getParameter("part-lower-x")) / 2;
    } else {
        _xHome = machineConfiguration.hasHomePositionX() ? machineConfiguration.getHomePositionX() : 0;
    }
    _yHome = machineConfiguration.hasHomePositionY() ? machineConfiguration.getHomePositionY() : 0;
    _zHome = machineConfiguration.getRetractPlane();
}

// format home positions
var words = [];
for (var i = 0; i < arguments.length; ++i) {
    // define the axes to move
    switch (arguments[i]) {
    case X:
        // special conditions
if (getProperty("homePositionCenter")) { // output X in standard block by itself if centering
   writeBlock(gMotionModal.format(0), xOutput.format(_xHome));
   _xyzMoved[0] = false;
   break;
 }
words.push("X" + xyzFormat.format(_xHome));
break;
case Y:
   words.push("Y" + xyzFormat.format(_yHome));
   break;
case Z:
   words.push("Z" + xyzFormat.format(_zHome));
   retracted = true;
   break;
}

// output move to home
if (words.length > 0) {
   if (_useG28) { // use G28 to move to home position
      gAbsIncModal.reset();
      writeBlock(gFormat.format(28), gAbsIncModal.format(91), words);
      writeBlock(gAbsIncModal.format(90));
   } else { // use G53 to move to home position
      gMotionModal.reset();
      writeBlock(gAbsIncModal.format(90), gFormat.format(53), gMotionModal.format(0), words);
   }

   // force any axes that move to home on next block
   if (_xyzMoved[0]) {
      xOutput.reset();
   }
   if (_xyzMoved[1]) {
      yOutput.reset();
   }
   if (_xyzMoved[2]) {
      zOutput.reset();
   }
}

Sample writeRetract Function
**6 Manual NC Commands**

Manual NC commands are used to control the behavior of individual operations when there is not a setting in the operation form for controlling a specific feature of a control. You can use Manual NC commands to display a message, insert codes into the output NC file, perform an optional stop, define a setting, etc. The Manual NC menu is accessed from different areas of the ribbon menu depending on the product you are running.

![Selecting a Manual NC Command in the HSM Products (Fusion 360, Inventor, HSMWorks)](image)

Once you select the Manual NC menu you will see a form displayed that is used to select the type of Manual NC command that you want to pass to the post processor and optionally the parameter that will be passed with the command.

![Defining a Manual NC Command](image)

If you use a Manual NC command in your part, then it is necessary that the post processor is equipped to handle this command. Some of the commands are supported by the stock post processors, such as *Stop*, *Optional stop*, and *Dwell*, while support would have to be added to the post processor to support other Manual NC commands. If you use a Manual NC command that is not supported by the post, then it will either generate an error or be ignored. The general rule is it will generate an error if the `onCommand` function is called and will be ignored when another function is called.
6.1 onManualNC and expandManualNC

```javascript
function onManualNC(command, value) {
  expandManualNC(command, value)
}
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>command</td>
<td>The Manual NC command that invoked the function.</td>
</tr>
<tr>
<td>value</td>
<td>The value entered with the command.</td>
</tr>
</tbody>
</table>

The `onManualNC` function is defined in the post processor and is used to process Manual NC commands. It accepts the command and the value that is assigned to the command. If the `onManualNC` function is not defined in the post processor, then a separate function will be called as listed in the table below.

The `expandManualNC` command can also be used to process the Manual NC command using the separate functions listed in the table. It is typically used as the default condition in the `onManualNC` function to process commands where you do not care if they are entered as a Manual NC command or from an internal call in the post processor.

The following table describes the Manual NC commands along with the function that will be called when the command is processed when the `onManualNC` function does not exist or `expandManualNC` is called.

<table>
<thead>
<tr>
<th>Manual NC Command</th>
<th>Description</th>
<th>Command</th>
<th>Value</th>
<th>Function Called</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comment</td>
<td>Operator message</td>
<td>COMMAND_COMMENT</td>
<td>message</td>
<td>onComment</td>
</tr>
<tr>
<td>Stop</td>
<td>Machine stop</td>
<td>COMMAND_STOP</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Optional Stop</td>
<td>Optional stop</td>
<td>COMMAND_OPTIONAL_STOP</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Dwell</td>
<td>Dwell</td>
<td>COMMAND_DWELL</td>
<td>Dwell time in seconds</td>
<td>onDwell</td>
</tr>
<tr>
<td>Tool break control</td>
<td>Check for tool breakage</td>
<td>COMMAND_BREAK_CONTROL</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Measure tool</td>
<td>Automatically measure tool length</td>
<td>COMMAND_TOOL_MEASURE</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Start chip transport</td>
<td>Start chip conveyor</td>
<td>COMMAND_START_CHIP_TRANSPORT</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Stop chip transport</td>
<td>Stop chip conveyor</td>
<td>COMMAND_STOP_CHIP_TRANSPORT</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Open door</td>
<td>Open main door</td>
<td>COMMAND_OPEN_DOOR</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Close door</td>
<td>Close main door</td>
<td>COMMAND_CLOSE_DOOR</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Calibrate</td>
<td>Calibration of machine</td>
<td>COMMAND_CALIBRATE</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Manual NC Command</td>
<td>Description</td>
<td>Command</td>
<td>Value</td>
<td>Function Called</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------</td>
<td>-----------------------</td>
<td>----------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Verify</td>
<td>Verify integrity of machine</td>
<td>COMMAND_VERIFY</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Clean</td>
<td>Request a cleaning cycle</td>
<td>COMMAND_CLEAN</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Action</td>
<td>User defined action</td>
<td>COMMAND_ACTION</td>
<td>text</td>
<td>onParameter</td>
</tr>
<tr>
<td>Print message</td>
<td>Print a message from the machine</td>
<td>COMMAND_PRINT_MESSAGE</td>
<td>message</td>
<td>onParameter</td>
</tr>
<tr>
<td>Display message</td>
<td>Display operator message</td>
<td>COMMAND_DISPLAY_MESSAGE</td>
<td>message</td>
<td>onParameter</td>
</tr>
<tr>
<td>Alarm</td>
<td>Create an alarm on the machine</td>
<td>COMMAND_ALARM</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Alert</td>
<td>Request an alert event on the machine</td>
<td>COMMAND_ALERT</td>
<td></td>
<td>onCommand</td>
</tr>
<tr>
<td>Pass through</td>
<td>Output literal text to NC file</td>
<td>COMMAND_PASS THROUGH</td>
<td>text</td>
<td>onPassThrough</td>
</tr>
<tr>
<td>Force tool change</td>
<td>Force a tool change</td>
<td>section.getForceToolChange()</td>
<td>(none)</td>
<td></td>
</tr>
<tr>
<td>Call program</td>
<td>Call a subprogram</td>
<td>COMMAND_CALL_PROGRAM</td>
<td>text</td>
<td>onParameter</td>
</tr>
</tbody>
</table>

**6.1.1 Sample onManualNC Function**

The onManualNC function is a recent addition to the post processor and will not be found in most generic post processors. You do not have to define it to process Manual NC commands, and if it is defined, do not need to process all Manual NC commands in this function. It could be used to process only the commands where you need to know if they were generated from a CAM Manual NC command instead of a direct call from within the post processor.

For example, the following onManualNC function definition could be used to process comments entered using the CAM Manual NC command differently than comments generated from the post processor. It simply appends the text ‘MSG,’ prior to the comment for a Manual NC Display comment command. All other Manual NC commands are processed normally.

```javascript
function onManualNC(command, value) {
    switch (command) {
    case COMMAND_DISPLAY_MESSAGE:
        writeComment("MSG," + value);
        break;
    default:
        expandManualNC(command, value); // normal processing of Manual NC command
    }
}
```
6.1.2 Delay Processing of Manual NC Commands

Manual NC commands are processed at the placement in the operation tree where they are entered, which means that they will be processed prior to the call to onSection. Since onSection typically terminates the previous operation prior to starting the new operation, this might not be the desirable location to process the Manual NC command.

The following code examples show how Manual NC commands can be buffered and output at any point during the operation. You can simply copy the onManualNC and executeManualNC functions into your post processor and add the appropriate call(s) to executeManualNC where you want to process the Manual NC commands.

```javascript
/**
 * Buffer Manual NC commands for processing later
 */
var manualNC = [];
function onManualNC(command, value) {
    manualNC.push({command:command, value:value});
}

/**
 * Processes the Manual NC commands
 * Pass the desired command to process or leave argument list blank to process all buffered commands
 */
function executeManualNC(command) {
    for (var i = 0; i < manualNC.length; ++i) {
        if (!command || (command == manualNC[i].command)) {
            switch(manualNC[i].command) {
                case COMMAND_DISPLAY_MESSAGE:
                    writeComment("MSG, " + manualNC[i].value);
                    break;
                default:
                    expandManualNC(manualNC[i].command, manualNC[i].value);
            }
        }
    }
}
```
Manual NC Commands Support Functions

The calls to process the Manual NC commands can be placed anywhere in the post processor. In the following code example, the COMMAND_DISPLAY_MESSAGE command is processed just before the tool change block is output and the rest of the Manual NC commands after the tool change block.

```
executeManualNC(COMMAND_DISPLAY_MESSAGE); // display Manual NC message
writeBlock("T" + toolFormat.format(tool.number), mFormat.format(6));
if (tool.comment) {
    writeComment(tool.comment);
}
executeManualNC(); // process remaining Manual NC commands
```

Processing of Manual NC Commands in the Desired Location

The following sections give a description of the functions that are called by the Manual NC commands outside of the onManualNC function and samples on how they are handled in the functions. The onComment and onDwell functions are described in the Entry Functions chapter, since they are simple functions and behave in the same manner no matter how they are called.

### 6.2 onCommand

```
function onCommand(command) {

Arguments | Description
--- | ---
command | Command to process.
```

All Manual NC commands that do not require an associated parameter are passed to the onCommand function and as you see from the Manual NC Commands table, this entails the majority of the commands. The onCommand function also handles other commands that are not generated by a Manual NC command and these are described in the onCommand section in the Entry Functions chapter.

```
// define commands that output a single M-code
var mapCommand = {
    COMMAND_STOP:0,
    COMMAND_OPTIONAL_STOP:1,
    COMMAND_START_CHIP_TRANSPORT:31,
    COMMAND_STOP_CHIP_TRANSPORT:33
    ...
};

function onCommand(command) {
    switch (command) {
        ...
        case COMMAND_BREAK_CONTROL: // handle the 'Tool break' command
            if (!toolChecked) { // avoid duplicate COMMAND_BREAK_CONTROL
                onCommand(COMMAND_STOP_SPINDLE);
            }
    }
```

Manual NC Commands  6-201
onCommand(COMMAND_COOLANT_OFF);
writeBlock(
    gFormat.format(65),
    "P" + 9853,
    "T" + toolFormat.format(tool.number),
    "B" + xyzFormat.format(0),
    "H" + xyzFormat.format(getProperty("toolBreakageTolerance"))
);
toolChecked = true;
}
return;
case COMMAND_TOOL_MEASURE: // ignore tool measurements
    return;
}

// handle commands that output a single M-code
var stringId = getCommandStringId(command);
var mcode = mapCommand[stringId];
if (mcode != undefined) {
    writeBlock(mFormat.format(mcode));
} else {
    onUnsupportedCommand(command);
}

/**
 * Handling Manual NC Commands in the onCommand Function
 */

6.3 onParameter

function onParameter(name, value) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>name</td>
<td>Parameter name.</td>
</tr>
<tr>
<td>value</td>
<td>Value stored in the parameter.</td>
</tr>
</tbody>
</table>

The onParameter function is not only called for all parameters defined in the intermediate file (see the many calls to onParameter in the dump.cps post processor output) it also handles the Action, Call program, Display message, and Print message Manual NC commands. It is passed both the name of the parameter being defined and the text string associated with that parameter.

<table>
<thead>
<tr>
<th>Manual NC Command</th>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>action</td>
<td>text</td>
</tr>
<tr>
<td>Call program</td>
<td>call-subprogram</td>
<td>text</td>
</tr>
<tr>
<td>Display message</td>
<td>display</td>
<td>text</td>
</tr>
<tr>
<td>Print message</td>
<td>Print</td>
<td>text</td>
</tr>
</tbody>
</table>

Manual NC Commands  6-202
This section will describe how the Action command can be used, since this is the most commonly used of these commands.

The Action command is typically used to define post processor settings, similar to the post properties defined at the top of the post processor, except that the settings defined using this command typically only apply to a single operation. Since the HSM operations are executed in the order that they are defined in the CAM tree, the Manual NC command will always be processed prior to the operation that they precede. You can also use the Action command to define a setting so that the command can be executed within another section of the post, by referencing this setting. You can even define settings that are typically set in the post properties into your program, so you are not reliant on making sure that the property is set for a specific program. In this case the Action command would set the value of the post property based on the input value associated with the command.

It is the onParameter function’s responsibility to parse the text string passed as part of the Action command. The text string could be a value, list of values, command and value, etc. The following table lists the Action commands that are supported by the sample post processor code used in this section. These Action commands set variables that will be used elsewhere in the program.

<table>
<thead>
<tr>
<th>Action Command</th>
<th>Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoothing</td>
<td>Off, Low, Medium, High</td>
<td>Sets the smoothing type</td>
</tr>
<tr>
<td>Tolerance</td>
<td>.001-.999</td>
<td>Smoothing tolerance</td>
</tr>
<tr>
<td>fastToolChange</td>
<td>Yes, No</td>
<td>Overrides the fastToolChange post property</td>
</tr>
</tbody>
</table>

Sample Action Type Manual NC Commands

In this example, the format for entering the Action Manual NC command is to specify the command followed by the ':' separator which in turn is followed by the value, in the Action text field.

```javascript
var smoothingType = 0;
var smoothingTolerance = .001;
function onParameter(name, value) {
  var invalid = false;
  var smoothingType = 0;
  var smoothingTolerance = .001;
  function onParameter(name, value) {
    var invalid = false;
    `
switch (name) {
    case "action":
        var sText1 = String(value).toUpperCase();
        var sText2 = new Array();
        sText2 = sText1.split(":");
        if (sText2.length !== 2) {
            error(localize("Invalid action command: ") + value);
            return;
        }
        switch (sText2[0]) {
            case "SMOOTHING":
                smoothingType = parseChoice(sText2[1], "OFF", "LOW", "MEDIUM", "HIGH");
                if (smoothingType == undefined) {
                    error(localize("Smoothing type must be Off, Low, Medium, or High");
                    return;
                }
                break;
            case "TOLERANCE":
                smoothingTolerance = parseFloat(sText2[1]);
                if (isNaN(smoothingTolerance) || (smoothingTolerance < .001) || (smoothingTolerance > .999)) {
                    error(localize("Smoothing tolerance must be a value between .001 and .999");
                    return;
                }
                break;
            case "FASTTOOLCHANGE":
                var fast = parseChoice(sText2[1], "YES", "NO");
                if (fast == undefined) {
                    error(localize("fastToolChange must be Yes or No");
                    return;
                }
                setProperty("fastToolChange", fast);
                break;
        }
    default:
        error(localize("Invalid action parameter: ") + sText2[0] + ":" + sText2[1]);
        return;
}

/* returns the choice specified in a text string compared to a list of choices */
function parseChoice() {
    var stat = undefined;
    for (i = 1; i < arguments.length; i++) {
        if (String(arguments[0]).toUpperCase() == String(arguments[i]).toUpperCase()) {
            if (String(arguments[i]).toUpperCase() == "YES") {
                stat = true;
            }
        }
    }
    return stat;
}
Handling the Action Manual NC Command

To make it easier to use custom Action Manual NC commands you can use the Template capabilities of HSM. First you will create the Manual NC command that you will turn into a template using the example in the Action Command Format picture shown above. Once the Manual NC command is created you will want to give it a meaningful name by renaming it in the Operation Tree.

Now you will create a template from this Manual NC command by right clicking on the Manual NC command and selecting Store As Template. You will want to give the template the same name as you did in the rename operation.

The template is now ready to be used in other operations and parts. You do this by right clicking a Setup or a Folder in the Operations Tree, position the mouse over the Create From Template menu and select the template you created.
6.4 onPassThrough

Function onPassThrough (value)

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td>Text to be output to the NC file.</td>
</tr>
</tbody>
</table>

The Pass through Manual NC command is used to pass a text string directly to the NC file without any processing by the post processor. It is similar to editing the NC file and adding a line of text by hand. The text string could be standard codes (G, M, etc.) or a simple message. Since the post has no control or knowledge of the codes being output, it is recommended that you use the Pass through command sparingly and only with codes that cannot be output using another method.

The onPassThrough function handles the Pass through Manual NC command and is passed the text entered with the command. The following sample code will accept a text string with comma delimiters that will separate the text into individual lines.

```javascript
function onPassThrough(text) {
    var commands = String(text).split(",");
    for (text in commands) {
        writeBlock(commands[text]);
    }
}
```

Output Lines of Codes/Text Separated by Commands Using the Pass through Manual NC Command

Like the Action Manual NC command, you can setup a Template to use with the Pass through command if you find yourself needing to output the same codes in multiple instances.

7 Debugging

7.1 Overview

The first thing to note when debugging is that there is not an interactive debugger associated with the Autodesk CAM post processors. This means that all debugging information must be output using settings within the post and with explicit writes. This section describes different methods you can use when debugging your post.
You can also use the HSM Post Processor Editor to aid in debugging your program as described in the Running/Debugging the Post section of this manual.

7.2 The dump.cps Post Processor

The dump.cps post processor will process an intermediate CNC file and output a file that contains all of the information passed from HSM to the post processor. The output file has a file extension of .dmp. The contents of the dump file will show the settings of all parameter values and will list the entry functions called along the arguments passed to the function and any settings that apply to that function. The dump.cps output can be of tremendous value when developing and debugging a post processor.

```
342: onParameter('dwell', 0)
344: onParameter('incrementalDepth', 0.03937007874015748)
346: onParameter('incrementalDepthReduction', 0.003937007932681737)
348: onParameter('minimumIncrementalDepth', 0.01968503937007874)
350: onParameter('accumulatedDepth', 5)
352: onParameter('chipBreakDistance', 0.004023600105694899)
354: onMovement(MOVEMENT_CUTTING /*cutting*/)
354: onCycle()
    cycleType='chip-breaking'
    cycle.clearance=123456
    cycle.retract=0.19685039370078738
    cycle.stock=0
    cycle.depth=0.810440544068344
    cycle.feedrate=15.748000257597194
    cycle.retractFeedrate=39.370100366787646
    cycle.plungeFeedrate=15.748000257597194
    cycle.dwell=0
    cycle.incrementalDepth=0.03937007874015748
    cycle.incrementalDepthReduction=0.003937007932681737
    cycle.minimumIncrementalDepth=0.01968503937007874
    cycle.accumulatedDepth=5
    cycle.chipBreakDistance=0.004023600105694899
354: onCyclePoint(-1.25, 0.4999999924907534, -0.810440544068344)
355: onCyclePoint(1.25, 0.4999999924907534, -0.810440544068344)
356: onCycleEnd()
```

Sample dump.cps Output

7.3 Debugging using Post Processor Settings

There are variables available to the developer that control the output of debugging information. This section contains a description of these variables.
### 7.3.1 `debugMode`

```java
debugMode = true;
```

Setting the `debugMode` variable to true enables the output of debug information from the `debug` command and is typically defined at the start of the post processor.

### 7.3.2 `setWriteInvocations`

```java
setWriteInvocations (value);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td><code>true</code> outputs debug information for the entry functions.</td>
</tr>
</tbody>
</table>

Enabling the `setWriteInvocations` setting will create debug output in the NC file similar to what is output using the `dump` post processor. The debug information contains the entry functions (onParameter, onSection, etc.) called during post processing and the parameters that they are called with. This information will be output prior to actually calling the entry function and is labeled using the `!DEBUG:` text.

```
!DEBUG: onRapid(-0.433735, 1.44892, 0.23622)
N190 Z0.2362
!DEBUG: onLinear(-0.433735, 1.44892, 0.0787402, 39.3701)
N195 G1 Z0.0787 F39.37
!DEBUG: onLinear(-0.433735, 1.44892, -0.5, 19.685)
N200 Z-0.5 F19.68
```

### 7.3.3 `setWriteStack`

```java
setWriteStack (value);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>value</td>
<td><code>true</code> outputs the call stack that outputs the line to the NC file.</td>
</tr>
</tbody>
</table>

Enabling the `setWriteStack` setting displays the call stack whenever text is output to the NC file. The call stack will consist of the `!DEBUG:` label, the call level, the name of the post processor, and the line number of the function call (the function name is not included in the output).

```
!DEBUG: 1 rs274.cps:108
!DEBUG: 2 rs274.cps:919
!DEBUG: 3 rs274.cps:357
N125 M5
```

...  
108: writeWords2("N" + sequenceNumber, arguments);
7.4 Functions used with Debugging

Functions that can be used to output debug information to the log and NC files include `debug`, `writeln`, and `log`. Additionally, the `writeComment` function present in almost all post processors can be used.

The text provided to the debug functions can contain operations and follow the same rules as defining a string variable in JavaScript. You can also specify vectors or matrices and these will be properly formatted for output. For example,

```javascript
var x = 3;
debug("The value of x is " + x);
```

For floating point values you may want to create a format that limits the number of digits to right of the decimal point, as some numbers can be quite long when output.

```javascript
var numberFormat = createFormat({decimals:4});
var x = 3;
debug("The value of x is " + numberFormat.format(x));
```

When writing output debug information to the log and/or NC files it is recommended that you precede the debug text with a fixed string, such as "DEBUG – ", so that it is easily discernable from other output.

### 7.4.1 debug

```javascript
depug (text);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>text</td>
<td>Outputs text to the log file when <code>debugMode</code> is set to <code>true</code>.</td>
</tr>
</tbody>
</table>

The `debug` function outputs the provided text message to the log file only when the `debugMode` variable is set to true. The text is output exactly as provided, without any designation that the output was generated by the `debug` function.

### 7.4.2 log

```javascript
log(text);
```
### Arguments

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>text</td>
<td>Outputs text to the log file.</td>
</tr>
</tbody>
</table>

The `log` function outputs the text to the log file. It is similar to the `debug` function, but does not rely on the `debugMode` setting.

#### 7.4.3 writeln

```plaintext
writeln(text);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>text</td>
<td>Outputs text to the NC file.</td>
</tr>
</tbody>
</table>

The `writeln` function outputs the text to the NC file. It is used extensively in post processors to output valid data to the NC file and not just debug text.

#### 7.4.4 writeComment

```plaintext
writeComment(text);
```

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>text</td>
<td>Outputs text to the NC file as a comment.</td>
</tr>
</tbody>
</table>

The `writeComment` function is defined in the post processor and is used to output comments to the output NC file. It is described in the `onComment` section of this manual.

#### 7.4.5 writeDebug

```plaintext
function writeDebug(text) {
  if (true) { // can use the global setting 'debugMode' instead
    writeln("DEBUG - " + text); // can use 'writeComment' instead
    log("DEBUG - " + text); // can use 'debug' instead
  }
}
```

The `writeDebug` function is not typically present in the generic post processors. You can create one to handle the output of debug information to both the log file and NC file so that if the post processor either fails or runs successfully you would still see the debug output.

Sample `writeDebug` Function

---

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AUTODESK CAM Post Processor Guide 11/7/23
8 Multi-Axis Post Processors

8.1 Adding Basic Multi-Axis Capabilities
Adding multi-axis capabilities to a post processor can be rather straight forward or difficult depending on the situation. This chapter will cover the basics and the more complex aspects of multi-axis support, such as adjusting points for a head, inverse time feedrates, etc.

The generic RS-274D Sample Multi-axis Post Processor is available to use as a sample for implementing multi-axis support in any post processor. It supports CAM defined and hardcoded machine configurations. You can use this post processor for testing rotary axes configurations and for copying functionality into your custom post processor.

Please note that support for 3+2 operations is not handled here, except for the setup of the machine. Refer to the Work Plane section in the onSection chapter for a description on how to handle 3+2 operations.

8.1.1 Create the Rotary Axes Formats
The output formats for the rotary axes must first be defined. In existing multi-axis posts and posts that contain the skeleton structure of multi-axis support these codes should already be defined. You should add (or verify that they already exist) the following definitions at the top of the post processor in the same area that all other formats are defined.

```javascript
var abcFormat = createFormat({decimals:3, forceDecimal:true, scale:DEG});
...
var aOutput = createVariable({prefix:"A"}, abcFormat);
var bOutput = createVariable({prefix:"B"}, abcFormat);
var cOutput = createVariable({prefix:"C"}, abcFormat);
```

Define the Rotary Axes Formats

The `scale:DEG` parameter specifies that the rotary axes angles will be output in degrees. If you require the output to be in radians, then omit the `scale` setting.

8.1.2 The Machine Configuration Settings and Functions
The machine configuration and the associated settings are above the `onOpen` function and define and activate the machine configuration in the post processor. If your post processor does not have this code, or it uses the older method of defining a machine configuration in `onOpen`, then you should copy this code from the RS-274D Sample Multi-axis post processor into your post. All lines between and including the following lines should be copied.

```javascript
// Start of machine configuration logic
...
// End of machine configuration logic
```

Copy this Code to your Custom Post Processor

Multi-Axis Post Processors  8-211
You will also need to add the following code to the top of the `onOpen` function to call the machine configuration functions.

```javascript
function onOpen() {
    // define and enable machine configuration
    receivedMachineConfiguration = machineConfiguration.isReceived();
    if (typeof defineMachine == "function") {
        defineMachine(); // hardcoded machine configuration
    }
    activateMachine(); // enable the machine optimizations and settings
}
```

Copy this Code to the Top of the `onOpen` Function

The variables at the top of the machine configuration code control certain aspects of multi-axis logic within the post processor.

```javascript
var compensateToolLength = false; // add the tool length to the pivot distance for nonTCP rotary heads
```

### Multi-axis Settings

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>compensateToolLength</td>
<td>This variable is only used for rotary head configurations that do not support TCP. When it is enabled, the body length of the tool (tool body length) will be added to the pivot distance. Rotary head configurations are discussed in detail in the Adjusting the Points for Offset Rotary Axes section.</td>
</tr>
</tbody>
</table>

### 8.1.3 Creating a Hardcoded Multi-Axis Machine Configuration

You can use a Machine Definition in the CAM system to define the rotary axis kinematics of the machine or it can be hardcoded in the post processor. This section describes how you would hardcode the machine configuration inside of the post processor script.

The hardcoded machine configuration can be found in the `defineMachine` function. It includes all applicable settings that are found in the Machine Definition and contains the following sections of code.

```javascript
function defineMachine() {
    // if (!receivedMachineConfiguration) { // CAM machine definition takes precedence
    if (true) { // hardcoded machine configuration takes precedence
        // define machine kinematics
        var useTCP = false; // TCP support
        var aAxis = createAxis({coordinate:X, table:true, axis:[1, 0, 0], offset:[0, 0, 0], range:[-120, 30], cyclic:false, preference:-1, tcp:useTCP});
        var cAxis = createAxis({coordinate:Z, table:true, axis:[0, 0, 1], offset:[0, 0, 0], cyclic:true, reset:0, tcp:useTCP});
        machineConfiguration = new MachineConfiguration(aAxis, cAxis);
    }
}
```

Define Machine Kinematics
The rotary axes can be customized to match the machine configuration using the parameters in the `createAxis` command.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>table</td>
<td>Set to <code>true</code> when the rotary axis is a table, or <code>false</code> if it is a head. The default if not specified is <code>true</code>.</td>
</tr>
<tr>
<td>axis</td>
<td>Specifies the rotational axis of the rotary axis in the format of a vector, i.e. <code>[0, 0, 1]</code>. This vector does not have to be orthogonal to a major plane, for example it could be <code>[0, .7071, .7071]</code>. The direction of the rotary axes are based on the righthand rule for tables and the lefthand rule for heads. You can change direction of the axis by supplying a vector pointing in the opposite direction, i.e. <code>[0, 0, -1]</code>. This parameter is required.</td>
</tr>
<tr>
<td>offset</td>
<td>Defines the rotational position of the axis in the format of a coordinate, i.e. <code>[0, 0, 0]</code>. For machines that support TCP the <code>offset</code> parameter can be omitted. The offset values for tables are based on the part origin defined in the Setup. The offset value for the rider or primary rotary head is based on the distance from the tool stop (or spindle face) position to the pivot point of the rotary head. The offset value for the carrier rotary head (when the machine has a head/head configuration) is based on the pivot point of the rider axis to the pivot point of the carrier axis. The default is <code>[0, 0, 0]</code>.</td>
</tr>
<tr>
<td>coordinate</td>
<td>Defines the coordinate of the axis, either X, Y, or Z. You will notice a number used in most of the generic posts, in this case 0=X, 1=Y, and 2=Z. Either specification is acceptable input. This parameter is required.</td>
</tr>
<tr>
<td>cyclic</td>
<td>Defines whether the axis is cyclic (continuous) in nature, in that the output will always be within the range specified by the <code>range</code> parameter. Cyclic axes will never cause the <code>onRewindFunction</code> to be called, since they are continuous in nature and do not have limits. The range applies specifically to output values for this axis. The default is <code>false</code>.</td>
</tr>
<tr>
<td>tcp</td>
<td>Defines whether the control supports Tool Center Point programming for this axis. Each axis can have its own setting. The default is <code>true</code>.</td>
</tr>
<tr>
<td>range</td>
<td>Defines the upper and lower limits of the rotary axis using the format <code>[lower, upper]</code>. If the rotary axis is cyclic, then the range sets the limits of the output values for this axis, if it is not cyclic the range is the actual physical limits of the machine.</td>
</tr>
<tr>
<td>preference</td>
<td>Specifies the preferred angle direction at the beginning of an operation. -1 = choose the negative angle, 0 = no preference, and 1 = choose the positive angle. The default is 0.</td>
</tr>
<tr>
<td>reset</td>
<td>Defines the starting position of the axis for a new operation and when the rotary axes need to be rewound and reconfigured due to exceeding the limits. 0 = remember the position from previous section, 1 = reset to 0 at start of operation, 2 = reset to 0 at automatic rewind, 3 = reset to 0 at start of operation and at automatic rewind. This parameter is implemented since R42225 of the post engine.</td>
</tr>
<tr>
<td>resolution</td>
<td>Specifies the resolution in degrees of the rotational actuator. Typically, this will be set to the number of digits to the right of the decimal as specified in the <code>createFormat</code> call for the rotary axes. The default is 0.</td>
</tr>
</tbody>
</table>
The order in which the axes are defined in the `new MachineConfiguration` call is important and must use the following order.

<table>
<thead>
<tr>
<th>Order</th>
<th>Rotary Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rotary head rider</td>
</tr>
<tr>
<td>2</td>
<td>Rotary head carrier</td>
</tr>
<tr>
<td>3</td>
<td>Rotary table carrier</td>
</tr>
<tr>
<td>4</td>
<td>Rotary table rider</td>
</tr>
</tbody>
</table>

### Sample Rotary Configurations

#### // 4 axis setup, A rotates around X, direction is positive
```javascript
var aAxis = createAxis({coordinate:X, table:true, axis:[1, 0, 0], cyclic:true, tcp:false, preference:1});
machineConfiguration = new MachineConfiguration(aAxis);
```

#### // 4 axis setup, A rotates around X, direction is negative
```javascript
var aAxis = createAxis({coordinate:X, table:true, axis:[-1, 0, 0], cyclic:true, tcp:false, preference:1});
machineConfiguration = new MachineConfiguration(aAxis);
```

#### // 5 axis setup, B rotates around Y, C rotates around Z, directions both positive
```javascript
var bAxis = createAxis({coordinate:Y, table:true, axis:[0, 1, 0], range:[-120,120], tcp:true, preference:1});
var cAxis = createAxis({coordinate:Z, table:true, axis:[0, 0, 1], cyclic:true, tcp:true});
machineConfiguration = new MachineConfiguration(bAxis, cAxis);
```

#### // Same table/table setup, without TCP, top and center of C-axis is defined as the origin
```javascript
var bAxis = createAxis({coordinate:Y, table:true, axis:[0, 1, 0], offset:0, 0, -12.5, range:[-120,120], tcp:false, preference:1});
var cAxis = createAxis({coordinate:Z, table:true, axis:[0, 0, 1], cyclic:true, tcp:false});
machineConfiguration = new MachineConfiguration(bAxis, cAxis);
```

#### // 5-axis head/head setup without TCP
```javascript
var aAxis = createAxis({coordinate:X, table:false, axis:[-1, 0, 0], offset:[0, 0, 8.75], range:[-120,120], tcp:false, preference:-1});
var cAxis = createAxis({coordinate:Z, table:false, axis:[0, 0, 1], cyclic:false, range:[-180, 180], tcp:false});
machineConfiguration = new MachineConfiguration(aAxis, cAxis);
```

The determination if the output coordinates should be at the pivot point of the rotary heads or the virtual tooltip position (as if the tool is vertical) is decided by the `setVirtualTooltip` function. This setting is only applied to rotary heads that do not support TCP. The virtual tooltip position is described in the `Adjusting the Points for Offset Rotary Axes` section.
Multi-Axis Post Processors

Virtual Tooltip Setting

It is possible on some machine configurations that the limits of the rotary axes will be exceeded and the tool has to be retracted and the rotary axes repositioned to within the limits of the machine. The following code defines the required settings for the retract/reconfigure logic. It is described in the Rewinding of the Rotary Axes when Limits are Reached section.

Retract/Reconfigure Settings

Multi-axis machines that do not support TCP will usually require inverse time or degree per minute feedrates. The multi-axis feedrate format is defined in the following section of code. Multi-axis feedrates are discussed in more detail in the Multi-Axis Feedrates section.

Multi-Axis Feedrates

// multi-axis feedrates
if (machineConfiguration.isMultiAxisConfiguration()) {
    machineConfiguration.setMultiAxisFeedrate(
        useTCP ? FEED_FPM : getProperty("useDPMFeeds") ? FEED_DPM :
        FEED_INVERSE_TIME,
        9999.99, // maximum output value for inverse time feed rates
        getProperty("useDPMFeeds") ? DPM_COMBINATION : INVERSE_MINUTES, //
        INVERSE_MINUTES/INVERSE SECONDS or DPM COMBINATION/DPM STANDARD
        0.5, // tolerance to determine when the DPM feed has changed
        1.0 // ratio of rotary accuracy to linear accuracy for DPM calculations
    );
}
Multi-Axis Feedrates Definition

The home position of the machine can be defined in the `defineMachine` function. The home positions are used in the `writeRetract` function when positioning the machine in machine coordinates (G53) or WCS coordinates (G00).

```csharp
/* home positions */
// machineConfiguration.setHomePositionX(toPreciseUnit(0, IN));
// machineConfiguration.setHomePositionY(toPreciseUnit(0, IN));
// machineConfiguration.setRetractPlane(toPreciseUnit(0, IN));
```

**Defining the Machine Home Coordinates**

Finally, the post processor engine needs to be informed of the hardcoded machine configuration.

```csharp
// define the machine configuration
setMachineConfiguration(machineConfiguration); // inform post kernel of hardcoded machine configuration
if (receivedMachineConfiguration) {
    warning(localize("The provided CAM machine configuration is overwritten by the postprocessor."));
    receivedMachineConfiguration = false; // CAM provided machine configuration is overwritten
}
```

**Informing the Post Engine of the Hardcoded Machine Configuration**

### 8.1.4 Calculating the Rotary Angles

Once a machine configuration is defined the rotary axes angles need to be calculated and the tool end point needs to be adjusted for the rotary axes if TCP is not supported. This holds true for CAM and hardcoded machine configurations. This is handled in the `activateMachine` function and should not have to be modified. It is described here for reference purposes only.

The `optimizeMachineAngles2` function calculates the rotary axes angles and adjusts the XYZ coordinates for the rotary axes if TCP is not supported. The following values are passed to the `optimizeMachineAngles2` function.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIMIZE_NONE</td>
<td>Don't adjust the coordinates for the rotary axes. Used for TCP mode.</td>
</tr>
<tr>
<td>OPTIMIZE_BOTH</td>
<td>Adjust the coordinates for the rotary axes. For rotary heads that do not support TCP it is possible that the tool length has to be added to the tool end point coordinates. This scenario is discussed further in the Adjusting the Points for Rotary Heads section of this chapter.</td>
</tr>
<tr>
<td>OPTIMIZE_TABLES</td>
<td>Adjust the coordinates for rotary tables. No adjustment will be made for heads.</td>
</tr>
<tr>
<td>OPTIMIZE_HEADS</td>
<td>Adjust the coordinates for rotary heads. No adjustment will be made for tables.</td>
</tr>
<tr>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>OPTIMIZE_AXIS</td>
<td>Adjust the coordinates for the rotary axes based on the TCP setting associated with the defined axes. This is the required setting for CAM defined Machine Definitions and hardcoded machine configurations that define the tcp variable in the createAxis definitions.</td>
</tr>
</tbody>
</table>

**Settings for Adjusting the Input Coordinates for the Rotary Axes**

Rotary head adjustments that require that the tool length be added to the offset distance of the axis cannot be adjusted using the `optimizeMachineAngles2` function, since the tool length will vary from tool to tool. Instead, the Section function `optimizeMachineAnglesByMachine` is called for each section. This is also true for post processors that may change the machine configuration during the processing of the operations. Following is the generic code used in the activateMachine function that is used to calculate the rotary axes angles and adjust the tool end point coordinates.

```javascript
// calculate the ABC angles and adjust the points for multi-axis operations
// rotary heads may require the tool length be added to the pivot length
// so we need to optimize each section individually
if (machineConfiguration.isHeadConfiguration() && compensateToolLength) {
    for (var i = 0; i < getNumberOfSections(); ++i) {
        var section = getSection(i);
        if (section.isMultiAxis()) {
            machineConfiguration.setToolLength(getBodyLength(section.getTool())); // define the tool length for head adjustments
            section.optimizeMachineAnglesByMachine(machineConfiguration, OPTIMIZE_AXIS);
        }
    }
} else { // tables and rotary heads with TCP support can be optimized with a single call
    optimizeMachineAngles2(OPTIMIZE_AXIS);
}
```

**Rotary Axes Calculations and Coordinate Transformation**

If the call to calculate the rotary axes and adjust the input coordinates is not made then the tool end point and tool axis vector will be passed to the `onRapid5D` and `onLinear5D` multi-axis functions.

### 8.1.5 Output Initial Rotary Position

A function should be defined that outputs the rotary axis position in a block by themselves. In legacy posts this code is contained inline can be found in multiple places within the post.

```javascript
/** Positions the rotary axes in rapid mode */
function positionABC(abc, force) {
    if (typeof unwindABC == "function") {
        unwindABC(abc, false);
    }
    if (force) {
```
forceABC();
}
var a = aOutput.format(abc.x);
var b = bOutput.format(abc.y);
var c = cOutput.format(abc.z);
if (a || b || c) {
    if (!retracted) {
        if (typeof moveToSafeRetractPosition == "function") {
            moveToSafeRetractPosition();
        } else {
            writeRetract(Z);
        }
    }
}
onCommand(COMMAND_UNLOCK_MULTI_AXIS);
gMotionModal.reset();
writeBlock(gMotionModal.format(0), a, b, c);
setCurrentABC(abc); // required for machine simulation
}

Output Initial Rotary Axes Positions

The initial rotary axes positions must be calculated prior calling the positionABC function. The function getInitialToolAxisABC() is used to obtain the initial rotary axes positions for multi-axis operations.

if (currentSection.isMultiAxis()) {
    var abc = section.getInitialToolAxisABC();
    positionABC(abc, true);
}

Calculate Initial Rotary Angles for a Multi-axis Operation

8.1.6 Create the onRapid5D and onLinear5D Functions

Now that you have the machine defined you will need to verify that the onRapid5D and onLinear5D functions are present. These are the functions that will process the tool path generated by multi-axis operations. If your post already has these functions defined, then great you should be (almost) ready to go, if not then add the following functions to your post.

function onRapid5D (_x, _y, _z, _a, _b, _c) {
    if (!currentSection.isOptimizedForMachine()) {
        error(localize("This post configuration has not been customized for 5-axis simultaneous toolpath."));
        return;
    }
    if (pendingRadiusCompensation >= 0) {
        error(localize("Radius compensation mode cannot be changed at rapid traversal."));
        return;
    }
}
```javascript
} 
var x = xOutput.format(_x);
var y = yOutput.format(_y);
var z = zOutput.format(_z);
var a = aOutput.format(_a);
var b = bOutput.format(_b);
var c = cOutput.format(_c);
if (x || y || z || a || b || c) {
    writeBlock(gMotionModal.format(0), x, y, z, a, b, c);
    feedOutput.reset();
} 
} 

function onLinear5D(_x, _y, _z, _a, _b, _c, feed, feedMode) {
    if (!currentSection.isOptimizedForMachine()) {
        error(localize("This post configuration has not been customized for 5-axis simultaneous toolpath.");
        return;
    }
    if (pendingRadiusCompensation >= 0) {
        error(localize("Radius compensation cannot be activated/deactivated for 5-axis move.");
        return;
    }
    var x = xOutput.format(_x);
    var y = yOutput.format(_y);
    var z = zOutput.format(_z);
    var a = aOutput.format(_a);
    var b = bOutput.format(_b);
    var c = cOutput.format(_c);
    var f = feedOutput.format(_feed);
    // get feedrate number
    var fMode = feedMode == FEED_INVERSE_TIME ? 93 : 94;
    var f = feedMode == FEED_INVERSE_TIME ? inverseTimeOutput.format(feed) :
        feedOutput.format(feed);
    if (x || y || z || a || b || c) {
        writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), x, y, z, a, b, c, f);
    } else if (f) {
        if (getNextRecord().isMotion()) { // try not to output feed without motion
            feedOutput.reset(); // force feed on next line
        } else {
            writeBlock(gfFeedModeModal.format(fMode), MotionModal.format(1), f);
        }
    }
```
Both of these functions as presented are basic in nature and the requirements for your machine may require some modification.

### 8.1.7 Multi-Axis Common Functions

There are functions that are useful when developing a post processor for a multi-axis machine. These functions are used to determine if the rotary axes are configured, the beginning and ending tool axis or rotary axes positions for an operation, and control the flow of the multi-axis logic.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>machineConfiguration.isMultiAxisConfiguration()</code></td>
<td>Returns <code>true</code> if a machine configuration containing rotary axes has been defined. It is still possible to create output for some multi-axis machines if the rotary axes have not been defined, by outputting the tool axis vector instead of the rotary axes positions or by using Euler angles for 3+2 operations.</td>
</tr>
<tr>
<td><code>machineConfiguration.getABCByPreference(matrix, current, controllingAxis, type, options)</code></td>
<td>Returns the preferred rotary axes angles for the provided matrix. This matrix is usually the Work Plane matrix (<code>currentSection.workPlane</code>). <code>getABCByPreference</code> is described in further detail in the <em>Work Plane – 3+2 Operations</em> section.</td>
</tr>
<tr>
<td><code>machineConfiguration.getDirection(abc)</code></td>
<td>Returns the tool axis vector that corresponds to the specified ABC angles.</td>
</tr>
<tr>
<td><code>section.isOptimizedForMachine()</code></td>
<td>Returns <code>true</code> if the rotary axes angles have been calculated for the section.</td>
</tr>
<tr>
<td><code>section.isMultiAxis()</code></td>
<td>Returns <code>true</code> if the operation specified by <code>section</code> is a multi-axis operation.</td>
</tr>
<tr>
<td><code>section.getGlobalInitialToolAxis()</code></td>
<td>Returns the initial tool axis for the provided section as a Vector. Usually used at the start of an operation using the <code>currentSection</code> variable.</td>
</tr>
<tr>
<td><code>section.getInitialToolAxisABC()</code></td>
<td>Returns the initial rotary axes angles for the provided section as a Vector. Usually used at the start of an operation using the <code>currentSection</code> variable. An error will be generated if a machine configuration containing rotary axes has not been defined.</td>
</tr>
<tr>
<td><code>section.getGlobalFinalToolAxis()</code></td>
<td>Returns the final tool axis for the provided section as a Vector. Usually used at the start of an operation using <code>getPreviousSection()</code>.</td>
</tr>
<tr>
<td><code>section.getFinalToolAxisABC()</code></td>
<td>Returns the final rotary axes angles for the provided section as a Vector. Usually used at the start of an operation using <code>getPreviousSection()</code>. An error will be generated if a machine configuration containing rotary axes has not been defined.</td>
</tr>
<tr>
<td>Function</td>
<td>Description</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>section.getOptimizedTCPMode()</td>
<td>Returns the mode used to adjust the output coordinates for the rotary axes for this section. The different modes are listed in the <em>Calculating the Rotary Angles</em> section in this chapter.</td>
</tr>
<tr>
<td>getCurrentABC()</td>
<td>Returns the current rotary axes angles as a Vector.</td>
</tr>
<tr>
<td>getCurrentDirection()</td>
<td>When the machine configuration is configured with defined rotary axes, the current rotary axes angles as a Vector will be returned. If the machine configuration does not contain rotary axes, then the tool axis Vector will be returned. It will return the Work Plane forward vector when in a 3-axis or 3+2 operation.</td>
</tr>
<tr>
<td>getCurrentToolAxis()</td>
<td>Returns the current tool axis Vector. It will return the Work Plane forward vector when in a 3-axis or 3+2 operation.</td>
</tr>
<tr>
<td>is3D()</td>
<td>Returns <em>true</em> if the entire program is a 3-axis operation with no multi-axis operations. Returns <em>false</em> if even one operation is a 3+2 or multi-axis operation.</td>
</tr>
<tr>
<td>setCurrentABC(abc)</td>
<td>Sets the current ABC position in the post engine. This function should be called whenever the rotary angles are calculated and output within the post processor.</td>
</tr>
</tbody>
</table>

**Multi-Axis Common Functions**

### 8.2 Output of Continuous Rotary Axis on a Rotary Scale

There are two different styles that are commonly used for rotary axes output, using a linear scale or a rotary scale. A linear scale is the more standard case in today's machines and will move on a progressive scale similar to a linear axis output. For example, a value of 720 degrees will move the axis two revolutions from 0 degrees. A linear scale is almost always used with a non-continuous axes and can be used with a continuous rotary axis.

A rotary scale on the other hand typically outputs the rotary angle positions between 0 and 360 degrees, usually with the sign ± specifying the direction. If a sign is not required and the control will always take the shortest route, then it is pretty straightforward to output the rotary axis on a rotary scale, simply define it as a cyclic axis with a range of 0 to 360 degrees.

```
var aAxis = createAxis({coordinate:0, table:true, axis:[1, 0, 0], cyclic:true, range:[0, 360]});
```

**Create Rotary Axis Using a Rotary Scale. Machine will Take the Shortest Route**

For controls that require a sign to designate the direction the rotary axis will move, you will need to define the rotary axis on a linear scale. Yes, it sounds counterintuitive, but the output variable will handle converting the linear scale value to a signed rotary scale value.

```
var aAxis = createAxis({coordinate:0, table:true, axis:[1, 0, 0], cyclic:true});
```

**Create Rotary Axis Using a Linear Scale when Output Using a Rotary Scale**
The `createOutputVariable` function can be used to output a directional value for a rotary axis on a rotary scale.

```javascript
var aOutput = createOutputVariable({prefix:"A", type:TYPE_DIRECTIONAL, cyclicLimit:360, cyclicSign:1}, aFormat);
```

**Create the Output Variable using a Rotary Scale**

There are no more modifications needed.

### 8.3 Adjusting the Points for Offset Rotary Axes

The post processor kernel has support for offset tables and heads when TCP is not supported on the machine. The offsets from the part origin to the rotary center(s) must be defined when the axis is created. This is done using the `offset` parameter in `createAxis`.

```javascript
var aAxis = createAxis({coordinate:X, table:false, axis:[-1, 0, 0], offset:[0, 0, 8.75], range:[-120,120], tcp:false, preference:-1});
```

**Create an Offset Rotary Head**

It is important to know how the offsets are applied to each style of rotary axis. For rotary heads remember the head rider axis is defined first and then the head carrier axis. When the carrier and rider heads share a common pivot point, then only the offset for the rider axis needs to be defined. This offset is defined from the tool stop position to the pivot point. When the pivot points are different, the carrier axis offset is defined as the offset from the rider pivot point. Most machines will use a common pivot point for both rotary axes.

<table>
<thead>
<tr>
<th>Rotary Axis</th>
<th>Rotary Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotary head rider</td>
<td>Distance from tool stop to pivot point</td>
</tr>
<tr>
<td>Rotary head carrier</td>
<td>Distance from Head Rider pivot point to Head</td>
</tr>
<tr>
<td></td>
<td>Carrier pivot point</td>
</tr>
<tr>
<td>Rotary table carrier</td>
<td>Distance from part origin to center of table</td>
</tr>
<tr>
<td>Rotary table rider</td>
<td>Distance from part origin to center of table</td>
</tr>
</tbody>
</table>

**Non-TCP Rotary Axis Offsets**

---

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When defining an offset rotary table, defining the offset is all that is needed before the rotary angles and transformed coordinates are calculated.

For offset heads on machines that do not support TCP there are a couple of more function calls that may be needed.

It is possible that the tool length needs to be added to the offset of the head rider axis defined in the `createAxis` function. On small hobbyist machines it could be that the tool will always be the same length and can then be defined as part of the offset. On machines that use different tool lengths you will need to inform the post engine of the tool length to be added to the pivot distance prior to calculating the offset coordinates for the section. This is done by calling the `machineConfiguration.setToolLength` function with the length of the tool from the tool end point to the tool stop position used to define the offset for the head.
Tool Length Definition

The post processor will typically use the *Overall length* of the tool as defined in the CAM system as the tool length.

<table>
<thead>
<tr>
<th>Geometry</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>2 in</td>
</tr>
<tr>
<td>Shaft diameter</td>
<td>1.5748 in</td>
</tr>
<tr>
<td>Overall length</td>
<td>5.90551 in</td>
</tr>
<tr>
<td>Length below hold...</td>
<td>1.9685 in</td>
</tr>
<tr>
<td>Shoulder length</td>
<td>0.7874 in</td>
</tr>
<tr>
<td>Flute length</td>
<td>0.19685 in</td>
</tr>
<tr>
<td>Corner radius</td>
<td>0 in</td>
</tr>
<tr>
<td>Taper angle</td>
<td>0 degrees</td>
</tr>
</tbody>
</table>

Overall Length Defines the Tool Length

The output of the offset head coordinates can either be at the pivot point of the axis or the tool end point when the rotary axes are at 0 degrees (the tool is vertical). You would normally setup the machine with the tool tip at Z0. In this case the output coordinates will be at the virtual tool tip, meaning that the coordinates will be where the tool tip position would be when the rotary axes are at 0 degrees, even when the axes are tilted.
The `machineConfiguration.setVirtualTooltip` function is used to define whether the output coordinates are at the pivot point or at the virtual tool tip in a hardcoded machine configuration. In either case it is important that the proper offset distance and tool length are provided in order for the correct XYZ coordinates to be calculated. The `activateMachine` function handles the calculation of offset tables and heads based on the definition of each rotary axes and the following settings.

### 8.4 Calculation of the Multi-Axis Tool Position

It is possible to manually calculate the machine linear position based on the tool end point position or the tool end point position based on the machine linear position based on the rotary axis positions. The `machineConfiguration.getOptimizedPosition` function performs both conversions.

```python
machineConfiguration.getOptimizedPosition(current, abc, tcpType, optimizeType, force)
```

Adjust a Coordinate for the Rotary Axis Positions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>current</td>
<td>Vector</td>
<td>Either the tool tip or machine XYZ position based on <code>tcpType</code>.</td>
</tr>
<tr>
<td>abc</td>
<td>Vector</td>
<td>The rotary axis positions.</td>
</tr>
<tr>
<td>tcpType</td>
<td>Value</td>
<td>Type of conversion.</td>
</tr>
<tr>
<td>optimizeType</td>
<td>Value</td>
<td>Type of optimization.</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>force</td>
<td>Boolean</td>
<td>Set to true to adjust the values even if TCP is in effect. Valid for TCP_XYZ_OPTIMIZED and TCP_TOOL_OPTIMIZED.</td>
</tr>
</tbody>
</table>

### getOptimizedPosition Parameters

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
<th>Current Input Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCP_XYZ</td>
<td>Converts the tool tip to the machine XYZ position.</td>
<td>Tool tip</td>
</tr>
<tr>
<td>TCP_TOOL</td>
<td>Converts the machine XYZ position to the tool tip position.</td>
<td>Machine XYZ</td>
</tr>
<tr>
<td>TCP_XYZ_OPTIMIZED</td>
<td>Converts the tool tip to the machine XYZ position only when the input coordinates are adjusted for the rotary axes (non-TCP).</td>
<td>Position as supplied to onRapid5D and onLinear5D.</td>
</tr>
<tr>
<td>TCP_TOOL_OPTIMIZED</td>
<td>Converts the machine XYZ position to the tool tip position only when the input coordinates are adjusted for the rotary axes (non-TCP).</td>
<td>Position as supplied to onRapid5D and onLinear5D.</td>
</tr>
</tbody>
</table>

### tcpType Values

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTIMIZE_BOTH</td>
<td>Adjust the coordinates for both tables and heads.</td>
</tr>
<tr>
<td>OPTIMIZE_TABLES</td>
<td>Adjust the coordinates for rotary tables only.</td>
</tr>
<tr>
<td>OPTIMIZE_HEADS</td>
<td>Adjust the coordinates for rotary heads only.</td>
</tr>
</tbody>
</table>

```javascript
// calculate the machine XYZ position from the tool tip position
var xyz = machineConfiguration.getOptimizedPosition(toolTip, abc, TCP_XYZ, OPTIMIZE_BOTH, false);

function onRapid5D(_x, _y, _z, _a, _b, _c) {
    // calculate the tool tip position
    // if the input coordinates are not adjusted for the rotary axes, the output coordinate will be
    // the same as the input coordinate
    var toolTip = machineConfiguration.getOptimizedPosition(
        new Vector(_x, _y, _z),
        new Vector(_a, _b, _c),
        TCP_TOOL_OPTIMIZED, OPTIMIZE_HEAD, false);
}
```

### Sample Coordinate Conversions

8.5 Handling the Singularity Issue in the Post Processor

The post processor kernel handles the problem when the tool axis direction approaches the singularity of the machine. The singularity is defined as the tool axis orientation that is perpendicular to a rotary axis.
either a table or head. When the tool direction approaches the singularity, you may notice that the rotary axis can start to swing violently even if there is only a small deviation in the tool axis. If you can imagine a machine with an A-axis trunnion carrying a C-axis table and the tool axis is $0, \sin(0.001), \cos(0.001)$. This causes the output rotary positions to be $A.001 C0$. Now if the rotary axis changes to $0, \sin(0.001), \cos(0.001)$, a change of less than $0.002$ degrees you will notice that the rotary positions to be $A.001 C90$. You can see where a very small directional change in the tool axis ($<0.002$) will cause a 90-degree change in the C-axis.

The singularity logic in the kernel will massage the tool axis direction to keep the tool within tolerance and minimize the rotary axis movement in these cases. A safeguard that linearizes the moves around the singularity has also been implemented. This linearization will add tool locations as necessary to keep the tool endpoint within tolerance of the part.

There are settings in the post processor that manage how the singularity issue is handled. These settings are defined using the following command.

```plaintext
machineConfiguration.setSingularity(adjust, method, cone, angle, tolerance, linearizationTolerance)
```

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>adjust</td>
<td>Set to <code>true</code> to enable singularity optimization within the post processor. Singularity optimization includes the ability to adjust the tool axis to minimize singularity issues (large rotary axis movement when the tool axis approaches perpendicularity to a rotary axis) and the linearization of the tool endpoint within tolerance of the part.</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>method</td>
<td>When set to SINGULARITY_LINEARIZE_OFF it disables the linearization of the moves to keep the tool endpoint within tolerance of the programmed tool path around the singularity. SINGULARITY_LINEARIZE_ROTARY will linearize the moves around the singularity. Additional points are added to keep the tool within the specified tolerance and is optimized for revolved movement as if the tool were moving around a cylinder or other revolved feature. SINGULARITY_LINEARIZE_LINEAR will also add additional points to keep the tool within tolerance, but will keep the tool endpoint moving in a straight line. The default is SINGULARITY_LINEARIZE_ROTARY.</td>
</tr>
<tr>
<td>cone</td>
<td>Specifies the angular distance that the tool axis vector must be within in reference to the singularity point before the singularity logic is activated. This is usually a small value (less than 5 degrees), since the further away the tool axis is from the singularity, the less noticeable the fluctuations in the rotary axes will be and the less benefit this feature will provide. This parameter is specified in radians and the default value is .052 (3 degrees).</td>
</tr>
<tr>
<td>angle</td>
<td>The minimum angular delta movement that the rotary axes must move prior to considering adjusting the tool axis vector for singularity optimization. This limit is used to keep from adjusting the tool axis vector when the rotary axes do not fluctuate greatly. This is typically set to a value of 10 degrees or more. This parameter is in radians and the default value is .175 (10 degrees).</td>
</tr>
<tr>
<td>tolerance</td>
<td>The tolerance value used to keep the tool within tolerance when the tool axis is adjusted to minimize rotary axis movement around the singularity. The default value is .04mm (.0015in).</td>
</tr>
<tr>
<td>linearizationTolerance</td>
<td>The tolerance value to use when additional points are added to keep the tool endpoint within tolerance of the programmed move when the tool axis is near the singularity. The default value is .04mm (.0015in).</td>
</tr>
</tbody>
</table>

The default settings are valid for most tool paths, but this command allows for some tweaking in special cases where you want to fine tune the output.

### 8.6 Rewinding of the Rotary Axes when Limits are Reached

The post processor kernel will select the starting angles of the rotary axes based on the best possible solution to avoid rewind situations when one of the rotary axes crosses its limits. This is accomplished by scanning the entire operation to see if a rewind of the rotary axes is required due to limit violations and if so adjusting the starting angles of the rotary axes to see if the rewind can be avoided. If a solution to avoid the rewind cannot be found, then the solution that produces the most rotary movement prior to requiring a rewind will be used.

The best possible solution for the rotary axes is always selected at the start of an operation and when a rewind is required due to a rotary axis crossing the limits, the tool will always stop on the exact limit of the axis.
the machine, eliminating scenarios where a valid solution for the rewinding of the rotary axes could not always be found.

When a rewind is required there is a group of functions that can be added to the custom post processor to handle the actual rewinding of the affected rotary axis. This code can be easily copied into your custom post processor and modified to suit your needs with just a little bit of effort.

One setting that is very important when defining a rotary axis is the cyclic parameter in the call to createAxis. cyclic is considered synonymous with continuous, meaning that this axis has no limits and will not be considered when determining if the rotary axes have to be repositioned to stay within limits. The range specifier used in conjunction with a cyclic axis defines the output limits of a rotary axis, for example specifying a range of [0,360] will cause all output angles for this axis to be output between 0 and 360 degrees. The range for a non-cyclic axis defines the actual physical limits of that axis on the machine and are used to determine when a rewind is required. Please note that the physical limits of the machine may be a numeric limit of the control instead of a physical limit, such as 9999.9999.

Another important setting is the reset parameter, which allows you to define the starting angle at the start of an operation and after a rewind of the axes has occurred. By default, the post engine will use the ending angle of the previous multi-axis operation. Some controls allow for the rotary axis encoder to be reset so that the stored angle is reset to be within the 0-360 degrees without unwinding the axis. In this case you will want to issue the proper codes to reset the axis encoder, for example G28 C0, and specify reset:3 when you create the axis.

Now on to how you can implement the automatic rewind capabilities in your post. The bulk of the feature is handled by the post processor kernel, but there are some variables and functions that are required in your post. The variables used for retract/reconfigure are either defined in the CAM Machine Definition settings or in the defineMachine function for hardcoded machine configurations.

```cpp
// retract / reconfigure
var performRewinds = false; // set to true to enable the retract/reconfigure logic
if (performRewinds) {
    machineConfiguration.enableMachineRewinds(); // enables the retract/reconfigure logic
    safeRetractDistance = (unit == IN) ? 1 : 25; // additional distance to retract out of stock
    safeRetractFeed = (unit == IN) ? 20 : 500; // retract feed rate
    safePlungeFeed = (unit == IN) ? 10 : 250; // plunge feed rate
    machineConfiguration.setSafeRetractDistance(safeRetractDistance);
    machineConfiguration.setSafeRetractFeedrate(safeRetractFeed);
    machineConfiguration.setSafePlungeFeedrate(safePlungeFeed);
    var stockExpansion = new Vector(toPreciseUnit(0.1, IN), toPreciseUnit(0.1, IN), toPreciseUnit(0.1, IN)); // expand stock XYZ values
    machineConfiguration.setRewindStockExpansion(stockExpansion);
}
```

Retract/Reconfigure Settings Defined in defineMachine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>performRewinds</td>
<td>When set to false an error will be generated when a rewind of a rotary axis is required. Setting it to true will enable the rewind logic.</td>
</tr>
</tbody>
</table>

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safeRetractDistance | Defines the distance to be added to the retract position when the tool is positioned past the stock material to safely remove it from the stock. If it is set to 0, then the tool will retract to the outer stock plus the stock expansion.

safeRetractFeed | Specifies the feedrate to retract the tool prior to rewinding the rotary axis.

safePlungeFeed | Specifies the feedrate to plunge the tool back into the part after rewinding the rotary axis.

stockExpansion | The tool will retract past the defined stock by default. You can expand the defined stock on all sides by defining the stockAllowance vector, which contains the expansion value for X, Y, and Z.

### Variables that Control Tool Retraction

You will need to copy the retract/reconfigure functions from a post that supports this logic into your post. These functions are defined in the following section of code and include the designated functions.

```c
// Start of onRewindMachine logic
...
// End of onRewindMachine logic
```

##### Copy this Code into Your Post

<table>
<thead>
<tr>
<th>Function</th>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>onRewindMachineEntry</td>
<td>(none)</td>
<td>This function is called at the start of the automatic rewind process and allows the user to override the default rewind logic. Returning <code>true</code> from this function will disable the rewind logic in the post engine, while <code>false</code> will continue with the rewind/reconfigure process.</td>
</tr>
<tr>
<td>onMoveToSafeRetractPosition</td>
<td>(none)</td>
<td>Moves the tool to a safe retract position after retracting the tool from the part.</td>
</tr>
<tr>
<td>onRotateAxes</td>
<td>x, y, z, a, b, c</td>
<td>Repositions the rotary axes to their new location as provided by (a,b,c) after the tool has been moved to its safe position.</td>
</tr>
<tr>
<td>onReturnFromSafeRetractPosition</td>
<td>x, y, z</td>
<td>Repositions the linear axes to the position of the tool when it was retracted from the part.</td>
</tr>
</tbody>
</table>

#### Automatic Rewind Entry Functions

The `onRewindMachineEntry` function is used to either override or supplement the standard rewind logic. It will simply return `false` when the standard rewind logic of retracting the tool, repositioning the rotary axes, and repositioning the tool is desired. Code can be added to this function for controls that just require the encoder to be reset or to output the new rotary axis position when the control will automatically track the tool with the rotary axis movement. The following example resets the C-axis encoder when it is currently at a multiple of 360 degrees and the B-axis does not change.
function onRewindMachineEntry(_a, _b, _c) {
  // reset the rotary encoder if supported to avoid large rewind
  if (false) { // disabled by default
    if ((abcFormat.getResultingValue(_c) == 0) && !abcFormat.areDifferent(getCurrentDirection().y, _b)) {
      writeBlock(gAbsIncModal.format(91), gFormat.format(28), "C" + abcFormat.format(0));
      writeBlock(gAbsIncModal.format(90));
      return true;
    }
  }
  return false;
}

function onMoveToSafeRetractPosition() {
  writeRetract(Z); // retract to home position
  // cancel TCP so that tool doesn't follow rotaries
  if (currentSection.isMultiAxis() && operationSupportsTCP) {
    disableLengthCompensation(false);
  }
  if (false) { // enable to move to safe position in X & Y
    writeRetract(X, Y);
  }
}

function onRotateAxes(_x, _y, _z, _a, _b, _c) {
  // position rotary axes
  xOutput.disable();
}

Sample Code to Reset Encoder Instead of Rewinding C-axis

Returning a value of true designates that the onRewindMachineEntry function performed all necessary actions to reposition the rotary axes and the retract/reposition/plunge sequence will not be performed. Returning false will process the retract/reposition/plunge sequence normally.

The onMoveToSafeRetractPosition function controls the move to a safe position after the tool is retracted from the part and before the rotary axes are repositioned. It will typically move to the home position in Z and optionally in X and Y using a G28 or G53 style block. You should find similar code to retract the tool when positioning the rotary axes for a 3+2 operation and in the onClose function, which positions the tool at the end of the program. You should use the same logic found in these areas for the onMoveToSafeRetractPosition function.

Move to a Safe Position Prior to Repositioning Rotary Axes

The onRotateAxes function is used to position the rotary axes to their new position as calculated by the post engine. _a, _b, _c define the new rotary axis position. _x, _y, _z should be ignored and not used.
Multi-Axis Post Processors

8.7 Multi-Axis Feedrates

During multi-axis contouring moves, the machine control will typically expect the feedrate numbers to be either in Inverse Time or some form of Degrees Per Minute. Inverse Time feedrates are simply the inverse of the time that the move takes, i.e. $1/movetime$. If your control supports both Inverse Time and Degrees Per Minute feedrates, it is recommended that you use Inverse Time as this is the most accurate. Please note that if your machine supports TCP (Tool Control Point) programming, then it probably supports direct Feed Per Minute (FPM) feedrates during multi-axis contouring moves and does not require either Inverse Time or DPM feedrates.

Multi-axis feedrate calculations are handled by the post engine and will work with all machine configurations; table/table, head/head, and head/table. One capability of the multi-axis feedrate calculation is that it considers the actual tool tip movement in reference to the rotary axes movement and
not just the straight-line movement along the programmed tool tip, creating more accurate multi-axis feedrates. In the following picture the move along the arc caused by the movement of the rotary axis (green arc) is used in the calculation instead of the straight-line move generated by HSM (blue line).

Multi-axis feedrate support is handled in the CAM Machine Definition or in the `defineMachine` function for a hardcoded machine configuration.

```java
// multi-axis feedrates
if (machineConfiguration.isMultiAxisConfiguration()) {
    machineConfiguration.setMultiAxisFeedrate(
        useTCP ? FEED_FPM : getProperty("useDPMFeeds") ? FEED_DPM : FEED_INVERSE_TIME,
        9999.99, // maximum output value for inverse time feed rates
        getProperty("useDPMFeeds") ? DPM_COMBINATION : INVERSE_MINUTES, //
        INVERSE_MINUTES/INVERSE_SECONDS or DPM_COMBINATION/DPM_STANDARD
        0.5, // tolerance to determine when the DPM feed has changed
        1.0 // ratio of rotary accuracy to linear accuracy for DPM calculations
    );
}
```

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>feedMode</td>
<td>FEED_INVERSE_TIME (inverse time), FEED_DPM (degrees per minute), or FEED_FPM (programmed feedrate).</td>
</tr>
</tbody>
</table>
maximumFeedrate | Defines the maximum value that can be output for both inverse time and degrees per minute feedrates.

feedType | Multi-axis feedrate options. For inverse time feedrates, the options are INVERSE_MINUTES or INVERSE_SECONDS, defining the units of time to use in inverse time feedrate calculations. For DPM feedrates, then the options are DPM_STANDARD for straight degrees per minute calculations or DPM_COMBINATION which uses a combination of degrees per minute and linear feed per minute (this is the most typical for machines that want a form of DPM feedrates).

outputTolerance | The tolerance for deciding whether to output a feedrate value or not. If the feedrate value is within this tolerance of the previous feedrate value, then it will be set to the previous value. This is used to minimize the output of multi-axis feedrate numbers.

bpwRatio | Defines the pulse weight ratio for the rotary axes when DPM feedrates are output as a combination of linear and rotary movements. The pulse weight is a scale factor based on the rotary axes accuracy compared to the linear axes accuracy. For example, it should be set to .1 when the linear axes are output on .0001 increments and the rotary axes on .001 increments.

### setMultiAxisFeedrate Parameters

If Inverse Time feedrates are supported you will need to create the `inverseTimeOutput` variable at the top of the post processor code and if the accuracy of the Inverse Time feedrates is different than the standard FPM feedrate you will also need to create a new format to associate with it. The `gFeedModeModal` modal variable will also need to be defined for support of G93/G94 output if it does not already exist.

```javascript
var gFeedModeModal = createModal({}, gFormat); // modal group 5 // G93-94
... var inverseFormat = createFormat({decimals:4, forceDecimal:true});
... var inverseTimeOutput = createVariable({prefix:"F", force:true}, feedFormat);
```

### Create `inverseTimeOutput` Variable

Now there are other areas of the post processor that need to be changed to support these feedrate modes. First, the `onLinear5D` function must have support added to receive and output the feedrate mode and to output the feedrate value using the correct format.

```javascript
function onLinear5D(_x, _y, _z, _a, _b, _c, feed, feedMode) {
    if (!currentSection.isOptimizedForMachine()) {
        error(localize("This post configuration has not been customized for 5-axis simultaneous toolpath."));
        return;
    }
    // at least one axis is required
```
if (pendingRadiusCompensation >= 0) {
    error(localize("Radius compensation cannot be activated/deactivated for 5-axis move."))); return;
}
var x = xOutput.format(_x);
var y = yOutput.format(_y);
var z = zOutput.format(_z);
var a = aOutput.format(_a);
var b = bOutput.format(_b);
var c = cOutput.format(_c);

// get feedrate number
var fMode = feedMode == FEED_INVERSE_TIME ? 93 : 94;
var f = feedMode == FEED_INVERSE_TIME ? inverseTimeOutput.format(feed) : feedOutput.format(feed);
if (x || y || z || a || b || c) {
    writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), x, y, z, a, b, c, f);
} else if (f) {
    if (getNextRecord().isMotion()) { // try not to output feed without motion
        feedOutput.reset(); // force feed on next line
    } else {
        writeBlock(gFeedModeModal.format(fMode), gMotionModal.format(1), f);
    }
}

---

**onLinear5D Required Changes**

You will need to reset the feedrate mode to FPM either at the end of the multi-axis operation or on a standard 3-axis move. It is much easier to do this at the end of the section, otherwise you would have to modify all instances that output feedrates, such as in onLinear, onCircular, onCycle, etc.

```javascript
function onSectionEnd() {
    ...
    if (currentSection.isMultiAxis()) {
        writeBlock(gFeedModeModal.format(94)); // inverse time feed off
    }
}
```

**Reset FPM Mode in onSectionEnd**

writeBlock(gFeedModeModal.format(94), gMotionModal.format(1), gFormat.format(40), x, y, z, f);

---

**Optionally Reset FPM Mode in All Output Blocks with Feedrates**

It is possible that your machine control does not support standard inverse time or DPM feedrates. If this is the case you will need to write your own function to handle multi-axis feedrates. The getMultiAxisMoveLength function will assist in the movement length calculations required for
calculating multi-axis feedrates. It takes the current position for the linear and rotary axes and will calculate the tool tip, linear axes, and rotary axes lengths of the move from the previous location.

```javascript
var length = machineConfiguration.getMultiAxisLength(x, y, z, a, b, c);
```

**Calculate the Length of the Multi-Axis Move**

`getMultiAxisMoveLength` will return `MoveLength` object, which can then be accessed using the following functions to obtain the different move lengths.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getRadialToolTipMoveLength</td>
<td>Calculated tool endpoint movement along the actual tool path.</td>
</tr>
<tr>
<td>getLinearMoveLength</td>
<td>Combined linear delta movement.</td>
</tr>
<tr>
<td>getRadialMoveLength</td>
<td>Combined rotary delta movement.</td>
</tr>
</tbody>
</table>

**MoveLength Functions**

```javascript
var moveLength = getMultiAxisMoveLength(x, y, z, a, b, c);
var toolTipLength = moveLength.getRadialToolTipMoveLength();
var xyzLength = moveLength.getLinearMoveLength();
var abcLength = moveLength.getRadialMoveLength();
```

**Retrieve the Calculated Move Lengths for the Tool Tip, Linear Axes, and Rotary Axes**

### 8.8 Polar Interpolation

Polar interpolation replaces a linear axis in a 3-axis milling operation with a rotary axis. Polar interpolation can be used to keep machining operations within the limits of the machine or simplify the output of circular milling/drilling operations. It is sometimes referred to as XZC interpolation since it is quite common to replace the Y-axis with the C-axis.

It can be supported in the control, for example using G12.1 on Fanuc style controls or handled within the post processor. Machine control polar interpolation is typically supported on Mill/Turn machines.
This section describes how to implement post processor generated polar interpolation support in your post and how to activate it using a Manual NC command. The *Haas Next Generation* post processor has polar interpolation implemented and can be used as a reference and to copy code from into your post.

### 8.8.1 Polar Interpolation Functions

The following functions are used with post generated polar interpolation. The `setPolarMode` and `setPolarFeedMode` functions are defined in the post processor, all other functions are embedded in the post processor kernel.

**Sample Output Without and With Polar Interpolation**

```
N55 G0 B0. C0.
N60 M10
N65 M12
N70 M6
N75 G1 X5.75 Y0. F650.
N80 G0 G43 Z4.6 H2
N85 G0 Z4.2
N90 G1 Z4.0394 F13.333
N95 Z3.
N100 G3 X-5.75 I-5.75 J0. F40.
N105 X5.75 I5.75 J0.
N110 G0 Z4.6
N55 G0 B0. C0.
N60 M6
N65 G1 X5.75 Y0. F650.
N70 G0 G43 Z4.6 H2
N75 G0 Z4.2
N80 G1 Z4.0394 F13.333
N85 Z3.
N90 G93 C179. F2.227
N95 C350. F2.227
N100 C360. F199.29
N105 G0 Z4.6
N110 G94
```

**Without Polar Interpolation**

```
N95 X-6.2354 Y3.6
N100 X-3.6 X6.2354
N105 X0. Y7.2
N110 X3.6 Y6.2354
N115 X6.2354 Y3.6
N120 X7.2 Y0.
N125 X6.2354 Y-3.6
N130 X3.6 Y-6.2354
N135 X0. Y-7.2
N140 X-3.6 Y-6.2354
N145 X-6.2354 Y-3.6
N150 G90
N80 G98 G81 X7.2 Y0. Z3. R4.2 F40.
N95 C150.
N90 C120.
N95 C90.
N100 C60.
N105 C30.
N110 C360.
N115 C330.
N120 C300.
N125 C270.
N130 C240.
N135 C210.
N140 C80
```

**With Polar Interpolation**
<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>activatePolarMode(tolerance, angle, axis)</code></td>
<td>Activates polar interpolation. <code>tolerance</code> specifies the tolerance to use to keep the tool within the programmed tool path. It is typically set to be tighter than the post processor defined tolerance by a factor of 2 or 4 (<code>tolerance / 2</code>) to keep a smooth finish. <code>angle</code> defines the current angle of the rotary axis used in polar interpolation. <code>axis</code> defines the line that the tool can move along during polar interpolation. A vector of (1, 0, 0) keeps the tool along the X-axis.</td>
</tr>
<tr>
<td><code>deactivatePolarMode()</code></td>
<td>Disables polar interpolation.</td>
</tr>
<tr>
<td><code>getPolarPosition(x, y, z)</code></td>
<td>Returns the polar coordinates as a <code>VectorPair</code> for the input <code>x,y,z</code> coordinates. The first vector is the XYZ coordinates and the second vector is the ABC angles of the polar position.</td>
</tr>
<tr>
<td><code>isPolarModeActive()</code></td>
<td>Returns <code>true</code> if polar mode is in effect.</td>
</tr>
<tr>
<td><code>setCurrentPositionAndDirection(position)</code></td>
<td>Sets the current XYZ and ABC position. <code>position</code> is a <code>VectorPair</code> that contains the XYZ coordinates in the first vector and the ABC angles in the second vector.</td>
</tr>
<tr>
<td><code>setPolarFeedMode(mode)</code></td>
<td>Defines the feedrate mode for polar interpolation. This will usually be set to either Inverse Time or DPM feedrates depending on capabilities of the control. This multi-axis feedrate mode only needs to be changed for polar interpolation if the machine supports TCP and outputs FPM (programmed) feedrates with multi-axis moves. Polar interpolation is not output using TCP, so requires a different feedrate mode in this case. <code>mode</code> determines if polar interpolation is being activated (<code>true</code>) or deactivated (<code>false</code>). This function must be defined in the post processor.</td>
</tr>
<tr>
<td><code>setPolarMode(section, mode)</code></td>
<td>Enables/disables polar interpolation mode for the specified section. <code>section</code> should be set to <code>currentSection</code>. <code>mode</code> can be set to <code>true</code> to enable polar interpolation or <code>false</code> to disable it. This function must be defined in the post processor.</td>
</tr>
</tbody>
</table>

Polar Interpolation Functions

The required polar interpolation variables and functions can be copied from the *Haas Next Generation* post processor. These functions are bounded by the *Start of polar interpolation* and *End of polar interpolation* comments.

```c
// Start of polar interpolation
... // End of polar interpolation
```

Copy the Required Polar Interpolation Code
Most of this code will not require any modification. You may want to change the line/vector that polar interpolation will move along during generation of the polar coordinates. This is defined by the `polarDirection` variable at the top of the copied code. It is set to the X-axis (1, 0, 0) by default.

```javascript
// Start of polar interpolation
var usePolarMode = false; // controlled by manual NC operation, enables polar interpolation for a single operation
var defaultPolarDirection = new Vector(1, 0, 0); // default direction for polar interpolation
var polarDirection = defaultPolarDirection; // vector to maintain tool at while in polar interpolation
```

### Define the Axis Line for Polar Interpolation

You may have to modify the `setPolarFeedMode` to set the proper feedrate mode for polar interpolation. If your machine does not support TCP, then this function can be blank and the same feedrate mode for multi-axis and polar interpolation operations will be used.

```javascript
function setPolarFeedMode(mode) {
    if (machineConfiguration.isMultiAxisConfiguration()) {
        machineConfiguration.setMultiAxisFeedrate(
            !mode ? multiAxisFeedrate.mode : getProperty("useDPMFeeds") ? FEED_DPM : FEED_INVERSE_TIME,
            multiAxisFeedrate.maximum,
            !mode ? multiAxisFeedrate.type : getProperty("useDPMFeeds") ? DPM_COMBINATION : INVERSE_MINUTES,
            multiAxisFeedrate.tolerance,
            multiAxisFeedrate.bpwRatio
        );
        if (!receivedMachineConfiguration) {
            setMachineConfiguration(machineConfiguration);
        }
    }
}
```

### setPolarFeedMode to Use when TCP is Supported

```javascript
function setPolarFeedMode(mode) {
    if (machineConfiguration.isMultiAxisConfiguration()) {
        machineConfiguration.setMultiAxisFeedrate(
            !mode ? multiAxisFeedrate.mode : getProperty("useDPMFeeds") ? FEED_DPM : FEED_INVERSE_TIME,
            multiAxisFeedrate.maximum,
            !mode ? multiAxisFeedrate.type : getProperty("useDPMFeeds") ? DPM_COMBINATION : INVERSE_MINUTES,
            multiAxisFeedrate.tolerance,
            multiAxisFeedrate.bpwRatio
        );
        if (!receivedMachineConfiguration) {
            setMachineConfiguration(machineConfiguration);
        }
    }
}
```

### setPolarFeedMode to Use when TCP is Not Supported

#### 8.8.2 Manual NC Command to Enable Polar Interpolation

The Action Manual NC `usePolarMode` command is used to enable polar interpolation for a single operation and must be placed prior to this operation. Polar interpolation will be automatically cancelled after this operation, but since polar interpolation is handled in the post processor, you can make changes to make the command modal.
The `usePolarMode` Manual NC command is implemented in the `onManualNC` function.

```javascript
function onManualNC(command, value) {
    switch (command) {
    case COMMAND_ACTION:
        if (String(value).toUpperCase() == "USEPOLARMODE") {
            usePolarMode = true;
        }
        break;
    default:
        expandManualNC(command, value);
    }
}
```

### Implementing the `usePolarMode` Manual NC Command

#### 8.8.3 Calculating the Polar Interpolation Initial Angle

The initial XYZ position and ABC angles for polar interpolation is calculated in the `defineWorkPlane` function.

```javascript
function defineWorkPlane(_section, _setWorkPlane) {
    var abc = new Vector(0, 0, 0);
    if (machineConfiguration.isMultiAxisConfiguration()) { // use 5-axis indexing for multi-axis mode
        if (isPolarModeActive()) { // calculate the initial ABC position for polar interpolation
            abc = getCurrentDirection();
        } else {
            abc = _section.isMultiAxis() ? _section.getInitialToolAxisABC() :
                getWorkPlaneMachineABC(_section.workPlane, _setWorkPlane);
        }

        // polar interpolation is treated as a multi-axis operation
        if (_section.isMultiAxis() || isPolarModeActive()) {
            cancelTransformation();
            if (_setWorkPlane) {
                if (activeG254) {
                    writeBlock(gFormat.format(255)); // cancel DWO
                }
            }
        }
    }
}
```
Calculating the Initial ABC Position for Polar Interpolation in defineWorkPlane

Polar interpolation converts a 3-axis operation to a multi-axis operation, so it must be treated as such. This means that the rotary axis must be unlocked prior to the initial positioning move, but not clamped afterwards. This is handled in the setWorkPlane function.

Don’t Lock the Rotary Axis During Polar Interpolation in setWorkPlane

There could be code in the onCommand function for unlocking the rotary axis that may need to be changed also.

Unlocking the Rotary Axis During Polar Interpolation in onCommand

8.8.4 Initializing Polar Interpolation

The following modifications to onSection must be made to support polar interpolation. First, you need to enable polar interpolation. This code is usually placed prior to the defineWorkPlane call.

// Use new operation property for polar milling
if (currentSection.machiningType &&
    (currentSection.machiningType == MACHINING_TYPE_POLAR)) {
    usePolarMode = true;
}

// Update polar coordinates direction according to operation property
polarDirection = currentSection.polarDirection;
}

// enable polar interpolation
if (usePolarMode && (tool.type != TOOL_PROBE)) {
    if (polarDirection == undefined) {
        error(localize("Polar direction property must be a vector - x,y,z.");
        return;
    }
Enabling Polar Interpolation in onSection

8.8.5 Disabling Polar Interpolation

Polar interpolation is disabled after each operation in the `onSectionEnd` function when it is only active for a single operation.

```javascript
function onSectionEnd() {
  ...
  setPolarMode(currentSection, false);
}
```

Disabling Polar Interpolation in onSectionEnd

8.8.6 Enabling Polar Interpolation in Drilling Cycles

Polar interpolation is supported for both 3-axis milling operations and in drilling cycles. The milling operations will be converted to multi-axis operations once polar interpolation is activated, calling `onRapid5D` and `onLinear5D` linear motion. No modifications to these functions need to be made to support polar interpolation.

Drilling cycle locations will still call `onCyclePoint` during polar interpolation, so modifications must be made to output the rotary axis with the cycle positions. This is done by making the following modification to the `getCommonCycle` function for the first point of a cycle operation.

```javascript
function getCommonCycle(x, y, z, r, c) {
  forceXYZ();

  if (isPolarModeActive()) { // format polar interpolation position
    var polarPosition = getPolarPosition(x, y, z);
    return [xOutput.format(polarPosition.first.x), yOutput.format(polarPosition.first.y),
            zOutput.format(polarPosition.first.z),
            aOutput.format(polarPosition.second.x),
            bOutput.format(polarPosition.second.y),
            cOutput.format(polarPosition.second.z),
            “R” + xyzFormat.format®];
  }
}
```

Multi-Axis Post Processors  8-242
} else { // format linear interpolation position

    if (incrementalMode) {
        zOutput.format(c);
        return [xOutput.format(x), yOutput.format(y),
                "Z" + xyzFormat.format(z - r),
                "R" + xyzFormat.format(r - c)];
    } else {
        return [xOutput.format(x), yOutput.format(y),
                zOutput.format(z),
                "R" + xyzFormat.format(r)];
    }
}
}

Formatting the Polar Interpolation Cycle Position in getCommonCycle

In the onCyclePoint function you need to format the cycle location for polar interpolation for the 2\textsuperscript{nd} through final cycle point.

// 2nd through nth cycle point
} else {
    if (cycleExpanded) {
        expandCyclePoint(x, y, z);
    } else {

        if (isPolarModeActive()) { // format polar interpolation position
            var polarPosition = getPolarPosition(x, y, z);
            writeBlock(xOutput.format(polarPosition.first.x), yOutput.format(polarPosition.first.y),
                        zOutput.format(polarPosition.first.z),
                        aOutput.format(polarPosition.second.x), bOutput.format(polarPosition.second.y),
                        cOutput.format(polarPosition.second.z));
            return;
        }
    }
}

Formatting the Polar Interpolation Cycle Position in onCyclePoint

9 Support for Machine Simulation

Fusion can simulate the movements of a machine when replaying an operation using the Simulate with Machine process when a Machine Definition is attached to the CAM Setup and it contains a model of the machine.
Most Machine Definitions available in the Machine Library have associated CAD models of the machine that can be used for machine simulation. Checking the Simulation ready box in the Filters tab will display all machines that have a machine model and can be used for simulation. These will be shown in the Machine Definition list with a 3D cube next to their name.

### 9.1 Post Processor Support for Machine Simulation

Post processors that support machine simulation will have `CAPABILITY_MACHINE_SIMULATION` defined as one of their capabilities.

```
capabilities = CAPABILITY_MILLING | CAPABILITY_MACHINE_SIMULATION;
```

Specifying Machine Simulation Capabilities in the Post
The post will also have the `activateMachine` function present. One thing to note is that the post processor cannot make changes to the machine configuration when machine simulation is supported. This means that no calls to the `machineConfiguration.set` functions can be made nor can `setMachineConfiguration` be called.

There are some posts that can enable rotary axes using a post property. You cannot use this property to define the rotary axes if you wish to use machine simulation, the rotary axes must be defined in the external Machine Definition.

![Post properties](image)

**Using a Property to Define the Rotary Axis is not Allowed for Machine Simulation**

### 9.2 Placing the Part onto the Machine

Once you have a Machine Definition with a machine model assigned to the Setup you will need to place the part on the machine. This is handled in the tab of the Setup dialog box. You will need to select the Part Attach Point and the Table Attach Point. Optionally, you can shift the part by distances in the X, Y, and Z directions.

![Placing the Part onto the Machine](image)

### 9.3 Obtaining the Part/Machine Attach Points

```javascript
var partAttachPoint = section.getPartAttachPoint();
```
var tableAttachPoint = machineConfiguration.getTableAttachPoint();
var headAttachPoint = machineConfiguration.getHeadAttachPoint();

Obtaining the Part/Machine Attach Points

The `getPartAttachPoint` function returns the location on the part where it is attached to the machine model. This location will be in reference to the Work Coordinate System (WCS) Origin as defined in the CAM Setup.

The `getTableAttachPoint()` function returns the location on the machine where the part is attached. This is the same location as the part attach point except that it is in the Machine Coordinate System (MCS) in relation to where the machine origin is defined in the machine model.

The `getHeadAttachPoint()` function returns the location on the machine where the tool is attached to the spindle in the Machine Coordinate System (MCS).

10 Adding Support for Probing

Fusion 360, Inventor CAM, and HSM have support for multiple styles of probing operations, including WCS Probing, Geometry Probing, and Surface Inspection. While the probing capabilities are supported by many of the library post processors, they are not supported by all of them and custom post processors may not have these capabilities. This chapter discusses the required changes to a post processor to support the probing operations.

10.1 WCS Probing

WCS Probing is defined as probing operations that are used to probe the part for the purpose of defining a Work Coordinate System. While all Autodesk CAM products support WCS Probing, you will find these operations in a different area of the interface for each of the products.

You can check the post processor you are working with to see if it supports WCS Probing. The easiest method is to try to run a probing operation against the post, the post will fail if probing is not supported. You may see an error message complaining about the spindle speed being out of range (probe operations do not turn on the spindle) or a message that states that the probing cycle must be handled in the post processor.
If you receive either of these messages, then probing is not supported in your post processor and you will need to add it.

10.1.1 Probing Operations

There is a sample model available for testing the probing logic in a post processor. In Fusion 360 it is contained in the CAM Samples/Post Processor folder. This model contains a part designed for testing probing cycles using the available WCS Probing operations.

---

**Spindle Speed Error Message**

Error: Spindle speed out of range.
Error at line: 735
Error in operation: 'WCS Probe1'
Failed while processing onSection() for record 261.

---

**Machine Specific Error Message**

Error: The probe cycle 'probing-xy-outer-corner' is machine specific and must always be handled in the post configuration.
Error in operation: 'WCS Probe1'
Failed while processing onCycle() for record 280.
One thing you will notice when creating a probing operation is that interface is intelligent enough to only give you the probing operation types that apply to the type of geometry selected. For example, if you select a planar face perpendicular to the X-axis, then the only operations available to you are the X surface and Angle along X-axis operations.

Intelligent Probe Selection

The WCS Probing operations are considered a canned cycle in the post processor and therefore are output in the onCyclePoint function, with the probe type being stored in the cycleType variable. The following table lists the available probing operations. You should note that probing cycles cannot be expanded and must be handled in the post processor, either by performing the cycle, by giving an error, or by expanding the cycle in the post processor.

<table>
<thead>
<tr>
<th>cycleType</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>probing-x</td>
<td>Probes a wall perpendicular to the X-axis.</td>
</tr>
<tr>
<td>probing-y</td>
<td>Probes a wall perpendicular to the Y-axis.</td>
</tr>
<tr>
<td>probing-z</td>
<td>Probes a wall perpendicular to the Z-axis.</td>
</tr>
<tr>
<td>probing-x-wall</td>
<td>Probes a wall thickness in the X-axis</td>
</tr>
<tr>
<td>probing-y-wall</td>
<td>Probes a wall thickness in the Y-axis</td>
</tr>
<tr>
<td>probing-x-channel</td>
<td>Probes the open distance between two walls in the X-axis</td>
</tr>
<tr>
<td>probing-y-channel</td>
<td>Probes the open distance between two walls in the Y-axis</td>
</tr>
<tr>
<td>probing-x-channel-with-island</td>
<td>Probes the open distance between two walls with an island between the walls in the X-axis</td>
</tr>
<tr>
<td>probing-y-channel-with-island</td>
<td>Probes the open distance between two walls with an island between the walls in the Y-axis</td>
</tr>
<tr>
<td>probing-xy-circular-boss</td>
<td>Probes the outer wall of a circular boss</td>
</tr>
<tr>
<td>probing-xy-circular-partial-boss</td>
<td>Probes the outer wall of a circular boss that is not a complete 360 degrees</td>
</tr>
<tr>
<td>probing-xy-circular-hole</td>
<td>Probes the inner wall of a circular hole</td>
</tr>
<tr>
<td>probing-xy-circular-partial-hole</td>
<td>Probes the inner wall of a circular hole that is not a complete 360 degrees</td>
</tr>
<tr>
<td>cycleType</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>probing-xy-circular-hole-with-island</td>
<td>Probes the inner wall of a circular hole with an island in the hole</td>
</tr>
<tr>
<td>probing-xy-rectangular-boss</td>
<td>Probes the outer walls of a rectangular protrusion</td>
</tr>
<tr>
<td>probing-xy-rectangular-hole</td>
<td>Probes the inner walls of a rectangular hole</td>
</tr>
<tr>
<td>probing-xy-rectangular-hole-with-island</td>
<td>Probes the inner walls of a rectangular hole with an island in the hole</td>
</tr>
<tr>
<td>probing-xy-inner-corner</td>
<td>Probes an inner corner. Modifies the origin and rotation of the part.</td>
</tr>
<tr>
<td>probing-xy-outer-corner</td>
<td>Probes an outer corner. Modifies the origin and rotation of the part.</td>
</tr>
<tr>
<td>probing-x-plane-angle</td>
<td>Probes a wall at an angle to the X-axis. Modifies the rotation of the part.</td>
</tr>
<tr>
<td>probing-y-plane-angle</td>
<td>Probes a wall at an angle to the Y-axis. Modifies the rotation of the part.</td>
</tr>
</tbody>
</table>

The parameters defined in the WCS Probing operation are passed to the cycle functions using the *cycle* object. The following variables are available and are referenced as ‘cycle.parameter’.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>angleAskewAction</td>
<td>This parameter will only be defined with an angular probing cycle when the Askw box is checked. The only valid setting when it is defined is the string stop-message.</td>
</tr>
<tr>
<td>approach1</td>
<td>The direction the probe moves at it approaches the part. It is a string variable and can be either positive or negative.</td>
</tr>
<tr>
<td>approach2</td>
<td>The direction the probe moves as it approaches the part for the second face of a multi-face operation. It is a string variable and can be either positive or negative.</td>
</tr>
<tr>
<td>bottom</td>
<td>The final depth position along the probe axis to touch the part.</td>
</tr>
<tr>
<td>clearance</td>
<td>The height the probe rapids to on its way to the start of the probing operation and the position it returns to after the probing operation is finished.</td>
</tr>
<tr>
<td>depth</td>
<td>The unsigned incremental distance from the top of the part along the probe axis where the probe will touch the part.</td>
</tr>
<tr>
<td>feedrate</td>
<td>The feedrate the probe will approach the part at.</td>
</tr>
<tr>
<td>hasAngleTolerance</td>
<td>Set to 1 if an angular tolerance is specified. The angular tolerance is stored in the toleranceAngle parameter.</td>
</tr>
<tr>
<td>hasPositionalTolerance</td>
<td>Set to 1 if a positional tolerance is specified. The positional tolerance is stored in the tolerancePosition parameter.</td>
</tr>
<tr>
<td>hasSizeTolerance</td>
<td>Set to 1 if a size tolerance is specified. The size tolerance is stored in the toleranceSize parameter.</td>
</tr>
<tr>
<td>incrementComponent</td>
<td>Set to 1 if the Increment Component box is checked under Print Results.</td>
</tr>
</tbody>
</table>
### Probing Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>outOfPositionAction</td>
<td>This parameter will only be defined when the <em>Out of Position</em> box is checked. The only valid setting when it is defined is the string <em>stop-message</em>.</td>
</tr>
<tr>
<td>printResults</td>
<td>Set to 1 when the <em>Print Results</em> box is checked in the probing operation.</td>
</tr>
<tr>
<td>probeClearance</td>
<td>The approach distance in the direction of the probing operation. The probe will be positioned at this clearance distance prior to approaching the part.</td>
</tr>
<tr>
<td>probeOvertravel</td>
<td>The maximum distance the probe can move beyond the expected contact point and still record a measurement.</td>
</tr>
<tr>
<td>probeSpacing</td>
<td>The probe spacing between points on the selected face for Angle style probing.</td>
</tr>
<tr>
<td>retract</td>
<td>The height to feed from to the probing level and to retract the probe to after probing is finished.</td>
</tr>
<tr>
<td>stock</td>
<td>The top of the part.</td>
</tr>
<tr>
<td>toleranceAngle</td>
<td>The acceptable angular deviation of the geometric feature.</td>
</tr>
<tr>
<td>tolerancePosition</td>
<td>The acceptable positional deviation of the geometric feature.</td>
</tr>
<tr>
<td>toleranceSize</td>
<td>The acceptable size deviation of the geometric feature.</td>
</tr>
<tr>
<td>width1</td>
<td>The width of the boss or hole being probed.</td>
</tr>
<tr>
<td>width2</td>
<td>The width of the secondary walls (Y-axis) of a rectangular boss or hole being probed.</td>
</tr>
<tr>
<td>wrongSizeAction</td>
<td>This parameter will only be defined when probing a feature that defines a fixed size and the <em>Wrong Size</em> box is checked. The only valid setting when it is defined is the string <em>stop-message</em>.</td>
</tr>
</tbody>
</table>

#### 10.1.2 Adding the Core Probing Logic

Adding WCS Probing support requires the main logic to output the probing cycle, supporting functions, and some logic added to the main sections of the post processor. You should first open a post processor that contains support for probing before starting to add probing to your post processor, since the logic and most of the code will remain the same. Most of the generic post processors use Renishaw style probing Macros (Fanuc, Haas, etc.), but there are also controls that support probing without the use of these Macros, such as the Datron, Heidenhain, and Siemens controls. Be sure to start with closest match to the machine you are creating a post processor for. The examples used in this chapter use the code for the Renishaw style probing Macros.

The following functions support angular probing and safe probe positioning. They may have to be modified to match the requirements of your control. The code shown is for a Fanuc style control. They should be added prior to the *onCyclePoint* function.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>approach</td>
<td>Converts the cycle approach string to a number (-1/1).</td>
</tr>
</tbody>
</table>
### Function Description

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>setProbeAngleMethod</td>
<td>Determines the output method (G68, G54.4, rotational) for angular probing cycles.</td>
</tr>
<tr>
<td>setProbeAngle</td>
<td>Outputs the rotational blocks for angular probing cycles. This output may have to be modified to match your control.</td>
</tr>
<tr>
<td>protectedProbeMove</td>
<td>Positions the probe in a protected mode (P9810).</td>
</tr>
<tr>
<td>getProbingArguments</td>
<td>Formats the standard codes for all probing cycles based on the probing cycle parameters. This function is usually located after the <code>onCyclePoint</code> function and may have to be modified to match your control.</td>
</tr>
</tbody>
</table>

#### Required Probe Functions

```javascript
/** Convert approach to sign. */
function approach(value) {
    ...
}

function setProbeAngleMethod() {
    ...
}

/** Output rotation offset based on angular probing cycle. */
function setProbeAngle() {
    ...
}

function protectedProbeMove(_cycle, x, y, z) {
    ...
}

function getProbingArguments(cycle, updateWCS) {
    ...
}
```

**Required Angular and Safe Positioning Probe Functions**

The core logic for probing is in the `onCyclePoint` function. The first part of the code to copy into your post is at the top of the `onCyclePoint` function.

```javascript
if (isProbeOperation()) {
    if (!useMultiAxisFeatures && !isSameDirection(currentSection.workPlane.forward, new Vector(0, 0, 1))) {
        if (!allowIndexingWCSProbing && currentSection.strategy == "probe") {
            error(localize("Updating WCS / work offset using probing is only supported by the CNC in the WCS frame."));
        }
    }
}
```

---

**Adding Support for Probing 10-251**
return;
}
}
if (printProbeResults()) {
    writeProbingToolpathInformation(z - cycle.depth + tool.diameter / 2);
    inspectionWriteCADTransform();
    inspectionWriteWorkplaneTransform();
    if (typeof inspectionWriteVariables == "function") {
        inspectionVariables.pointNumber += 1;
    }
}
protectedProbeMove(cycle, x, y, z);

Required Probing Code at Top of onCyclePoint

All probing operations are considered a separate operation and are not modal. The following code in the onCyclePoint function should directly follow the required probing code you just added and needs to be modified as shown in the highlighted code to support probing.

if (isFirstCyclePoint() || isProbeOperation()) {
    if (!isProbeOperation()) {
        // return to initial Z which is clearance plane and set absolute mode
        repositionToCycleClearance(cycle, x, y, z);
    }
}

Required Modifications for Probing Support

The code that outputs the probing calls is usually located after the drilling cycle logic in the main switch block. Copy all code that contains the case statements for probing operations.

switch (cycleType) {
    case "drilling":
        ...
    case "probing-x": // copy from this line to before the “default” case
        ...
    default:
}

Calling the Probe Macro

Add the following code to the onCycleEnd function to end the probing operation.

function onCycleEnd() {
    if (isProbeOperation()) {
        zOutput.reset();
        gMotionModal.reset();
}
Adding the Supporting Probing Logic

There are various locations that contain support logic for probing operations in the post processor. Some of this code may already be in your post processor. The format used for the Probe WCS code needs to be added at the top of the post where other formats are defined, if it is not already present in the post processor.

```javascript
var probeWCSFormat = createFormat({decimals:0, forceDecimal:true});
```

**Required for Formatting the Probe WCS Code**

The `gRotationModal` modal is used to manage the output of the rotation codes (G68, G68.2, etc.). It is possible that this variable is already defined in the post processor, but may have to be updated to support probing. It should be defined as shown.

```javascript
var gRotationModal = createModal({
onchange: function () {
  if (probeVariables.probeAngleMethod == "G68") {
    probeVariables.outputRotationCodes = true;
  }
}
}, gFormat); // modal group 16 // G68-G69
```

**Defining the gRotationModal Modal**

The following variables are used to control the output of probing features probing output and should be defined in the `fixed settings` section at the top of the post processor.

```javascript
var allowIndexingWCSProbing = false; // specifies probe WCS with tool orientation is supported
var probeVariables = {
  outputRotationCodes: false, // defines if it is required to output rotation codes
  probeAngleMethod : "OFF", // OFF, AXIS_ROT, G68, G54.4
  compensationXY     : undefined
};
```

**Add to Fixed Settings Section**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>allowIndexingWCSProbing</td>
<td>Some controls do not allow for WCS probing operations when the tool orientation is at an angle the XY-plane, i.e. the rotary tables are not at 0 degrees. If this is the case for your machine, then disable this variable by defining it to be <code>false</code>. If WCS probing is allowed when the rotary axes are not at 0 degrees, then set this variable to <code>true</code>.</td>
</tr>
</tbody>
</table>

**Adding Support for Probing 10-253**
outputRotationCodes  | Controls the output of the angular probing codes. This variable is controlled by the post processor and should be set to `false`.
---|---
probeAngleMethod  | Defines the angular probing method to use. This method is usually defined by the post processor in the `setProbingAngleMethod` function and can be controlled by a post processor property. It should be set to `OFF`. Other valid values are `AXIS_ROT` (used when a C-axis rotary table is defined), `G68` (the standard rotation method), or `G54.4` (based on the post processor property `useG54x4`).
compensationXY  | Controls the output of the XY compensation variables in angular probing. This variable is controlled by the post processor and should be set to `undefined`.

### Probing Settings

Add the following variables to the *collected state* section at the top of the post processor.

```javascript
var g68RotationMode = 0;
var angularProbingMode;
```

**Add to Collected State Section**

The following function and variable definition should be added prior to the `onParameter` function. The `onParameter` function should also have the shown conditional added if it is not there.

```javascript
function printProbeResults() {
  return currentSection.getParameter("printResults", 0) == 1;
}

var probeOutputWorkOffset = 1;

function onParameter(name, value) {
  if (name == "probe-output-work-offset") {
    probeOutputWorkOffset = (value > 0) ? value : 1;
  }
}
```

**Add Prior to and to onParameter Function**

The following code needs to be added to the `onSection` function.

```javascript
if (tool.type != TOOL_PROBE) {
  var outputSpindleSpeed = insertToolCall || forceSpindleSpeed || isFirstSection() ||
    rpmFormat.areDifferent(spindleSpeed, sOutput.getCurrent()) ||
    (tool.clockwise != getPreviousSection().getTool().clockwise);
  ...
}
```

**Don’t Output Spindle Speed with a Probe Tool**

```javascript
setProbeAngle(); // output probe angle rotations if required
```

**Adding Support for Probing** 10-254
// set coolant after we have positioned at Z
setCoolant(tool.coolant);

Set Rotation Based on Angular Probing Results

```
if (isProbeOperation()) {
    validate(probeVariables.probeAngleMethod != "G68", "You cannot probe while G68 Rotation is in effect.");
    validate(probeVariables.probeAngleMethod != "G54.4", "You cannot probe while workpiece setting error compensation G54.4 is enabled.");
    writeBlock(gFormat.format(65), "P" + 9832); // spin the probe on inspectionCreateResultsFileHeader();
} else {
    // surface Inspection
    if (isInspectionOperation() && (typeof inspectionProcessSectionStart == "function")) {
        inspectionProcessSectionStart();
    }
}
```

// define subprogram
subprogramDefine(initialPosition, abc, retracted, zIsOutput);
retracted = false;

Add at the end of the onSection Function

Coolant should be disabled during probing operations, so make sure that the following conditional is in the `getCoolantCodes` function.

```
function getCoolantCodes(coolant) {
    var multipleCoolantBlocks = new Array(); // create a formatted array to be passed into the outputted line
    if (!coolants) {
        error(localize("Coolants have not been defined."));
    }
    if (isProbeOperation()) { // avoid coolant output for probing
        coolant = COOLANT_OFF;
    }
}
```

Disable Coolant for Probing Operations

The probe should be turned off and angular probing codes output in the `onSectionEnd` function.

```
function onSectionEnd() {
    …
    if (isProbeOperation()) {
        writeBlock(gFormat.format(65), "P" + 9833); // spin the probe off
    if (probeVariables.probeAngleMethod != "G68") {
```
### 10.1.4 Adding Support for Printing Probe Results

A property can be added for controlling whether the probing results are output to a single file or in separate files for each probe/inspection operation.

**singleResultsFile**: 
- **title**: "Create single results file",
- **description**: "Set to false if you want to store the measurement results for each probe / inspection toolpath in a separate file",
- **type**: "boolean",
- **value**: true,
- **scope**: "post"

Add a Property to Control the Output of the Probe Results into a Single or Multiple Files

The following functions should be included if your control supports the printing of probing results. The modifications that you already made to support probing will handle the calls to these functions to output the probing results. These functions are defined consecutively and are usually located after the `writeRetract` function.

```javascript
var isDPRNTopen = false;

function inspectionCreateResultsFileHeader() {
  ...
}

function getPointNumber() {
  ...
}

function inspectionWriteCADTransform() {
  ...
}

function inspectionWriteWorkplaneTransform() {
  ...
}

function writeProbingToolpathInformation(cycleDepth) {
  ...
}
```
In the onClose function you will need to close the probe results file.

```plaintext
if (isDPRNTOpen) {
    writeln("DPRNT[END]’");
    writeBlock("PCLOS");
    isDPRNTOpen = false;
    if (typeof inspectionProcessSectionEnd == "function") {
        inspectionProcessSectionEnd();
    }
}
```

### Closing the Probing Results File

#### 10.2 Geometry Probing

Geometry Probing behaves similarly to WCS Probing. It is used to measure geometric features on the part during machining. The measured geometric features are checked against specified tolerances for size and position. Based on the result, you can update the tool wear, or instruct the machine to stop machining if the feature is out of tolerance. Geometry Probing is initiated using the *Probe Geometry* operation listed in the PROBING menu.

The Pitch Circle Diameter (PCD) probing cycles are an addition to Geometry Probing that do not exist in WCS Probing. Like all other probing cycles, the PCD cycle types are stored in the `cycleType` variable.

<table>
<thead>
<tr>
<th>cycleType</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>probing-xy-pcd-hole</td>
<td>Probes holes around a PCD.</td>
</tr>
<tr>
<td>probing-xy-pcd-boss</td>
<td>Probes bosses around a PCD.</td>
</tr>
</tbody>
</table>

**Pitch Circle Diameter (PCD) Probing Cycles**
Like in WCS Probing, the parameters defined in the Geometry Probing operation are passed to the cycle functions using the *cycle* object. These are in addition to the parameters defined for WCS Probing, which are also available in Geometry Probing. The following variables are available and are referenced as ‘cycle.parameter’.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>numberOfSubfeatures</td>
<td>Number of geometric entities in a PCD probing operation.</td>
</tr>
<tr>
<td>pcdStartingAngle</td>
<td>The starting angle of the first geometric entity to be probed in a PCD probing operation.</td>
</tr>
<tr>
<td>toolDiameterOffset</td>
<td>Defines the tool diameter offset register used to machine the feature.</td>
</tr>
<tr>
<td>toolLengthOffset</td>
<td>Defines the tool length offset register used to machine the feature.</td>
</tr>
<tr>
<td>toolWearErrorCorrection</td>
<td>The percentage of the deviation to update the tool wear by.</td>
</tr>
<tr>
<td>toolWearUpdateThreshold</td>
<td>The minimum deviation that will trigger a tool wear update.</td>
</tr>
<tr>
<td>updateToolWear</td>
<td>Enabled when tool wear compensation should be activated on the controller.</td>
</tr>
<tr>
<td>widthFeature</td>
<td>The diameter of the geometric feature for a PCD probing operation.</td>
</tr>
<tr>
<td>widthPCD</td>
<td>The pitch circle diameter (PCD) of the geometric features.</td>
</tr>
</tbody>
</table>

To add Geometry Probing to your post you will first need to implement WCS Probing. After this there are only minor changes required to support Geometry Probing.

The *probeMultipleFeatures* variable instructs the post engine that multiple geometric entities can be probed in a single operation. The probing logic in all posts now support this feature, so it should be set to *true*. It should be defined with the other post engine variables (*allowedCircularPlanes*, *highFeedrate*, etc.).

```c
highFeedrate = (unit == IN) ? 500 : 5000;
probeMultipleFeatures = true;
```
Enable the Probing of Multiple Geometric Entities

If the control supports PCD probing cycles be sure to include cases for these cycles in `onCyclePoint`, where the other probing cycle code is located.

```java
case "probing-xy-pcd-hole":
    protectedProbeMove(cycle, x, y, z);
    writeBlock(
        gFormat.format(65), "P" + 9819,
        "A" + xyzFormat.format(cycle.pcdStartingAngle),
        "B" + xyzFormat.format(cycle.numberOfSubfeatures),
        "C" + xyzFormat.format(cycle.widthPCD),
        "D" + xyzFormat.format(cycle.widthFeature),
        "K" + xyzFormat.format(z - cycle.depth),
        "Q" + xyzFormat.format(cycle.probeOvertravel),
        getProbingArguments(cycle, false)
    );
    if (cycle.updateToolWear) {
        error(localize("Action -Update Tool Wear- is not supported with this cycle."));
        return;
    }
    break;

case "probing-xy-pcd-boss":
    protectedProbeMove(cycle, x, y, z);
    writeBlock(
        gFormat.format(65), "P" + 9819,
        "A" + xyzFormat.format(cycle.pcdStartingAngle),
        "B" + xyzFormat.format(cycle.numberOfSubfeatures),
        "C" + xyzFormat.format(cycle.widthPCD),
        "D" + xyzFormat.format(cycle.widthFeature),
        "Z" + xyzFormat.format(z - cycle.depth),
        "Q" + xyzFormat.format(cycle.probeOvertravel),
        "R" + xyzFormat.format(cycle.probeClearance),
        getProbingArguments(cycle, false)
    );
    if (cycle.updateToolWear) {
        error(localize("Action -Update Tool Wear- is not supported with this cycle."));
        return;
    }
    break;
```

**PCD Probing Support in onCyclePoint**

### 10.3 Inspect Surface

The Inspect Surface operation creates a probing strategy that specifies contact points across the surfaces of the model to be measured by a probe while the part is still on the machine tool. The results can then
be imported and compared against the model to identify if the manufactured part is in or out of tolerance.

Inspection streamlines the manufacturing process by letting you identify problem areas and decide on any rework needed early in the process. It also helps to reduce the need to move parts between the machine tool and a measuring device.

Surface Inspection is initiated using the *Inspect Surface* operation listed in the INSPECTION/PROBING menu.

If you wish to use the Inspect Surface operations, you will need a post processor that will allow you to output and run these inspection paths on your machine. You can either use one of the generic Inspection post processors available on the [Post Library for Autodesk Fusion 360](https://learn.autodesk.com), or modify your current milling post which is already set up for your machine to add in the inspection functionality. You will need to add support for probing to your post processor before adding the inspection capabilities.

The Inspection post processors will have the *inspection* or *inspect surface* suffix appended to the name of the post processor. These are the only post processors that support Inspect Surface operations. You will need to use one of these generic posts as a source for adding the inspection code to your post processor.

### 10.3.1 Inspect Surface Operations

Inspect Surface operations differ from the other probing operations, in that you will select points on the face of the part to inspect instead of individual features of the part.
The Surface Inspect operations are considered a cycle in the post processor and therefore call the `onCyclePoint` function, though they are expanded in the `inspectionCycleInspect` function. The standard `cycleType` variable to define the cycle type is not set for Surface Inspect operations, but rather the `isInspectionOperation` function is used to determine if it is a Surface Inspection cycle. This is further explained in the Adding the Supporting Surface Inspect Logic section. Unlike other cycles that pass a single point to the `onCyclePoint` function, the Surface Inspect cycle will contain the following 3 points per cycle location, with each location generating a separate and subsequent call to `onCyclePoint`.

<table>
<thead>
<tr>
<th>Location</th>
<th>How to determine</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>isFirstCyclePoint()</td>
<td>Safe move to approach inspection location</td>
</tr>
<tr>
<td>Second</td>
<td>(default)</td>
<td>Inspection move</td>
</tr>
<tr>
<td>Third</td>
<td>isLastCyclePoint()</td>
<td>Retract move</td>
</tr>
</tbody>
</table>

Three Points per Inspection Location

### 10.3.2 Inspection Parameters

The parameters defined in the Inspect Surface operation are passed to the inspection functions using either the `cycle` object or through section parameters (`getParameter`). These parameters are handled in the core Surface Inspect functions that are copied from an existing inspection post processor. Standard probing parameters can be referenced in the inspection functions.

The following variables are referenced as ‘`cycle.parameter`’.

<table>
<thead>
<tr>
<th>Cycle Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>linkFeed</td>
<td>The feedrate used to position between inspection locations.</td>
</tr>
<tr>
<td>measureFeed</td>
<td>The feedrate used to approach the part.</td>
</tr>
<tr>
<td>nominalI</td>
<td>The I-component of the vector normal to the surface inspection point.</td>
</tr>
</tbody>
</table>
### Cycle Parameter

<table>
<thead>
<tr>
<th>Cycle Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nominalJ</td>
<td>The J-component of the vector normal to the surface inspection point.</td>
</tr>
<tr>
<td>nominalK</td>
<td>The K-component of the vector normal to the surface inspection point.</td>
</tr>
<tr>
<td>nominalX</td>
<td>The X-axis position of the inspection point.</td>
</tr>
<tr>
<td>nominalY</td>
<td>The Y-axis position of the inspection point.</td>
</tr>
<tr>
<td>nominalZ</td>
<td>The Z-axis position of the inspection point.</td>
</tr>
<tr>
<td>outOfPositionAction</td>
<td>This parameter will only be defined when the Out of Position box is checked. The only valid setting when it is defined is the string stop-message.</td>
</tr>
<tr>
<td>pointID</td>
<td>The numeric ID of the inspection point.</td>
</tr>
<tr>
<td>safeFeed</td>
<td>The feedrate at which to approach the part.</td>
</tr>
</tbody>
</table>

---

### Inspection cycle Parameters

The following parameters are inspection specific and are prefixed with the operation: string. They are referenced using the getParameter("operation:parameter ") function.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>inspectUpperTolerance</td>
<td>The lower limit distance at which an inspected point is considered within tolerance of the model.</td>
</tr>
<tr>
<td>inspectSurfaceOffset</td>
<td>The positive or negative distance from the model from where inspection points are measured.</td>
</tr>
<tr>
<td>inspectUpperTolerance</td>
<td>The upper limit distance at which an inspected point is considered within tolerance of the model.</td>
</tr>
</tbody>
</table>

---

### 10.3.3 Adding the Core Inspect Surface Logic

Adding Surface Inspect support requires the main logic to be copied directly from a post processor that already supports inspection, and logic added to the main sections of the post processor. You should first open a post processor that contains support for inspection before starting to add Inspect Surface support to your post processor, since the logic and most of the code will remain the same. As of this writing, the following post processors have support for inspection, notice that all of them are named with the inspect surface or inspection suffix.

<table>
<thead>
<tr>
<th>Post Library Name</th>
<th>Filename</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATRON next Inspect Surface</td>
<td>datron next inspect surface.cps</td>
</tr>
<tr>
<td>Fanuc Inspection</td>
<td>fanuc inspection.cps</td>
</tr>
<tr>
<td>HAAS (pre-NGC) Inspect Surface</td>
<td>haas inspect surface.cps</td>
</tr>
<tr>
<td>HAAS – Next Generation Control Inspect Surface</td>
<td>haas next generation inspect surface.cps</td>
</tr>
<tr>
<td>Heidenhain Inspection</td>
<td>heidenhain inspection.cps</td>
</tr>
<tr>
<td>Hurco Inspect Surface</td>
<td>hurco inspect surface.cps</td>
</tr>
<tr>
<td>Results file generator for probing and inspect surface</td>
<td>result generator inspect surface.cps</td>
</tr>
<tr>
<td>Siemens SINUMERIK 840D Inspection</td>
<td>siemens 840D inspection.cps</td>
</tr>
</tbody>
</table>

---

*Post Processors that Support Surface Inspect Operations*
You can also search the online Post Library for Autodesk Fusion 360 to see if any other post processors have been added with inspection capabilities.

The main code for Inspect Surface logic is located at the end of the post processor. You will need to copy from the definition of `capabilities` located after the `onClose` or `onTerminate` function to the end of the file and add this code to the end of your post processor.

```javascript
capabilities |= CAPABILITY_INSPECTION;
description = "HAAS - Next Generation Control Inspect Surface";
longDescription = "Generic post for the HAAS Next Generation control with inspect surface capabilities.";
```

Copy From this Code to the End of the File for Core Surface Inspect Logic

### 10.3.4 Adding the Supporting Inspect Surface Logic

There are a number of locations that contain support logic for Inspect Surface operations in the post processor. You can refer to any of the generic post processors that support Inspect Surface operations for an example on where this code is implemented.

Add the following code at the end of the `onOpen` function.

```javascript
// Probing Surface Inspection
if (typeof inspectionWriteVariables == "function") {
  inspectionWriteVariables();
}
```

Add to the End of the `onOpen` Function
For multi-axis machines it is important that an actual machine configuration is defined and is not reliant
on 3+2 plane codes and/or IJK output. Please refer to the *Multi-Axis Post Processors* section for a
description on implementing multi-axis support to your post processor.

At the end of the *onSection* function, but before any subprograms are defined, add the following code.

```csharp
if (isInspectionOperation(currentSection) && (typeof inspectionProcessSectionStart == "function"))
{
    inspectionProcessSectionStart();
}
```

*Initialize the Surface Inspect Operation*

At the top of the *onCyclePoint* function add in the following code.

```csharp
if (isInspectionOperation(currentSection) && (typeof inspectionCycleInspect == "function")) {
    inspectionCycleInspect(cycle, x, y, z);
    return;
}
```

*Call the Controlling Surface Inspect Function*

At the start of the *onSectionEnd* function add the following code. The *writeBlock* statement in this
example will differ between the machine post processors.

```csharp
if (isInspectionOperation() && !isLastSection()) {
    // the following logic will differ depending on the post processor
    writeBlock(gFormat.format(103), "P0", formatComment("LOOKAHEAD ON"));
}
```

*Finalize the Surface Inspect Operation*

At the end of the *onClose* function, but before any subprogram statements, add the following code after
the results file is closed.

```csharp
if (typeof inspectionProgramEnd == "function") {
    inspectionProgramEnd();
}
```

*Finalize the Surface Inspect Program*

### 11 Additive Capabilities and Post Processors

So far in this guide we’ve discussed post processors as they pertain to subtractive machining, but Fusion
360 also supports Additive FFF (fused filament fabrication) printers. This chapter discusses the basics
of selecting a machine capable of additive manufacturing, generating an additive tool path, creating
output, and the details of an additive post processor.
11.1 Getting Started

This section will give an overview of creating an Additive tool path but will not go into great detail on all of the features of the Additive capabilities of Fusion 360, just enough to get you started on post processing.

You will of course need a model that you want to print to start with. For the examples in this manual we will use the Fusion Keychain model provided as a CAM sample with your installation of Fusion 360. This model contains subtractive manufacturing operations which can be combined with Additive manufacturing operations as long as your machine supports both capabilities.

You will see the ADDITIVE tab on the MANUFACTURE ribbon. Selecting this tab will display the Additive menus.

11.1.1 Finding a Machine

The first step in creating an Additive tool path is to define the machine that you will be using. Unlike Subtractive operations where the Machine Definition is optional, it is required for Additive operations. Pressing the Machine Library icon in the Additive menus will display the Machine Library dialog. Select the Fusion 360 Library menu and check the Additive box to list the available Additive machines. You can use the Search field or Vendor pull down menu to filter the machines that are displayed. We
will be using the *Prusa i3 MK2* machine. You should drag this machine into your Local library for both convenience and the ability to edit the machine.

**Finding an Additive Machine and Storing in Your Local Library**

Once you find your machine you may need to select the post processor and Print Settings that correspond to this machine. The machines in the Fusion 360 Library should all be assigned to the correct post processor for each machine, so it is rare that you would need to change the post processor. If necessary, you can select/change the post processor by right clicking on the *Prusa i3 MK3* machine and choosing *Change the selected post*.

**Selecting/Changing the Post Processor and Setting the Print Settings**
The *Post Library* dialog will then be displayed. Select the *Fusion 360 library* and check the Additive box to display only the post processors supporting the Additive capabilities. You will want to select the *Prusa i3 MK2* machine. You will need to drag this post processor into your Local library if you plan on editing it.

![Selecting the Post Processor](image)

You can also create linked folders on your computer to store both the machines and post processors. You do this by right clicking on the Linked menu and selecting the Link Folder menu. A browser will be displayed allowing you to select a folder to place your machines/posts.

![Selecting a Local Folder for The Machines and Post Processors](image)

To select the Print Settings for the printer, right click on the *Prusa i3 MK3* machine and choose *Select a print setting*. This will bring up the Print Setting Library dialog allowing you to either select an existing print setting or creating a custom print setting. Print Settings must be stored in the Local library in order to create or edit them.
Selecting the Print Setting

Once the Print Setting is in your local library you can edit it by pressing the button. Press the to create a new Print Setting, you will be prompted to select an existing Print Setting to use as the template for the new Print Setting.
11.1.2 Creating an Additive Setup

In the Fusion Keychain model you will notice that there is already a subtractive setup defined. For machines that support both additive and subtractive machining you can define both types of operations as long as they are in separate setups. The subtractive operations for these machines are exactly the same as they would be for a purely subtractive (milling) machine. For this sample we will be ignoring the subtractive setup and working with the additive only.

To create an Additive setup, press the Setup menu, change the Operation Type to Additive, and select the configuration for your machine by pressing the Select... button under Machine.
Defining an Additive Setup

If you have not already assigned a post processor to this machine you will need to do so now. Do this by pressing the Edit... button under the Machine prompt. The Machine Definition will display, change the Post location to Personal – local, and select the prusa.cps post processor from the Post Processor drop down menu.

Associating a Post Processor to a Machine Definition

You can select and/or edit the Print Settings directly from the Setup dialog when creating the Additive Setup. The Print Settings are specific to the creation of the Additive toolpaths, with settings to modify...
the bed temperature, nozzle temperature, layer thickness, infill style, etc. You can also create your own default print settings by giving them a new name.

Defining the Print Settings

After creating the Setup you should see a representation of the machine base and envelope with the part located on it. Feel free to rename the new setup to Additive so you know that this is an additive operation. If you were going to do both additive and subtractive operations in the same model, then you will want to move the Additive setup above the Subtractive setup.
If the part is not in the location on the machine where you want it, you can easily reposition it using the POSITION menus.

11.1.3 Creating and Simulating an Additive Operation

An Additive operation is automatically created when an Additive setup is created. You can see this operation by expanding the Additive setup in the Browser. There can only be one Additive operation per setup. You will need to generate the Additive Toolpath manually by selecting Generate from the ACTIONS menus or by pressing Ctrl+G. This may take a while depending on the complexity of the model.
To simulate the Additive toolpath press the *Simulate* button in the ACTIONS menus. Additive toolpaths simulate in the same manner as Subtractive toolpaths, but it is recommended that you place the cursor over the green slide bar at the bottom of the window, hold down the left mouse button, and move the mouse to the left and right to visualize the Additive process.
11.2 Creating a New Machine Definition

When adding a new Additive post processor you will need to create a corresponding Machine Definition. You do this by copying an existing Machine Definition into your Local library by opening the Machine Library dialog, selecting the Machine Definition you want to copy, and then pasting it into your Local folder.

![Machine Library Dialog]

Once you create a copy of the Machine Definition in your Local folder you will need to edit it and describe your machine. Be sure to give it a unique name and description and go through all sections to properly define the machine.
Duplicating and Editing the Machine Definition

After creating your Machine Definition you will need to copy a seed post into a local folder, for example prusa.cps, and give it a meaningful name. You can then assign this post processor to your machine. You can also select the default output folder for your G-code files when posting.

Assigning a Post Processor to Your Additive Machine

You are now ready to edit your post processor.

11.3 Additive Common Properties

The additive post processors have properties that are common to most of them. These properties are listed in the following table.
<table>
<thead>
<tr>
<th>Title</th>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative extrusion mode</td>
<td>relativeExtrusion</td>
<td>Selects between an absolute or relative extrusion mode.</td>
</tr>
<tr>
<td>Trigger</td>
<td>_trigger</td>
<td>Specifies the method used to trigger a change of extruder temperature. It can be disabled or controlled by the Z-height or layer number.</td>
</tr>
<tr>
<td>Trigger Value</td>
<td>_triggerValue</td>
<td>Specifies the Z-height difference or layer number increment to trigger an extruder temperature change.</td>
</tr>
<tr>
<td>Start Temperature</td>
<td>tempStart</td>
<td>The starting temperature in Celsius for the extruder, overrides the starting temperature in the Print Settings.</td>
</tr>
<tr>
<td>Temperature Interval</td>
<td>tempInterval</td>
<td>The degrees in Celsius to increase the temperature of the extruder for each trigger event.</td>
</tr>
</tbody>
</table>

The Temperature Tower properties are typically used to test new filaments in order to identify the best printing temperatures. These properties are listed in the Temperature Tower group.

### 11.4 Additive Variables

There are variables that are specific to Additive machines. These variables are either globally defined or are accessed through function calls. The following table lists the variables available for Additive machines.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>bedTemp</td>
<td>Temperature of bed.</td>
</tr>
<tr>
<td>commands</td>
<td>Post processor defined variable that defines the codes that are output for additive commands.</td>
</tr>
<tr>
<td>Extruder</td>
<td>An unnamed object that contains the extruder definition. This object is obtained by calling the getExtruder function.</td>
</tr>
<tr>
<td>layerCount</td>
<td>Number of printed layers for entire printing operation.</td>
</tr>
<tr>
<td>machineConfiguration</td>
<td>The machine configuration definition.</td>
</tr>
<tr>
<td>numberOfExtruders</td>
<td>Number of extruders used.</td>
</tr>
<tr>
<td>partCount</td>
<td>Number of bodies created during printing.</td>
</tr>
<tr>
<td>printTime</td>
<td>The amount of time the print should take.</td>
</tr>
<tr>
<td>settings</td>
<td>Post processor defined variable that defines settings specific to additive machines.</td>
</tr>
</tbody>
</table>

The post processor defined variables are defined in the getPrinterGeometry function from the machineConfiguration settings and are typically in all Additive post processors.

### 11.4.1 The machineConfiguration Object

The machineConfiguration object is standard between all machine types, milling, turning, additive, etc. machineConfiguration settings are always referenced using a function. The variables returned from the functions are described in the following table.
<table>
<thead>
<tr>
<th>MachineConfiguration Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>getCenterPositionX(id)</td>
<td>The center of the printer table in X.</td>
</tr>
<tr>
<td>getCenterPositionY(id)</td>
<td>The center of the printer table in Y.</td>
</tr>
<tr>
<td>getCenterPositionZ(id)</td>
<td>The center of the printer table in Z.</td>
</tr>
<tr>
<td>getExtruderOffsetX(id)</td>
<td>The offset in X from the reference extruder.</td>
</tr>
<tr>
<td>getExtruderOffsetY(id)</td>
<td>The offset in Y from the reference extruder.</td>
</tr>
<tr>
<td>getExtruderOffsetZ(id)</td>
<td>The offset in Z from the reference extruder.</td>
</tr>
<tr>
<td>getVendor()</td>
<td>The manufacturer of the printer.</td>
</tr>
<tr>
<td>getModel()</td>
<td>The model type of the printer.</td>
</tr>
<tr>
<td>getNumberExtruders()</td>
<td>Number of defined extruders.</td>
</tr>
<tr>
<td>getWidth()</td>
<td>The width of the machine in X.</td>
</tr>
<tr>
<td>getDepth()</td>
<td>The depth of the machine in Y.</td>
</tr>
<tr>
<td>getHeight()</td>
<td>The height of the machine in z.</td>
</tr>
</tbody>
</table>

**machineConfiguration Functions used for Additive**

### 11.4.2 The Extruder Object

There is not really a named Extruder object, meaning you cannot use the *new Extruder* syntax to create an object as you would a Vector, but there is the *getExtruder* function that will return an unnamed object that has extruder specific variables. Each extruder can be referenced by passing the extruder number to the *getExtruder* function.

```javascript
var totalLength = getExtruder(1).extrusionLength;
```

*Get the Total Length of Material Used for Extruder 1*

The following table defines the variables accessible using the *getExtruder* function.

<table>
<thead>
<tr>
<th>Extruder Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>extrusionLength</td>
<td>Total length of material used for this extruder during printing.</td>
</tr>
<tr>
<td>filamentDiameter</td>
<td>The diameter of the filament material.</td>
</tr>
<tr>
<td>materialName</td>
<td>The name of the material used for the extruder.</td>
</tr>
<tr>
<td>nozzleDiameter</td>
<td>The diameter of the extruder nozzle.</td>
</tr>
<tr>
<td>temperature</td>
<td>The temperature setting for the extruder.</td>
</tr>
</tbody>
</table>

**Extruder Variables**

### 11.4.3 The commands Object

The *commands* object is defined in the post processor and defines the output codes for common additive commands. Define the proper code to be output for each command in this definition. Some of the commands may have specifiers that define subcommands, such as *on* and *off* for fan. The following table lists the commands supported by the library additive post processors.
The code values can be a formatted number or a text string. If a command does not exist for your printer, then define the code as `undefined`.

```javascript
// Specify the required commands for your printer below.
var commands = {
  extruderChangeCommand : undefined, // command to change the extruder
  setExtruderTemperature: mFormat.format(104), // command to set the extruder temperature
  waitExtruder          : mFormat.format(109), // wait command for the extruder temperature
  setBedTemperature    : mFormat.format(140), // set the bed temperature
  waitBed               : mFormat.format(190), // wait for the bed temperature
  reportTemperatures   : undefined, // report the temperatures to the printer
  fan                   : {on:mFormat.format(106), off:mFormat.format(107)},
  extrusionMode         : {relative:mFormat.format(83),
                           absolute:mFormat.format(82)} // extrusion mode
};
```

<table>
<thead>
<tr>
<th>commands Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>extruderChangeCommand</td>
<td>Command to change the extruder.</td>
</tr>
<tr>
<td>setExtruderTemperature</td>
<td>Command to set the extruder temperature.</td>
</tr>
<tr>
<td>waitExtruder</td>
<td>The wait command when setting the extruder temperature.</td>
</tr>
<tr>
<td>setBedTemperature</td>
<td>Command to set the bed temperature.</td>
</tr>
<tr>
<td>waitBed</td>
<td>The wait command when setting the bed temperature.</td>
</tr>
<tr>
<td>reportTemperatures</td>
<td>Command to report the temperatures to the printer.</td>
</tr>
<tr>
<td>Fan</td>
<td>Commands to turn the fan on and off, defined using the syntax <code>{on:---, off:---}</code>.</td>
</tr>
<tr>
<td>extrusionMode</td>
<td>Commands to select either relative or absolute filament extrusion modes, defined using the syntax <code>{relative:---, absolute:---}</code>.</td>
</tr>
</tbody>
</table>

### The commands Object

#### 11.4.4 The settings Object

The `settings` object is post processor defined and defines fixed settings that are not controlled by post properties.

```javascript
var settings = {
  useG0              : true, // use G0 or G1 commands for rapid movements
  maximumExtruderTemp: 260 // specifies the maximum extruder temperature
};
```

<table>
<thead>
<tr>
<th>settings Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>useG0</td>
<td>Commands to use G0 or G1 commands for rapid movements</td>
</tr>
<tr>
<td>maximumExtruderTemp</td>
<td>Specifies the maximum extruder temperature</td>
</tr>
</tbody>
</table>
11.5 Additive Entry Functions

Additive post processors use most of the common Entry functions for Subtractive posts, with some specialized Entry functions for Additive post processors only. Remember that Entry functions are called from the post processor kernel based on the record type in the intermediate file, so this means that there is a difference between Subtractive and Additive intermediate files.

The following table defines the unique or modified Entry Functions for Additive post processors. You can reference the table in the subtractive Entry Functions section for a description of the common entry functions.

<table>
<thead>
<tr>
<th>Entry Function</th>
<th>Invoked When …</th>
</tr>
</thead>
<tbody>
<tr>
<td>onAcceleration(travel, printing, retract)</td>
<td>Acceleration is changed in an additive pass.</td>
</tr>
<tr>
<td>onBedTemp(temp, wait)</td>
<td>Bed temperature change.</td>
</tr>
<tr>
<td>onCircularExtrude(_clockwise, _cx, _cy, _cz, _x, _y, _z, _f, _e)</td>
<td>Additive circular pass.</td>
</tr>
<tr>
<td>onClose()</td>
<td>End of post processing.</td>
</tr>
<tr>
<td>onExtruderChange(id)</td>
<td>Change of extruders.</td>
</tr>
<tr>
<td>onExtruderTemp(temp, wait, id)</td>
<td>Extruder temperature change.</td>
</tr>
<tr>
<td>onExtrusionReset(length)</td>
<td>Resets the length of the extrusion material used.</td>
</tr>
<tr>
<td>onFanSpeed(speed, id)</td>
<td>Change of fan speed.</td>
</tr>
<tr>
<td>onJerk(x, y, z, e)</td>
<td>The axis jerk is changed in an additive pass.</td>
</tr>
<tr>
<td>onLayer(layer)</td>
<td>Change of layer level.</td>
</tr>
<tr>
<td>onMaxAcceleration(x, y, z, e)</td>
<td>Max axis acceleration is changed in an additive pass.</td>
</tr>
<tr>
<td>onOpen()</td>
<td>Post processor initialization.</td>
</tr>
<tr>
<td>onLinearExtrude(x, y, z, f, e)</td>
<td>Additive pass.</td>
</tr>
<tr>
<td>onParameter(string, value)</td>
<td>Each parameter setting.</td>
</tr>
<tr>
<td>onRapid(x, y, z)</td>
<td>Positioning Rapid move.</td>
</tr>
<tr>
<td>onSection()</td>
<td>Start of an operation.</td>
</tr>
</tbody>
</table>

Many of the entry functions will get their arguments and settings from either the Machine Definition or Print Settings. These dialogs can be accessed by pressing the right mouse button when over the Additive setup and selecting Edit.
This will display the Setup dialog, where you can select to edit either the Machine Definition (described in the previous section) or Print Settings. You can also display the Print Settings dialog by pressing the Print Settings button in the Additive menus.

11.5.1 Global Section

The global section for an Additive post is consistent with the standard global section for Subtractive posts, it contains the description of the post processor and machine, its capabilities, kernel settings, property table, and global variables. The capabilities of the post must be set to CAPABILITY_ADDITIVE.
The common global variables found in an Additive post are defined in the Additive Variables section.

### 11.5.2 onOpen

```javascript
function onOpen()
```

The `onOpen` function is called at the start of post processing and is used to define settings and output startup blocks. It usually varies from machine to machine.

1. Define settings
2. Output machine and program description
3. Output initial startup codes

Following is an example `onOpen` function.

```javascript
function onOpen() {
  setFormats(MM); // machine require input code in MM
  // output machine and program description
  if (typeof writeProgramHeader == "function") {
    writeProgramHeader();
  }

  // output start of program codes
  writeBlock(gFormat.format(unit == MM ? 21 : 20)); // set unit
  writeBlock("M115 U3.0.10 ; tell printer latest fw version");
  if (getProperty("printerModel") == "i3mk2mk3") {
    writeBlock(gFormat.format(28), "W ; home all without mesh bed level");
  } else if (getProperty("printerModel") == "mini") {
    writeBlock(gFormat.format(28), "; home all without mesh bed level");
  }
}
```

**Example onOpen Function**

### 11.5.3 onSection

```javascript
function onSection() {
```

The `onSection` function is called at the start of each Additive operation and outputs the starting codes for an Additive operation. It usually varies from machine to machine.

```javascript
function onSection() {
```

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// probe bed after heating
if (getProperty("printerModel") == "i3mk2mk3") {
    writeBlock(gFormat.format(80), "; mesh bed leveling");
} else if (getProperty("printerModel") == "mini") {
    writeBlock(gFormat.format(29), "; mesh bed leveling");
}

// output start of operation codes
writeBlock(gFormat.format(92), eOutput.format(0));
writeBlock(gAbsIncModal.format(90)); // absolute spatial co-ordinates
writeBlock(getCode(getProperty("relativeExtrusion") ? commands.extrusionMode.relative : commands.extrusionMode.absolute));

11.5.4 onClose

function onClose() {

The onClose function is called at the end of the last operation. It is used to output the end-of-program codes. It usually varies from machine to machine.

function onClose() {
    // output end-of-program codes
    writeBlock("G4 ; wait");
xOutput.reset();
yOutput.reset();
    if (getProperty("printerModel") == "i3mk2mk3") {
        writeBlock(gMotionModal.format(1), xOutput.format(0),
                   yOutput.format(toPreciseUnit(200, MM)), "; home X axis");
    } else if (getProperty("printerModel") == "mini") {
        writeBlock(gMotionModal.format(1), xOutput.format(0),
                   yOutput.format(toPreciseUnit(150, MM)), "; home X axis");
    }
    writeBlock(mFormat.format(84), "; disable motors");
}

11.5.5 onBedTemp

function onBedTemp(temp, wait) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>temp</td>
<td>The bed temperature in Celsius.</td>
</tr>
<tr>
<td>wait</td>
<td>Set to true when the machine should wait for the bed to warm up.</td>
</tr>
</tbody>
</table>
The `onBedTemp` function is called multiple times during a toolpath. At the start of the operation, `onBedTemp` is called with `wait` set to `false` to start heating the bed. It is called a second time prior to the start of the toolpath with `wait` set to `true` so that the machine waits for it to reach the targeted temperature. It will also be called at the end of the program to turn off the heating of the bed.

The maximum bed temperature is defined in the `Limits` tab when defining the Machine Definition in Fusion 360. The `onBedTemp` function is common to most additive posts.

```javascript
function onBedTemp(temp, wait) {
    if (wait) {
        writeBlock(getCode(commands.reportTemperatures));
        writeBlock(getCode(commands.waitBed), sOutput.format(temp));
    } else {
        writeBlock(getCode(commands.setBedTemperature), sOutput.format(temp));
    }
}
```

### onBedTemp Function

#### 11.5.6 onExtruderTemp

```javascript
function onExtruderTemp(temp, wait, id) {
    if (typeof executeTempTowerFeatures == "function" && getProperty("_trigger") != undefined) {
        if (getProperty("_trigger") != "disabled" && (getCurrentPosition().z == 0)) {
            temp = getProperty("tempStart"); // override temperature with the starting temperature
        }
    }
    if (wait) {
        writeBlock(getCode(commands.reportTemperatures));
    }
}
```

**Arguments**

<table>
<thead>
<tr>
<th>Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>temp</td>
<td>The extruder temperature in Celsius.</td>
</tr>
<tr>
<td>wait</td>
<td>Set to <code>true</code> when the machine should wait for the extruder to warm up.</td>
</tr>
<tr>
<td>id</td>
<td>Extruder number to set the temperature for. The first extruder is 0.</td>
</tr>
</tbody>
</table>

The `onExtruderTemp` function is called multiple times during a toolpath. At the start of the operation, `onExtruderTemp` is called with `wait` set to `false` to start heating the extruder. It is called a second time prior to the start of the toolpath with `wait` set to `true` so that the machine waits for it to reach the targeted temperature. It will also be called at the end of the program to turn off the heating of the extruder.

The desired extruder temperature is defined in the `Extruder` tab of the `Print Settings` dialog. The maximum extruder temperature is set in the `Extruder Configuration` tab when defining the Machine Definition in Fusion 360. The `onExtruderTemp` function is common to most additive posts.
writeBlock(getCode(commands.waitExtruder), sOutput.format(temp), tFormat.format(id));
} else {
    writeBlock(getCode(commands.setExtruderTemperature), sOutput.format(temp),
              tFormat.format(id));
}

onExtruderTemp Function

### 11.5.7 onExtruderChange

```javascript
function onExtruderChange(id) {
    if (id > machineConfiguration.getNumberExtruders()) {
        error(subst(localize("This printer does not support the extruder '%1'."),
                   integerFormat.format(id)));
        return;
    }
    writeBlock(getCode(commands.extruderChangeCommand), tFormat.format(id));
    activeExtruder = id;
    forceXYZE();
}
```

Sample onExtruderChange Function

### 11.5.8 onExtrusionReset

```javascript
function onExtrusionReset(length) {
    if (getProperty("relativeExtrusion")) {
        eOutput.format(0);
    }
}
```

The `onExtruderChange` function handles a switch between extruders, similar to a tool change in a subtractive machine. The number of extruders is defined in the Information tab when defining the Machine Definition in Fusion 360. The `onExtruderChange` function is common to most additive posts.

The `onExtrusionReset` function will be called to reset the length of the used additive material when the active extruder changes. At the beginning of the program it will be called with a value of 0 and when switching between one extruder and another it will pass the length of additive material used for the newly activated extruder. The `onExtruderChange` function is common to most additive posts.
onExtrusionReset Function

11.5.9 onFanSpeed

function onFanSpeed(speed, id) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>speed</td>
<td>The fan speed as a percentage of the default speed in the range of 0-255.</td>
</tr>
<tr>
<td>id</td>
<td>Extruder number to set the fan speed for, typically the active extruder.</td>
</tr>
</tbody>
</table>

The onFanSpeed function is used to turn on and off the fan used for cooling the extruded material. The fan is controlled starting at the layer after the number of disabled layers defined in the Cooling tab of the Print Settings dialog. The onFanSpeed function is common to most additive posts.

```javascript
function onFanSpeed(speed, id) {
  if (!commands.fan) {
    return;
  }
  if (speed == 0) {
    writeBlock(getCode(commands.fan.off));
  } else {
    writeBlock(getCode(commands.fan.on), sOutput.format(speed));
  }
}
```

onFanSpeed Function

11.5.10 onAcceleration

function onAcceleration(travel, printing, retract) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>travel</td>
<td>The travel acceleration, used for positioning moves.</td>
</tr>
<tr>
<td>printing</td>
<td>Printing acceleration, used for extrusion moves.</td>
</tr>
<tr>
<td>retract</td>
<td>Retract acceleration, used for extruder retract moves.</td>
</tr>
</tbody>
</table>

The onAcceleration function is invoked when the acceleration changes in an Additive toolpath. The acceleration values are provided in \((\text{velocity\_change/seconds})^2\).

```javascript
// set the current acceleration rate for the move types
```

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function onAcceleration(travel, printing, retract) {
    writeBlock(mFormat.format(204), "P" + integerFormat.format(printing), "T" +
               integerFormat.format(travel), "R" + integerFormat.format(retract));
}

onAcceleration Function

11.5.11 onMaxAcceleration

function onMaxAcceleration(x, y, z, e) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>The maximum acceleration along X.</td>
</tr>
<tr>
<td>y</td>
<td>The maximum acceleration along Y.</td>
</tr>
<tr>
<td>z</td>
<td>The maximum acceleration along Z.</td>
</tr>
<tr>
<td>e</td>
<td>The maximum acceleration of the extrusion.</td>
</tr>
</tbody>
</table>

The onMaxAcceleration function is invoked when the maximum axis acceleration changes in an Additive toolpath. The acceleration values are provided in (velocity_change/seconds)^2.

// set the maximum acceleration for each axes
function onMaxAcceleration(x, y, z, e) {
    writeBlock(mFormat.format(201), "X" + integerFormat.format(x), "Y" +
               integerFormat.format(y), "Z" + integerFormat.format(z), "E" + integerFormat.format(e));
}

onMaxAcceleration Function

11.5.12 onJerk

function onJerk(x, y, z, e) {

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>The X-axis jerk.</td>
</tr>
<tr>
<td>y</td>
<td>The Y-axis jerk.</td>
</tr>
<tr>
<td>z</td>
<td>The Z-axis jerk.</td>
</tr>
<tr>
<td>e</td>
<td>The extruder jerk.</td>
</tr>
</tbody>
</table>

The onJerk function is invoked when the axis jerk changes in an Additive toolpath. The jerk control values are provided in velocity_jerk/seconds.

// jerk control
function onJerk(x, y, z, e) {
    writeBlock(mFormat.format(205), "X" + integerFormat.format(x), "Y" + integerFormat.format(y),
               "Z" + integerFormat.format(z), "E" + integerFormat.format(e));
}
onJerk Function

11.5.13 onLayer

```javascript
function onLayer(layer) {

Arguments       Description
Layer            Current layer being printed.

The `onLayer` function is called for every printed layer and passes in the active layer. It can be used to output a comment prior to the toolpath for each layer and/or to increment a counter on the machine control to show the printing progress. The `onLayer` function is common to most additive posts.

```javascript
function onLayer(num) {
    if (typeof executeTempTowerFeatures == "function") {
        executeTempTowerFeatures(num);
    }
    writeComment("Layer : " + integerFormat.format(num) + " of " + integerFormat.format(layerCount));
}
```  

Sample onLayer Function

11.5.14 onParameter

```javascript
function onParameter(name, value) {

Arguments         Description
name               Parameter name.
value              Value stored in the parameter.

The `onParameter` function behaves the same as it does in a Subtractive post processor, but there is one parameter that is specific to Additive machines. This is the `feedRate` parameter that defines the travel speed that the machine will move when positioning without extruding material and for extruder changes. The `onParameter` function is common to all additive posts.

```javascript
function onParameter(name, value) {
    switch (name) {
        case "feedRate":
            rapidFeedrate = toPreciseUnit(value > highFeedrate ? highFeedrate : value, MM);
            break;
    }
}
```  

onParameter Function

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11.5.15 onRapid

```js
function onRapid(_x, _y, _z) {

  var rapidFeedrate = highFeedrate;

  function onRapid(_x, _y, _z) {
    var x = xOutput.format(_x);
    var y = yOutput.format(_y);
    var z = zOutput.format(_z);
    var f = feedOutput.format(rapidFeedrate);
    if (x || y || z || f) {
      writeBlock(gMotionModal.format(settings.useG0 ? 0 : 1), x, y, z, f);
      feedOutput.reset();
    }
  }
}
```

The `onRapid` function handles positioning moves, which do not extrude the additive material. The output of the `onRapid` function usually outputs a single block for the positioning move. The `onRapid` function is common to all additive posts.

11.5.16 onLinearExtrude

```js
function onLinearExtrude(_x, _y, _z, _f, _e) {

  var x = xOutput.format(_x);
  var y = yOutput.format(_y);
  var z = zOutput.format(_z);
  var f = feedOutput.format(_f);
  var e = eOutput.format(_e);
  if (x || y || z || f || e) {
    writeBlock(gMotionModal.format(1), x, y, z, f, e);
  }
}
```

The `onLinearExtrude` function handles linear moves that extrude the additive material. The tool position, feedrate and length of material to extrude are passed as the arguments. The `onLinearExtrude` function is common to all additive posts.
11.5.17 onCircularExtrude

```javascript
function onCircularExtrude(_clockwise, _cx, _cy, _cz, _x, _y, _z, _f, _e) {
    var x = xOutput.format(_x);
    var y = yOutput.format(_y);
    var z = zOutput.format(_z);
    var f = feedOutput.format(_f);
    var e = eOutput.format(_e);
    var start = getCurrentPosition();
    var i = iOutput.format(_cx - start.x, 0);
    var j = jOutput.format(_cy - start.y, 0);

    switch (getCircularPlane()) {
        case PLANE_XY:
            writeBlock(gMotionModal.format(_clockwise ? 2 : 3), x, y, i, j, f, e);
            break;
        default:
            linearize(tolerance);
            break;
    }
}
```

The `onCircularExtrude` function handles circular moves that extrude the additive material. The tool circle parameters, position, feedrate and length of material to extrude are passed as the arguments. The `onCircularExtrude` function is common to all additive posts.

### 11.6 Common Additive Functions

There are non-entry functions that are common to Additive post processors. Some of these are defined in the post processor kernel and some in the post processor itself. The following sections describes these functions.
11.6.1 getExtruder

```javascript
function getExtruder(id) {
  // Implementation...
}
```

### Arguments | Description
--- | ---
**id** | Extruder number to get information about.

The `getExtruder` function returns the Extruder variable, which includes information about the specified extruder. Unlike the entry functions where the extruder base is 0, in the `getExtruder` function the first extruder is referenced as `id`=1, the second as `id`=2, etc.

```javascript
writeComment("Material used: " + dimensionFormat.format(getExtruder(1).extrusionLength));
writeComment("Material name: " + getExtruder(1).materialName);
writeComment("Filament diameter: " + dimensionFormat.format(getExtruder(1).filamentDiameter));
writeComment("Nozzle diameter: " + dimensionFormat.format(getExtruder(1).nozzleDiameter));
```

**Sample Calls to getExtruder**

11.6.2 isAdditive

```javascript
function isAdditive() {
  // Implementation...
}
```

Returns *true* if any of the operations in the part are Additive in nature.

11.6.3 executeTempTowerFeatures

```javascript
function executeTempTowerFeatures(num) {
  // Implementation...
}
```

### Arguments | Description
--- | ---
**num** | The event that triggered the need to change the temperature. It is set to 1 on the first call and then successive numbers on the remaining calls.

The `executeTempTowerFeatures` function is defined in the post processor and sets the temperature based on the event specified by `num`. The initial value is 1 and ascends by 1 in each successive call. The `executeTempTowerFeatures` function is common to all additive posts that support Temperature Tower features.

```javascript
var nextTriggerValue;
var newTemperature;
var maximumExtruderTemp = 260;
function executeTempTowerFeatures(num) {
  if (settings.maximumExtruderTemp != undefined) {
    maximumExtruderTemp = settings.maximumExtruderTemp;
  }
  if (getProperty("_trigger") != "disabled") {
    var multiplier = getProperty("_trigger") == "height" ? 100 : 1;
    var currentValue = getProperty("_trigger") == "height" ?
```
Another additive capability supported by Fusion 360 and the post processor is multi-axis deposition, for example Directed Energy Deposition (DED). This technology is used to build up a part feature using a metal depositing method. This chapter discusses the basics of generating a deposition tool path, creating output, and the details of a deposition post processor.

12.1 Getting Started

This section will give an overview of creating a Deposition tool path using the multi-axis Feature Construction operation inside of Fusion 360. It will not go into great detail on all of the features of the Deposition capabilities of Fusion 360, just enough to get you started on post processing.

You will of course need a model to start with. For the examples in this manual, we will use the Fusion Keychain model provided as a CAM sample with your installation of Fusion 360. This model contains subtractive manufacturing operations which can be combined with Additive manufacturing operations as long as your machine supports both capabilities.
You will see the ADDITIVE tab on the MANUFACTURE ribbon. Selecting this tab will display the Additive menus.

### 12.1.1 Finding a Machine

The first step in creating a Deposition tool path is to define the machine that you will be using. Unlike Subtractive operations where the Machine Definition is optional, it is required for Deposition operations since they are considered Additive operations. Pressing the Machine Library icon in the Additive menus will display the Machine Library dialog. Select the Fusion 360 Library menu and check the Additive box under Capabilities and the DED box under Technologies, to list the available Deposition machines. Fusion 360 comes with a single DED machine. You should drag this machine into your Local library for both convenience and the ability to edit the machine.
Finding a DED Machine and Storing in Your Local Library

Once you find your machine you will need to select the post processor that corresponds to this machine. You can select/change the post processor by right clicking on the Autodesk Generic DED machine and choosing Select a post.

Selecting/Changing the Post Processor

The Post Library dialog will then be displayed. Select the Fusion 360 library and check the Additive box to display only the post processors supporting the Additive capabilities. For training purposes, you will select the Deposition sample post processor. This post processor is not a full post processor, but...
rather a template used to modify an existing post processor to include Deposition support. The post modification will be discussed later in this chapter.

![Selecting the Post Processor](image)

Selecting the Post Processor

You can also create linked folders on your computer to store both the machines and post processors. You do this by right clicking on the Linked menu and selecting the Link Folder menu. A browser will be displayed allowing you to select a folder to place your machines/posts.

![Selecting a Local Folder for The Machines and Post Processors](image)

Selecting a Local Folder for The Machines and Post Processors

12.1.2 Creating an Additive Setup for Deposition

In the Fusion Keychain model you will notice that there is already a subtractive setup defined. For machines that support both additive and subtractive machining you can define both types of operations as long as they are in separate setups. The subtractive operations for these machines are exactly the same as they would be for a purely subtractive (milling) machine. For this sample we will be ignoring the subtractive setup and working with the additive only.

To create an Additive setup, press the Setup menu, change the Operation Type to Additive, and select the configuration for your machine by pressing the Select... button under Machine.
Defining an Additive Setup

If you have not already assigned a post processor to this machine you will need to do so now. Do this by pressing the Edit... button under the Machine prompt. The Machine Definition will display, select the Post Processing menu, press the ... button and then select the Deposition sample post processor.

Feel free to rename the new setup to Deposition so you know that this is a deposition operation. If you are going to do both deposition and subtractive operations in the same model, then you will want to move the Deposition setup above the Subtractive setup.
12.1.3 Creating and Simulating a Deposition Operation
The Deposition operation in Fusion 360 is named Feature Construction and is located in the MULTI-AXIS pulldown.

Creating a Deposition Operation

A proper tool should be selected for depositing the material. Fusion 360 supports Electric Arc Wire, Laser Powder, and Laser Wire Deposition tools. If you don’t already have deposition tools defined, you can create one using the normal method for creating a tool by pressing the + menu in the Select Tool form.

Selecting/Defining a Deposition Tool

You will need to select the base the Feature being built lies on and the Feature itself. You can also generate multi-axis deposition moves by specifying a Forward Tilt and/or a Sideways Tilt.
For this exercise you can select the bottom surface of the keychain as the Base and the body of the keychain as the Feature. The remaining tabs/fields in the Feature Construction form are similar to other milling operations.

To simulate the Deposition toolpath press the Simulate button in the ACTIONS menus. Deposition toolpaths simulate in the same manner as Subtractive toolpaths, but it is recommended that you place the cursor over the green slide bar at the bottom of the window, hold down the left mouse button, and move the mouse to the left and right to visualize the Deposition process.
12.2 The Deposition Sample Post Processor

Unlike additive post processors, which are standalone and created for a specific machine, deposition capabilities are typically added to existing subtractive post processors for machines that support both subtractive and deposition operations. The Deposition Sample Post Processor contains the basic deposition functionality that can be added to a subtractive post. It is designed so that you can easily copy the required code from this post processor into a post processor that you want to add deposition capabilities to. In itself, it does not create a valid NC program for any machine.

The sample deposition post processor is broken up into separate sections, the first being code that will be placed into existing functions, new code to be added to your post processor, and code that is common to all other post processors used to create the sample output.

12.3 Deposition Specific Functions

You can start the modification of your post processor by copying the deposition specific functions into your post processor. This code is marked in the sample post processor as follows.

```csharp
// Start of Deposition logic
...
// End of Deposition logic

Copy this Code to Your Post Processor
```

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The following table describes the functions included in the deposition code that is being copied to your post.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
<th>Requires Editing</th>
</tr>
</thead>
<tbody>
<tr>
<td>setDepositionCommands()</td>
<td>Enable to keep deposition on during transition moves, or disable it to turn deposition off.</td>
<td>Yes</td>
</tr>
<tr>
<td>getProcessParameters()</td>
<td>Processes the deposition parameters and properties related to deposition operations and stores them in the processParameters object for use in other functions.</td>
<td>No</td>
</tr>
<tr>
<td>writeDepositionHeader(tool)</td>
<td>Writes out a header containing the deposition settings per operation.</td>
<td>Maybe</td>
</tr>
<tr>
<td>writeProcessEquipmentCommands (activate)</td>
<td>Writes out the commands to turn deposition on or off as defined in the setDepositionCommands function.</td>
<td>No</td>
</tr>
<tr>
<td>onLayer(index)</td>
<td>Entry function called when a new layer is started. index specifies the layer. 0 is the first layer, 1 the second, etc.</td>
<td>Maybe</td>
</tr>
<tr>
<td>onLayerEnd(index)</td>
<td>Entry function called when the current layer is completed.</td>
<td>Maybe</td>
</tr>
<tr>
<td>onMovemeDeposition(movement)</td>
<td>Called from the onMovement function. It turns on or off the depending on the movement type.</td>
<td>No</td>
</tr>
</tbody>
</table>

Deposition Specific Functions

12.3.1 Deposition Common Properties

The deposition functions have properties that are common between most depositing machines. These properties are listed in the following table.

<table>
<thead>
<tr>
<th>Title</th>
<th>Property</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposit during transitions</td>
<td>depositOnTransitions</td>
<td>Enable to keep deposition on during transition moves, or disable it to turn deposition off.</td>
</tr>
</tbody>
</table>

Common Deposition Properties

12.3.2 Deposition Commands

The commands to control the deposition operations are defined in the setDepositionCommands function and will need to be edited to output the correct codes for your machine. It contains the commands to turn on and off the process equipment for Electric Arc Wire, Laser Powder, and Laser Wire tools.
// insert startup codes for electric arc wire here
commands = {
    deposition : {on:mFormat.format(101), off:mFormat.format(103)},
    processEquipment: {
        on: [ // commands to turn on process equipment
            formatWords(gFormat.format(90), formatComment("ABSOLUTE MODE")),
            formatWords(gFormat.format(300), "F" + processParameter.gasFlowRate,
                formatComment("SHIELD GAS FLOW RATE")),
            formatWords(gFormat.format(301), "V" + processParameter.arcCurrent,
                formatComment("ARC VOLTAGE")),
            formatWords(gFormat.format(302), "A" + processParameter.arcVoltage,
                formatComment("ARC CURRENT")),
            formatWords(gFormat.format(303), "S" + processParameter.wireSpeed,
                formatComment("WIRE SPEED")),
            formatWords(mFormat.format(304), formatComment("PROCESS ON"))],
        off: [ // commands to turn off process equipment
            formatWords(mFormat.format(305), formatComment("PROCESS OFF")),
            formatWords(gFormat.format(303), "S0", formatComment("WIRE STOP")),
            formatWords(gFormat.format(300), "F0000", formatComment("GAS OFF"))]
    }
};
break;

Commands to Turn On and Off Deposition

12.3.3 Modifying Existing Functions to Support Deposition

After copying the deposition specific code and making the needed modifications you will need to modify existing functions in your post processor to support deposition operations.

<table>
<thead>
<tr>
<th>Function</th>
<th>Modification</th>
</tr>
</thead>
<tbody>
<tr>
<td>onSection</td>
<td>Add code to define the deposition commands, write the deposition operation head, and enable the deposition operation.</td>
</tr>
<tr>
<td>onSectionEnd</td>
<td>Add code to disable the deposition operation.</td>
</tr>
<tr>
<td>onMovement</td>
<td>Add a call to onMovementDeposition for a deposition operation.</td>
</tr>
</tbody>
</table>

Modification of Existing Functions for Deposition Support

function onSection() {
    // #### Add the code below into the onSection function of your postprocessor ####
    if (isDepositionOperation()) {
        setDepositionCommands(); // setup for deposition process parameters
        writeDepositionHeader(tool);
        writeProcessEquipmentCommands(true);
    }

    // Important note, make sure that you disable the spindle speed output for deposition
    // operations in your postprocessor.
}

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Enable a Deposition Operation in onSectionEnd

```javascript
function onSectionEnd() {
    // #### Add the code below into the onSectionEnd function of your postprocessor ####
    if (isDepositionOperation()) {
        writeProcessEquipmentCommands(false);
    }
}
```

Disable a Deposition Operation in onSectionEnd

```javascript
// #### If your postprocessor does not have the onMovement function, you have to add the
// entire function below. ####
function onMovement(movement) {
    // #### Add the code below into the onMovement function of your postprocessor. ####
    if (isDepositionOperation()) {
        onMovementDeposition(movement);
    }
}
```

Call onMovementDeposition from onMovement
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